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Structural evaluation of selected reinforced concrete buildings within the scope of urban renewal in Izmir province

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Abstract

In this study, 160 reinforced concrete buildings located in Izmir, with different numbers of floors and construction years, within the scope of urban renewal between 2013 and 2018, were examined, and their risk status was determined according to the Principles for Identification of Risky Buildings 2013 (RYTEIE 2013). Reinforced concrete buildings were evaluated in detail considering characteristic properties such as concrete compressive strengths, column longitudinal reinforcement ratios, floor weights, ratio of column sectional areas to floor areas, natural vibration periods, ratio of column axial stresses to existing concrete compressive strength, and failure ratios. The structures examined within the scope of the paper were also grouped into two main categories: before and after 1998. In addition, all these buildings were evaluated in terms of Life Safety (LS) performance level with the linear elastic calculation method given in Specification for Structures to be Built in Disaster Areas 2007 (DBYBHY 2007), which was also in force between 2013 and 2018. It is observed that 72% of reinforced concrete buildings were determined as risky buildings according to RYTEIE 2013 and couldn't provide the LS performance level according to DBYBHY 2007.

Keywords: *Risky building, urban renewal, reinforced concrete buildings, RYTEIE 2013*

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İzmir ili kentsel dönüşümü kapsamında seçilmiş betonarme binaların yapısal açıdan değerlendirilmesi

Öz

Bu çalışmada, İzmir ili sınırları içerisinde yer alan ve 2013 ile 2018 yılları arasında kentsel dönüşüme girmiş farklı kat sayılarına ve yapım yıllarına sahip 160 adet betonarme binanın karakteristik özellikleri incelenmiş ve Riskli Yapıların Tespit Edilmesine İlişkin Esaslar 2013 (RYTEİE 2013)'e göre risk durumları belirlenmiştir. Çalışmada incelenen betonarme binaların; beton basınç dayanımları, kolon boyuna donatı oranları, kat ağırlıkları, kolon kesit alanları toplamlarının kat alanına oranları, doğal titreşim periyodları, kolon eksenel gerilme ortalamalarının mevcut beton basınç dayanımına oranları, göçme oranları gibi karakteristik özellikleri detaylı şekilde değerlendirilmiştir. Çalışma kapsamında incelenen yapılar da 1998 öncesi ve sonrası olmak üzere iki ana kategoriye ayrılmıştır. Ayrıca, tüm binaların 2013 ile 2018 yılları arasında yürürlükte olan Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik 2007 (DBYBHY 2007)'de yer alan doğrusal elastik hesap yöntemi ile can güvenliği performans seviyesi açısından değerlendirmesi yapılmıştır. İncelenen betonarme binaların %72'sinin RYTEİE 2013'e göre Riskli bina olduğu ve DBYBHY 2007'ye göre can güvenliği performans düzeyini sağlamadığı görülmüştür.

Anahtar kelimeler: *Riskli bina, kentsel dönüşüm, betonarme binalar, RYTEİE 2013.*

1. Introduction

Catastrophic earthquakes cause loss of life as well as economic, social, and environmental losses. For this reason, evaluating the existing building stock against earthquake disasters and increasing the earthquake capacities of existing buildings by taking various actions or demolishing and reconstructing them have gained great importance in recent years.

It is stated in the literature that the building stock in Turkiye generally consists of 3- to 6-story reinforced concrete frame systems with inadequate design and construction quality [1]. For this reason, various studies based on rapid assessment methods have been conducted to comprehensively determine the current status of the building stock. In some of these studies, the validity of the evaluations made with the rapid assessment methods was investigated by comparing them with previously experienced earthquake data or the results of other rapid assessment methods. The data from the 1992 Erzincan earthquake and the 1999 Kocaeli and Düzce earthquakes were used in various studies [2-4] and the obtained damage results were evaluated together with rapid assessment methods. Perrone et al. [5] evaluated rapid visual scanning results for two hospitals during the 2009 L'Aquila and 2012 Emilia earthquakes. Coşkun et al. [6] evaluated 145 reinforced concrete buildings using the rapid assessment method they developed, comparing them with the results of another database.

In addition to these studies, in some studies, buildings were first examined with rapid assessment methods and then the results obtained were compared with the analysis results based on earthquake codes. Bal [7] examined 23 reinforced concrete buildings with rapid assessment methods and examined the analysis results using the seismic code. Arslan et al. [8] evaluated 66 buildings with an artificial intelligence-based rapid assessment method and compared the results with the analysis results based on the DBYBHY 2007. Işık and Kutanis [9] examined 94 reinforced concrete buildings within the borders of Bitlis province with the P25 fast visual scanning method. Arslan [10] applied the rapid assessment method to 10 reinforced concrete residential buildings and then compared the results with the elastic analysis results based on DBYBHY 2007. Gulay et al. [11] examined 6-storey and 7-storey reinforced concrete buildings damaged in the 1999 Kocaeli earthquake using the linear and nonlinear analysis methods given in DBYBHY 2007 and the P25 rapid visual assessment method. Then, they investigated the relationship between the detected damage states and the methods. Şengöz and Sucuoğlu [1] examined two reinforced concrete buildings with linear and non-linear analysis methods that were provided in DBYBHY 2007 and examined the differences between the evaluation methods. Uçar and Düzgün [12] examined 30 reinforced concrete residential buildings in Izmir province with incremental pushover analysis and obtained the fragility curves. Binici et al. [13] examined 10 reinforced concrete buildings using RYTEİE 2013 and the linear and non-linear analysis methods considering DBYBHY 2007. In their study, it was reported that three of the buildings were newly designed according to DBYBHY 2007, three of them were undamaged existing buildings, and four of them were damaged buildings in previous earthquakes.

From the literature evaluation, rapid assessment methods provide essential information in terms of building stock and play a significant role in determining the regions that can be evaluated within the scope of urban renewal. However, identifying buildings that are at risk of collapse or severe damage within the scope of a design earthquake, labeling them as risky buildings, and evacuating them for demolition is an important and difficult task. Accordingly, obtaining real test data from the field and performing structural analyses according to code requirements become substantial in the decision-making phase for urban renewal.

