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RESEARCH ARTICLE

URBAN TRANSFORMATION PROGRESS OF REINFORCED CONCRETE (RC) AND MASONRY-MIXED BUILDINGS IN ISTANBUL

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ABSTRACT

Istanbul city is the center of increasing industrialization in Turkey with proportionally developing problems, such as distorted settlements, and slums, etc. The rapid migration to Istanbul, which is located in the earthquake hazard risk zone, has resulted in a raised population and these structures. Urban regeneration/transformation/planning is expressed as a comprehensive action plan that aims to provide a lasting solution to be economic, physical, social, and environmental conditions of a diverting region to solve the problems in the cities. This paper analyzes the urban transformation process and applications of reinforced concrete (RC) and masonry or mixed masonry-RC buildings in Istanbul within the scope of the urban planning law called "Law on Transformation of Areas at Risk of Natural Disaster" (Law No. 6306 dated 2012). To reach this goal, a total of 400 risky building forms with 150 RC buildings as well as 250 masonry-mixed buildings considered according to Law No. 6306 is compiled and evaluated as risky building data. The general characteristics of the RC and masonry-mixed buildings in Istanbul are determined by a date range of such as 2012–2020. With the results obtained from the paper, significant contributions have been made to the knowledge and technological capabilities at the international/national level.

Keywords: Earthquake, Masonry, Reinforced concrete (RC) structures, Risky buildings, Urban regeneration

1. INTRODUCTION

Due to the increase in industrialization, cities have begun receiving immigrants, and housing/building has increased rapidly. The increase in housing has led to problems in the cities. Urban development has proceeded unplanned due to rapid population growth, lack of infrastructure, and unplanned housing. Therefore, urban regeneration/transformation/planning/renewal is one of the important issues today. The studies executed in the field of urban transformation in Turkey have started to be discussed recently, particularly after the destruction of the 1999 Izmit / Kocaeli / Golcuk (Mw7.4) and Duzce (Mw7.1) earthquakes in Turkey. After these earthquakes, the building damage inspection's result was announced that approximately 96,000 buildings were severely damaged, 58,000 buildings were moderately damaged, 122,000 buildings were slightly damaged, and 33,000 buildings were undamaged in the affected zone through a full report conducted by the Japan International Co-operation Agency (JICA) and Istanbul Metropolitan Municipality (IMM) [1–2]. Three important turning points of urban transformation in Turkey are migration from rural to urban, rapid urbanization, and the transformation process that started in the slum/squatter areas because of the improvement-development plan that started in the 1980s [3–5]. For these implementations, as another factor, the law called "Law on Transformation of Areas at Risk of Natural Disaster" [6] was rapidly announced and enacted in the cities as a risk assessment method. The purpose of this law is to determine the principles and procedures for improvement, elimination, and renovations to form healthy and safe living environments in compliance with the norms, codes of practice, and standards of science and art in disaster-risk areas and the lands, other than these areas, where risky masonry, masonry-mixed, concrete structures exist. The percentage of dwelling units destroyed by natural disasters during the last 70 years in Turkey are earthquake by

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61%, flood by 14%, a landslide by 15%, rock-fall by 5%, fire 4%, avalanche, storm, and rain by 1%. Earthquakes prove to be the most damaging natural disaster in the country [7].