In this study, 160 reinforced concrete buildings located in Izmir were examined, and their risk status was determined according to RYTEIE 2013 [14]. These buildings had different structural properties and numbers of floors and were evaluated within the scope of the urban renewal law between 2013 and 2018. Details that reveal the characteristic features of the reinforced concrete buildings, such as concrete compressive strengths, slab weights, column longitudinal reinforcement ratios, ratios of the total column cross-sectional areas to the slab area, building natural vibration period values, the ratio of column axial stress averages to the existing concrete compressive strength f_{cm}, and collapse ratio, were examined. In addition, all buildings were analyzed with the elastic method according to DBYBHY 2007 [15], which was in effect between 2013 and 2018, and their earthquake performance levels were examined based on satisfying the LS performance. The analyses were performed using IdeCAD version 8.62, and the analysis results of the buildings according to RYTEİE 2013 [14] and DBYBHY 2007 [15] were given separately since they are totally independent methods.

2. Evaluation of risky buildings according to RYTEİE 2013

A substantial amount of the existing building stock in Turkey is at risk of earthquake, and the requirement for rapid identification and renewal of these buildings has emerged. Accordingly, RYTEİE 2013 [14] came into force within the scope of Law No. 6306 on the Transformation of Areas under Disaster Risk to detect risky buildings under the influence of earthquakes. RYTEİE 2013 [14] was used during the urban renewal works of thousands of buildings in Turkiye between 16.05.2012 and 16.02.2019.

RYTEİE 2013 [14] is based on risk calculation with the elastic analysis method and has been applied to buildings up to 8 floors, including the ground floor, and buildings whose height does not exceed 25 m. In RYTEİE 2013 [14], the equivalent earthquake load method or modal combination method can be used. According to RYTEİE 2013 [14], a building that has a risk of collapse or severe damage under a design earthquake that has a 10% probability of being exceeded in 50 years is considered a risky building. It is also specifically stated that it cannot be concluded that the LS performance level specified in DBYBHY 2007 [15] is achieved for a building that is not considered as risky building in RYTEİE 2013 [14]. According to RYTEİE 2013 [14], surveys of reinforced concrete buildings are prepared, and destructive and non-destructive material tests should be made for both concrete and reinforcement bars at first. After collecting all the information for the analysis, an analysis model of the building is created. Next, structural analyses are carried out considering the limits provided in RYTEİE 2013 [14].

In RYTEIE (2013) [14], when the average axial stress of the column obtained from vertical loads exceeds $0.65f_{cm}$ and any column or wall limit is exceeded, the building is considered as a risky building. If the axial stress average of the vertical members is equal to or below $0.1f_{cm}$ and the ratio of the shear forces acting on the walls and columns exceeding the limit to the total floor shear force acting on the floor exceeds 35%, the building is considered risky building and interpolation is made for intermediate values. According to RTYEİE 2013 [14], risk assessment is only made for the critical floor, and if the highest floor drift ratio calculated as a result of the analysis occurs on another floor, the assessment is made by checking only the floor drift limit values for this floor. If any floor is determined to be risky, the building is considered a risky building according to the rules given in RTYEİE 2013 [14]. Thus, the shear force ratio exceeding the limits for any earthquake direction was identified as the collapse ratio in the current study.

3. Reinforced concrete buildings used in numerical analyses

Within the scope of the study, a total of 160 reinforced concrete buildings with 8 floors or less, which were built in different years within the borders of Izmir province and evaluated within the scope of urban transformation between 2013 and 2018, were examined. These buildings were analyzed, and their risk situations were determined according to RYTEİE 2013 [14]. Subsequently, the structural performances of these buildings were also investigated from LS performance perspective based on DBYBHY 2007 [15]. Modal combination method was used in the calculations of all buildings. The buildings examined in the study were modeled from real life, and their structural system was made of reinforced concrete. Preparing the survey and floor plans, determining the soil class of these buildings, and taking material samples for concrete and reinforcement were carried out within the period between 2013 and 2018, and therefore RYTEİE 2013 [14] and DBYBHY 2007 [15] were used since these codes were in force in the same time period. Afterwards, numerical analyses were performed, and evaluations were made according to the provisions of RYTEİE 2013 [14] and DBYBHY 2007 [15] separately.

3.1. Classification of reinforced concrete buildings

The structures examined within the scope of the research were grouped into two main categories: before and after 1998. The main reason for this categorization was the major differences between the earthquake codes that were in force during the time period. In particular, Specification for Structures to be Built in Disaster Areas 1998 (ABYYHY 1998 [17], which came into force in 1998, contains significant changes compared to Specification for Structures to be Built in Disaster Areas 1975 (ABYYHY 1975) [18]. In addition, after the 1999 Adapazarı and Kocaeli earthquakes, the Building Inspection Law came into force in 19 provinces, including Izmir, in 2001, in order to eliminate the deficiencies in the constructions of buildings in Turkiye. With the putting into practice of this law, all of the reinforced concrete structures built in the benchmark provinces were constructed under building assessment. In addition, with the 2004 circular published by the Ministry of Public Works and Settlement, the use of ready-mixed concrete in buildings became mandatory [19]. Accordingly, buildings built after 1998 in Izmir had significant differences in terms of regulations and design rules, control mechanisms, material type, and quality compared to buildings built before 1998.

The construction period of 160 reinforced concrete buildings that were analyzed in the current study was examined first. It was observed that 28 buildings were built in 1945-1975, 92 buildings were built in 1975-1998, and 40 buildings were built in 1998-2018. As it can be outlined, 82% of the buildings examined within the scope of the study were built in 1975 or later. The construction periods of the buildings were presented in detail in Table 1. This situation is very similar to the 84% ratio obtained for the same period in a study conducted using rapid scanning methods, considering 4968 reinforced concrete buildings in the Balçova district of Izmir [20]. The buildings considered within the scope of the current study were classified in Figure 1, taking into account their number of floors. In Figure 1, a total of 120 buildings shown in dark color were built before 1998, and a total of 40 buildings shown in light color were built after 1998.

Table 1. Construction period of the buildings

Construction period	Year of the seismic code that is in force	Number of buildings
2007-2018	Specification for buildings to be built in disaster areas 2007 (DBYBHY 2007)	38
1998-2007	Specification for structures to be built in disaster areas 1998 (ABYYHY 1998)	2
1975-1998	Specification for buildings to be built in disaster areas 1975 (ABYYHY 1975)	92
1968-1975	Specification for buildings to be built in disaster areas 1968 (ABYYHY 1968)	11
1962-1968	Specification for buildings to be built in disaster areas 1962 (ABYYHY 1962)	9
1953-1962	Regulation on buildings to be constructed in earthquake zones 1953 (YBYYHY 1953)	6
1949-1953	Turkiye earthquake zones building regulations 1949 (TYBYY 1949)	1
1940-1944	Italian building instructions for construction in earthquake zones 1940 (ZMYİAİYT 1940)	1

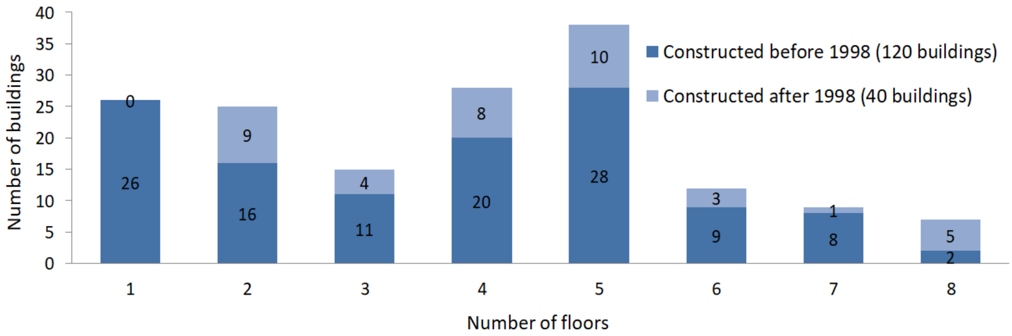


Figure 1. Classification of buildings according to the number of floors.

Considering the number of floors in the 160 buildings assessed within the scope of the study, it was observed that the majority of buildings with 5 floors or less was 82%. This ratio was similar and did not contain any major contradiction with the available literature since Özcebe et al. [21] determined the ratio as 75% for 13885 buildings in Zeytinburnu district of Istanbul and Özçelik et al. [20] reported the ratio as 85% for 4968 buildings in Balçova district of Izmir.

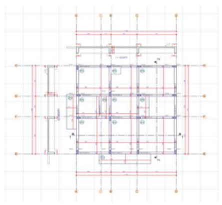
3.2. Building information forms and details of reinforced concrete buildings

Building information forms that cover structural properties and details were created for the 160 reinforced concrete buildings examined in the study, and one of these forms is given as an example in Figure 2. All of the building information forms containing three-dimensional visuals, floor plans, and many structural and non-structural information about the buildings were given within the scope of the first author's master's thesis and are available as open access at the Turkish national thesis center [22].

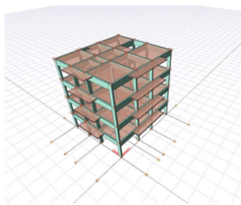
BUILDING INFORMATION FORM

BUILDING INFORMATION					
Building Label	56	Date of Construction	1976	Address	Izmir

INFORMATION ABOUT STRUCTURAL SYSTEM			
Width x Length (m)	11.30 x 10.20	Number of Floors	4
Compressive Strength of Concrete (MPa)	9.28	Rebar Material	S220



Formwork Plan



View of 3D Model

ANALYSIS RESULTS			
RYTEİE 2013	Risky Building	DBYBHY 2007	Collapse

Figure 2. Building information form [22].

120 of the buildings examined in the study were built before 1998, and within the scope of the urban transformation law, destructive and non-destructive tests were carried out on the critical floor of the building (usually the ground floor) to determine the current concrete strength and reinforcement status. Among the 120 buildings examined, in those that were licensed and had a static project at the time of construction, the reinforcement realization ratio was calculated and reflected in the analysis model. For those without

static projects, the average amount of reinforcement obtained from destructive and non-destructive test results was used and applied to static models. In addition, the surveys of buildings built without a license or without a project, or those that had a permit and a project but were constructed differently on site, were prepared, and irregularities in the plan and façade were recorded in the surveys. For buildings that had an existing static project and implemented directly on-site, a static analysis model was created with the information from the project. In all 120 buildings built before 1998, the reinforcement steel was unribbed, and the reinforcement class was S220. Since all of the buildings examined were residential buildings, the building importance coefficient was taken into account as 1.00. In cases where the load-carrying system projects of the buildings did not exist or were in contradiction with the project, the information level coefficient according to RYTEİE 2013 [14] was taken into account as 0.90. On the other hand, 40 buildings that were built after 1998 were licensed, designed, and built using ready-mixed concrete under the supervision of building inspection. For this reason, it was assumed that the reinforcement status and concrete class specified in the static projects were complied with, and calculations were made by directly taking into account the building structural system projects. All of these buildings were analyzed, and their risk statuses were evaluated according to RYTEİE 2013 [14]. In addition, it was also evaluated whether the buildings provide the LS performance for the design earthquake, which has a 10% probability of exceeding the target performance level in 50 years, according to DBYBHY 2007 [15].

4. Numerical analysis results of reinforced concrete buildings

The data regarding the reinforced concrete buildings examined within the scope of the study were evaluated, and the findings were presented.

4.1. Evaluation of structural properties of reinforced concrete buildings

Concrete compressive strength values, floor weights, column longitudinal reinforcement ratios, ratios of the sum of column cross-sectional areas to the floor plan area, building natural vibration period values, and ratios of column axial stress averages to the existing concrete compressive strength f_{cm} were evaluated for the reinforced concrete buildings.

The average concrete compressive strength of reinforced concrete buildings is listed according to building number and shown in Figure 3. The first 120 buildings in Figure 3 were built before 1998, and the next 40 buildings were built after 1998. The concrete strength of buildings built before 1998 was obtained from field examinations and laboratory tests. The average concrete compressive strength was 8.89 MPa, and the standard deviation value was 3.24 MPa considering the laboratory test results of the first 120 buildings, as in Figure 3. Here, it can be seen that concrete compressive strengths for many buildings were below the minimum design value of B160 for concrete in ABYYHY 1975 [18]. The last 40 buildings given in Figure 3 were built after 1998, and laboratory studies could not be conducted for these buildings. However, considering that ready-mixed concrete was used in these buildings and that they were inspected within the scope of the building inspection system, the concrete compressive strength values in the construction projects were used in the calculations.

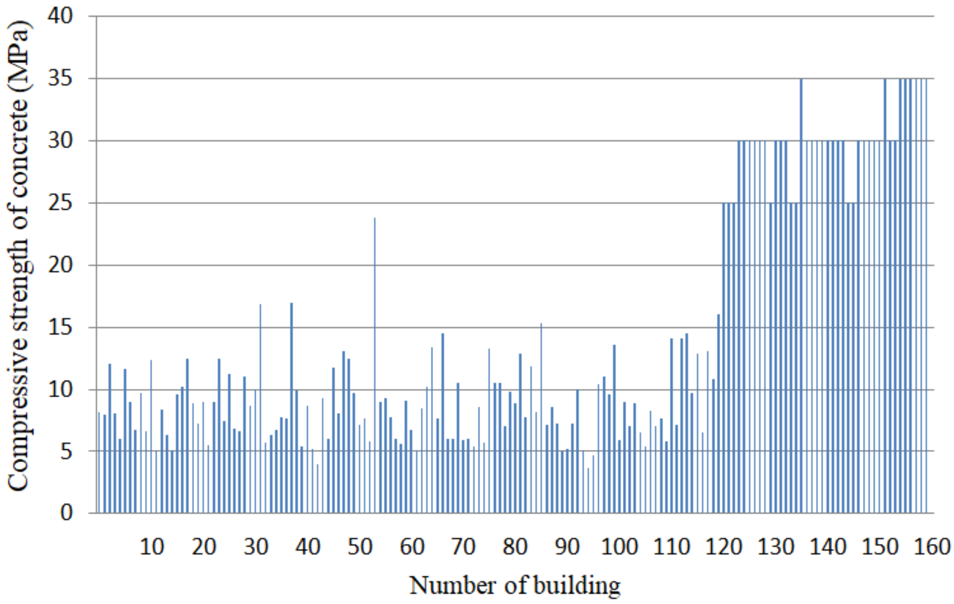


Figure 3. The average compressive strength of reinforced concrete buildings.

The floor weights of the buildings examined in the study are given in Figure 4. In the determination of floor weights, the load combination of G+0.3Q was used since all buildings in the current study were residential. The average of the floor weights of the buildings built before 1998 was determined as 8.93 kN/m^2, and the standard deviation was 1.98 kN/m^2. The average of the floor weights of the buildings built after 1998 was 12.30 kN/m^2, and the standard deviation was 2.38 kN/m^2. This increase in average floor weights after 1998 can be explained by the increase in the cross-sections of structural members due to code requirements.

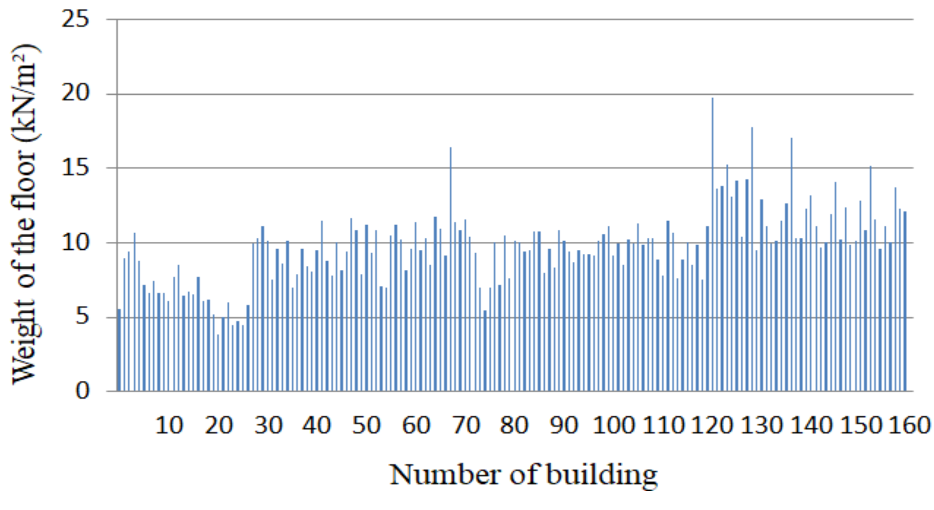


Figure 4. Average floor weight of the reinforced concrete buildings.

The columns of the buildings were examined in terms of longitudinal reinforcement ratios, as shown in Figure 5. The longitudinal reinforcement ratios of columns were determined for the buildings built before 1998, and the average column longitudinal reinforcement ratio was calculated as 0.88% with a standard deviation of 0.30%. Although the minimum longitudinal reinforcement ratio was 1% in ABYYHY 1975 [18], the column longitudinal reinforcement ratios were below 1% for 72% of the 92 buildings constructed during the period when this regulation was valid. Considering the column longitudinal reinforcement ratios of buildings built after 1998, the average longitudinal reinforcement ratio was determined to be 1.14%, and the standard deviation was 0.17%. It was observed that all of these 40 buildings that were examined met the minimum longitudinal reinforcement ratio requirement of 1% specified in ABYYHY 1998 [17] and DBYBHY 2007 [15]. The active use of computer software that allows automatic control of minimum requirements in building modeling and static analysis may be one of the results of this achievement.

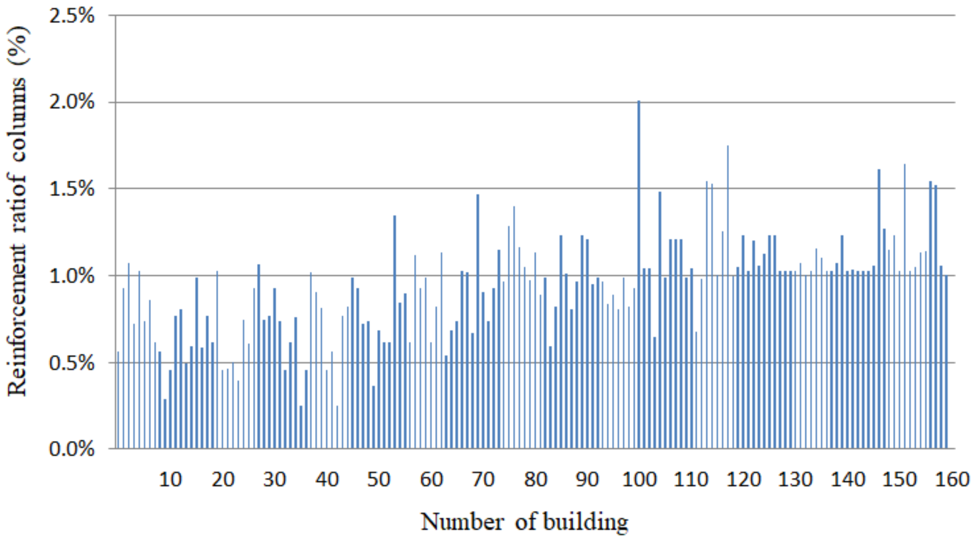


Figure 5. Average longitudinal reinforcement ratios of columns.

The ratio of the total column cross-sectional area to the floor area is given in Figure 6.

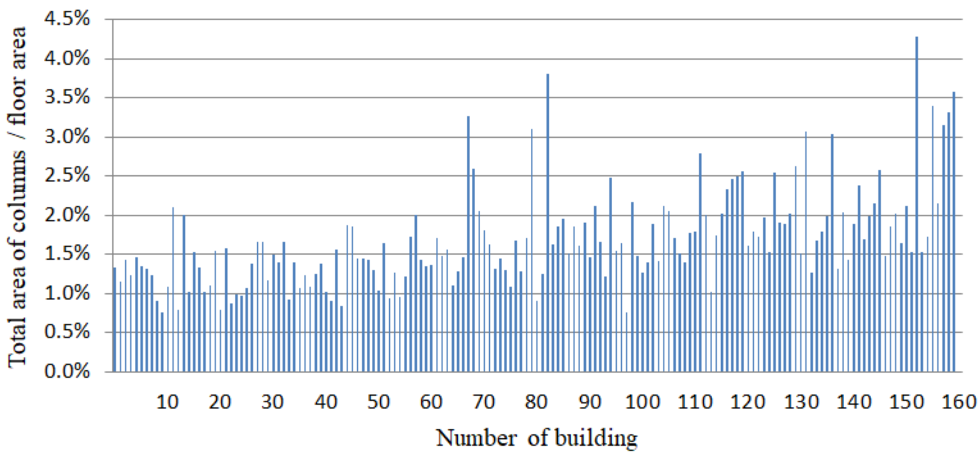


Figure 6. Ratio of the total column cross-sectional area to the floor area.

The average ratio of the total column area to the floor area of buildings built before 1998 was 1.54%, and the standard deviation was 0.52%, according to the current study. The average ratio of the total column area to the floor area of buildings that were built after 1998 was 2.13%, and the standard deviation was 0.69%. In ABYYHY 1975 [18], the minimum column size was 25 cm, while in ABYYHY 1998 [18] and DBYBHY 2007 [15], the minimum column size was 25 cm and the minimum cross-sectional area was

750 cm². There was a 20% increase in the minimum column cross-sectional area in between these regulations. Accordingly, it was observed that increasing the minimum value of the column cross-sectional area in the codes caused an increase in the ratio of total column areas to floor area. On the other hand, it can also be noted that, as the number of floors increased, the ratio of the total column area to the floor area increased as expected.

Since the effective flexural stiffness of the members of the structural system was calculated differently in RYTEİE 2013 [14] and DBYBHY 2007 [15], the natural periods were determined differently according to both codes. According to RYTEİE 2013 [14], the flexural stiffness of uncracked sections was taken into account as 50% for columns and 30% for beams and shear-walls, while in the DBYBHY 2007 [15] performance evaluation section, it was 40% for beams and was calculated between 40% and 80% for columns depending on the level of the axial force. Therefore, the natural vibration periods of buildings, which were generated by numerical models, were slightly different from each other, as shown in Figure 7.

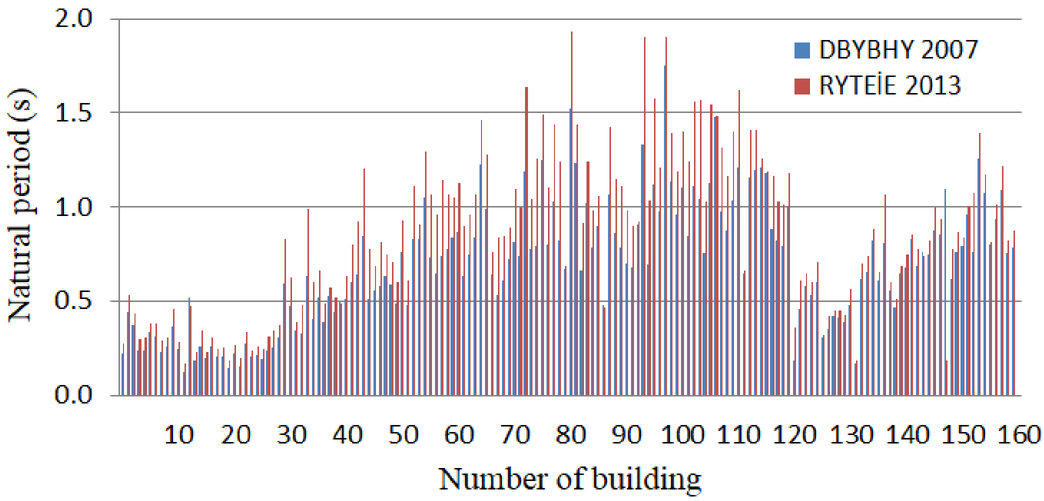


Figure 7. Natural periods of buildings.

The ratio of critical floor column average axial stresses to the existing concrete compressive strength f_{cm} was shown in Figure 8. It was observed that the average column axial stress exceeded $0.50xf_{cm}$ in 12 of the 120 buildings built before 1998. On the other hand, in 40 buildings built after 1998, it was determined that the ratio of column average axial stresses to concrete compressive strength was at the level of 15%.

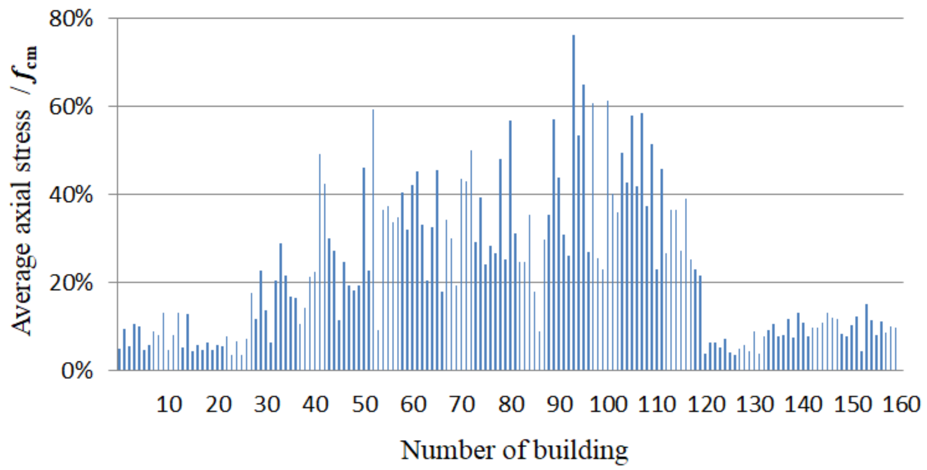


Figure 8. Ratio of the average axial stress of columns to the existing concrete compressive strength, f_{cm}.

4.2. Collapse ratios of reinforced concrete buildings according to RYTEİE 2013

The collapse ratios of 160 buildings were examined according to RYTEİE 2013 [14], and they were shown in Figure 9. Among these buildings, the average collapse ratio of 120 buildings built before 1998 was determined to be 0.87, and the standard deviation was 0.20. The average collapse ratio of 40 buildings built after 1998 was 0.17. The decrease in collapse ratios can be the result of improvements in load-carrying structural systems, analysis methods, and minimum code requirements.

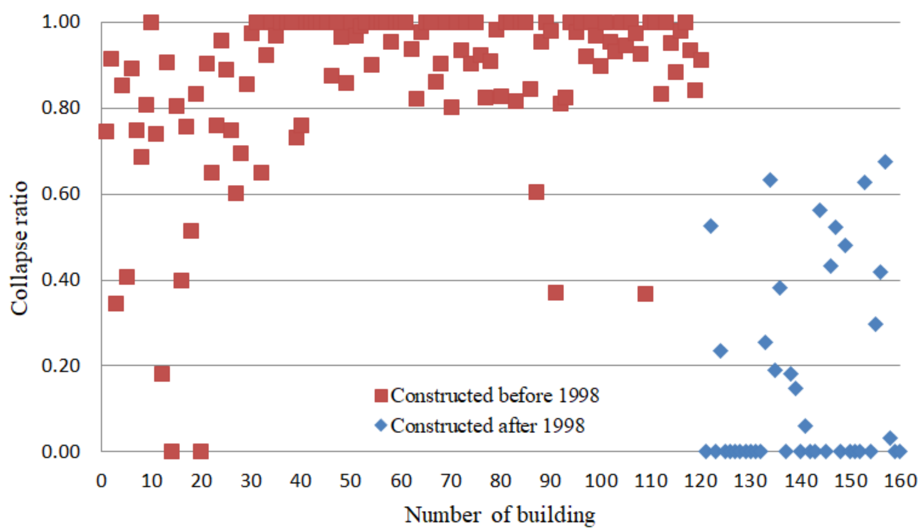


Figure 9. Collapse ratio of the buildings.

4.3. Evaluation of risk situations and earthquake performance results

In the current study, the risk situations of 160 reinforced concrete buildings were evaluated according to RYTEİE 2013 [14]. In addition, these buildings were also evaluated according to DBYBHY 2007 [15] as buildings that satisfied or did not satisfy the LS level. The analysis results for all examined buildings were presented in Figure 10, and 126 out of 160 buildings were determined to be risky building according to RYTEİE 2013 [14]. On the other hand, the number of buildings that did not satisfy the LS performance level was determined to be 126, according to DBYBHY 2007 [15]. When buildings that were built before 1998 were focused, 116 of 120 buildings were determined to be risky building according to RYTEİE 2013 [14], and 107 of 120 buildings were not able to satisfy the LS level given in DBYBHY 2007 [15]. On the other hand, when buildings that were built after 1998 were examined, 10 of the 40 buildings were determined to risky building according to RYTEİE 2013 [14] and 19 of the 40 buildings were not able to satisfy the level provided in DBYBHY 2007 [15].

From the current study, all of the 94 buildings that were built before 1998 and had 2 or more floors were determined to be risky buildings according to RYTEİE 2013 [14], and it was observed that they could not also satisfy the LS level given in DBYBHY 2007 [15]. The buildings that have only one floor provided relatively better results. 22 of 26 buildings were determined to be risky buildings according to RYTEİE 2013 [14], and 13 out of 26 buildings were not able to satisfy the LS level provided in DBYBHY 2007 [15].

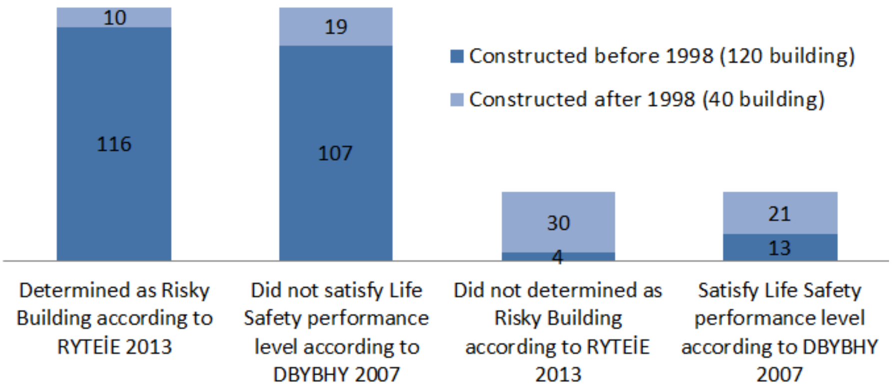


Figure 10. Analysis results of the reinforced concrete buildings according to RYTEİE 2013 [14] and DBYBHY 2007 [15].

Among the 160 reinforced concrete buildings examined in the current study, 126 buildings were determined to be risky building according to RYTEİE 2013 [14] or could not satisfy the LS level according to DBYBHY 2007 [15]. The analysis results were presented for each of the perpendicular horizontal earthquake directions separately, as in Figure 11.

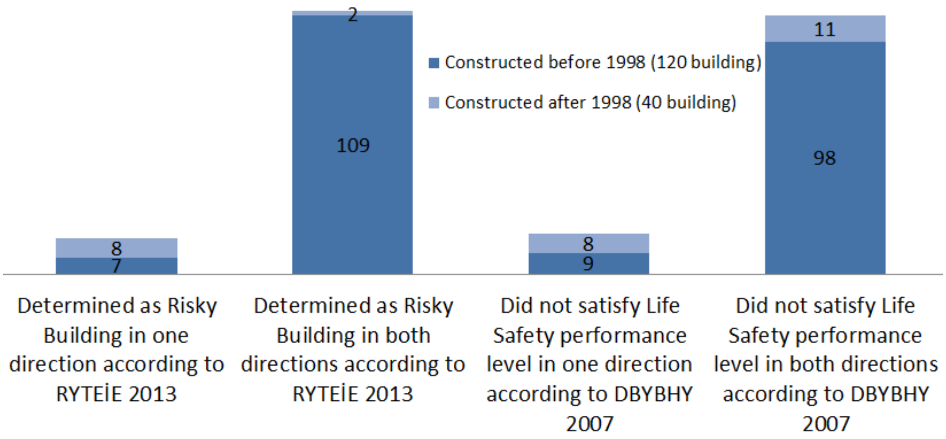


Figure 11. Analysis results of buildings in terms of earthquake directions.

According to RYTEIE 2013 [14], 111 of 126 buildings were determined to be risky building in both earthquake directions, and 15 of them were determined to be risky building in one of the earthquake directions. On the other hand, 109 of the 126 buildings were not able to satisfy the LS level in both earthquake directions, according to DBYBHY 2007 [15], and 17 of them were not able to satisfy the LS level in one of the earthquake directions, according to DBYBHY 2007 [15].

The number of risky buildings according to RYTEİE 2013 [14] and the number of buildings that satisfy the LS level according to DBYBHY 2007 [15] were shown together in Figure 12. It was observed that 23 of the buildings were not determined as risky buildings according to RYTEİE 2013 [14] and at the same time met the LS level according to DBYBHY 2007 [15]. It was determined that 22 of the buildings were calculated as risky building according to RYTEİE 2013 [14] or did not satisfy the LS level according to DBYBHY 2007 [15]. It was observed that 115 of the buildings were determined to be risky building according to RYTEİE 2013 [14] and also did not satisfy the LS level according to DBYBHY 2007 [15].

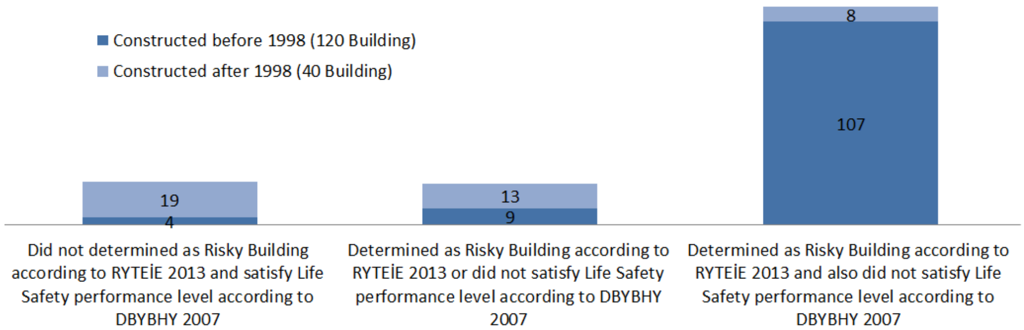


Figure 12. Evaluation of the analysis results of reinforced concrete buildings.

5. Conclusions

In the paper, 160 reinforced concrete buildings that underwent urban renewal between 2013 and 2018 in Izmir were analyzed, and their risk statuses were determined according to RYTEİE 2013 [14]. Numerous characteristic features of the buildings, such as concrete compressive strengths, floor weights, column longitudinal reinforcement ratios, ratios of the sum of column cross-sectional areas to floor area, natural vibration periods, the ratio of column axial stress averages to the current concrete compressive strength, and collapse ratios, were examined comparatively. In addition, all buildings were evaluated in terms of LS performance level using the elastic calculation method provided in DBYBHY 2007 [15], which was also in force between 2013 and 2018. The results obtained in the study are summarized below.

- When the buildings were examined in terms of concrete compressive strength, laboratory test results showed that 92% of the buildings built between 1975 and 1998 did not meet the minimum B160 design strength value prescribed for concrete compressive strength in ABYYHY 1975 [18]. It was determined that 96% of the 85 buildings were determined to risky buildings according to RYTEİE 2013 [14], and 87% of them did not meet the LS performance level according to DBYBHY 2007 [15].

- Considering the average floor weights of buildings, it was observed that there was a 38% increase in buildings built after 1998 compared to those built before 1998. The increase ratio obtained here was similar to the increase in the ratio of the total column areas to the floor area, and it is thought that this situation occurs due to the increase in the size of the members of the load-carrying system in buildings constructed after 1998.
- When the buildings were examined in terms of column longitudinal reinforcement ratios, it was seen that the column longitudinal reinforcement ratios in buildings built after 1998 increased by 30% compared to buildings built before 1998. In addition, 97% of the 66 buildings with a column longitudinal reinforcement ratio of less than 1% were determined to be risky building according to RYTEİE 2013 [14], and 86% of them did not meet the LS performance level according to DBYBHY 2007 [15]. This situation clearly showed the importance of the longitudinal reinforcement ratio in the columns. In fact, two buildings that were not considered risky building according to RYTEİE 2013 [14] and nine buildings that provided the LS level according to DBYBHY 2007 [15] were single-story buildings.
- It was determined that the ratio of the total column area to the floor area increased by 38% in buildings built after 1998 compared to before 1998. It was understood that this ratio increased for buildings built after 1998 due to the increase in the minimum values for the dimensions of the column sections in the earthquake codes.
- Natural vibration period values of buildings were examined for buildings with the same number of floors, taking into account their construction years. For all floor numbers examined, it was understood that the building natural vibration period values decreased in buildings built after 1998 compared to buildings built before 1998, since the horizontal stiffness of these buildings increased. In addition, due to different approaches for effective flexural stiffness in RYTEİE 2013 [14] and DBYBHY 2007 [15], it was observed that the building natural vibration period values obtained in RYTEİE 2013 [14] analyses were longer.
- Buildings were also evaluated by the ratio of column average axial stresses to the existing concrete strength f_{cm} for critical floors. It has been determined that all 12 buildings with average column axial stresses exceeding $0.50xf_{cm}$ were determined to be risky building according to RYTEİE 2013 [14] and did not meet the LS level according to DBYBHY 2007 [15]. In addition, it was observed that two of these buildings exceeded the column axial stress average value of $0.65xf_{cm}$ and were directly classified as risky building according to RYTEİE 2013 [14]. According to the calculation method given in RYTEİE 2013 [14], as the column axial stress to f_{cm} ratio increases, the limit value of the floor shear force ratio decreases, and in cases of low concrete strength and high axial stress levels, the possibility of such buildings being identified as risky buildings increases. For this reason, since the axial stress levels of buildings with a high number of floors and relatively small column cross-sections will be high, it would be vital to carry out material tests and building risk assessments as soon as possible.
- When all buildings in the study were examined in terms of collapse ratio according to RYTEİE 2013 [14], it was seen that the average collapse ratio of buildings built after 1998 decreased by 80% compared to before 1998. This shows that advances in regulations, increases in material quality, and developments such as building inspections contribute positively to reducing the risk of buildings.
- It was observed that 79% of 160 buildings were determined to be risky building according to RYTEİE 2013 [14] and did not provide the LS level according to DBYBHY 2007 [15]. Moreover, 97% of the buildings built before 1998 were

determined to be risky building according to RYTEİE 2013 [14], and 89% of them did not meet the LS level according to DBYBHY 2007 [15]. It has been determined that all buildings with two or more floors built before 1998 were risky building according to RYTEİE 2013 [14] and did not meet the LS level according to DBYBHY 2007 [15]. On the other hand, 25% of the buildings built after 1998 were determined risky buildings according to RYTEİE 2013 [14], and 48% of them did not meet the LS level according to DBYBHY 2007 [15]. Consequently, it became necessary to urgently examine two- and more-story reinforced concrete buildings, especially those built before 1998.

- The analysis results were also evaluated separately for each of the horizontal earthquake directions perpendicular to each other. According to RYTEİE 2013 [14] analyses, 88% of the buildings were determined to be risky building in both directions, and according to DBYBHY 2007 [15], 86% of the buildings that did not meet the LS performance level in both directions.
- When the analysis results are evaluated together, 72% of the buildings were considered to be risky building according to RYTEİE 2013 [14], and at the same time, did not meet the LS performance level according to DBYBHY 2007 [15]. Besides, 14% of the buildings were not considered risky building according to RYTEİE 2013 [14] and did not meet the LS performance level according to DBYBHY 2007 [15]. If these buildings were evaluated in terms of the years they were built, 89% of the buildings built before 1998 were considered risky building according to RYTEİE 2013 [14], and at the same time, they did not meet the LS performance level according to DBYBHY 2007 [15]. Besides, only 3% of them were not considered risky building according to RYTEİE 2013 [14] and at the same time provided LS performance level according to DBYBHY 2007 [15]. For the buildings that were built after 1998, 47% of them were able to meet both code requirements. On the other hand, it is also quite remarkable that 20% of the buildings built after 1998 were determined to be risky building according to RYTEİE 2013 [14] and also could not meet the LS performance level according to DBYBHY 2007 [15].

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