As a center for tourism and industry, Istanbul is prone to earthquakes since it is sandwiched between the Black Sea in the north and the Sea of Marmara to the south. In the last five centuries, Istanbul has seen at least seven big earthquakes in 1509, 1719, 1754, 1766, 1894, and 1912. The influence of the 1999 Izmit and Duzce earthquakes on Istanbul can be explained by the killed several hundred residents of Istanbul along with 16,000 people living in the Marmara and northwest Black Sea regions. Furthermore, lastly, an Mw7.0 earthquake announced by the United States Geological Survey (USGS) hit the western province of Izmir, Turkey on Friday, October 30, 2020, was felt in Istanbul [8]. The built-environment of Istanbul separately consisted of about 1,000,000 buildings in 2002. It was estimated that a large number of buildings (about 50,000~70,000) in Istanbul were anticipated in severe damage because of the probable earthquake-scenario that occurs [1, 9]. The number of buildings available in Istanbul has specifically increased from 1,000,000 to around one million 728 thousand between 2002 and 2020. According to the Ministry of Environment and Urbanization of Turkey, 65 risky areas were declared in 23 districts of Istanbul, and 120 thousand independent sections were included in the urban transformation [5]. Urban transformation is the most important item of the urban agenda in Istanbul. Assessing the seismic vulnerability of the building stocks in Istanbul earthquake-prone city is of increasing importance since such information is needed for reliable estimation of losses that possible future earthquakes are likely to induce. The outcome of such loss assessment studies, which are also similarly aimed for this technical article, can be used in the planning of earthquake protection strategies [10–11]. In contrast, it is not easy to find the structural properties and characteristics of building stocks when considering the size of the building inventory of Istanbul.

Generally, the major building structure types used in Turkey, and also in Istanbul can be classified, such as (i) reinforced concrete (RC) frames (ii) RC frames with structural walls/dual systems (iii) load-bearing wall (masonry) (iv) tunnel-formwork and structural wall systems (v) precast concrete buildings. A great number of residential and commercial buildings in Istanbul are constructed in RC with masonry infill and most of this construction is made up of cast-in-situ RC beam-column frames with hollow brick infill panels and partition walls that are rarely provided with any structural connection to the frame. Using load-bearing walls has traditionally formed a large part of residential construction in Istanbul. With the introduction of tunnel-form techniques after 1998, tunnel-formwork and structural wall systems have been mostly used in high-rise buildings constructed in urban areas of Istanbul [12]. In this paper, masonry-mixed buildings will be accepted as both masonry and the transition buildings between RC and masonry buildings. Various studies on earthquake risk that consist the building data are available in the literature. For instance, a project has been conducted by BU-ARC [13] that consists of building data. In that project, the total number of buildings was accepted as 724,609 based on the State Institute of Statistic of Turkey [14] building census data, now known as the Turkish Statistical Institute (TUIK 2000). But, this data from aerial photographs did not contain building attribute information. For this reason, TSI/TUIK 2000 data included in building inventories, such as construction type, number of floors/stories, and construction years for the regions of Turkey were joined using a geocoding method in TUIK 2014 [15]. The latest studies for Istanbul about building risk analysis against earthquakes have been completed in this period, where the building stock increased and some buildings were demolished because of urban transformation. Due to the updating, the building data of Istanbul were crucial for earthquake risk analyses, this consideration motivated the research presented in this paper to study and develop RC and masonry-mixed building data of Istanbul within the urban transformation.

The principal aim of this study is to provide statistical information on the risky building stock of Istanbul for use in risk and loss assessment models. To this end, in this paper, a total of 400 risky building detection-examination forms with 150 RC and 250 masonry-mixed real mostly residential and commercial buildings in Istanbul, which were transformed under urban transformation from the date of entry of Law No. 6306 into force to 2020, were collected and reviewed according to districts. The building information in the database obtained from these completed building forms has important details on risky buildings such as; the administrative information, the general structure, the structural system, the material properties, the soil and site information, and the damage condition of the investigated building as the document of reports, drawings, photos, videos, etc. Through assessing the obtained data sourced from the existing risky housing stock in urban areas of Istanbul, the characteristics of the RC and masonry-mixed buildings have briefly complied. As revealing the novelty of this study, the strength capacities and the seismic effectiveness of selected buildings were particularly examined. The Turkish Earthquake Code (TEC-2007) [16] was usually used for the evaluation and strengthening of existing risky buildings in Turkey on the date of Law No. 6306 enacted. To enable rapid identification of buildings under high seismic risk, a new specification called "Guidelines for the Assessment of Buildings under High Risk in accordance with Law no. 6306", hereafter called the Turkish Risky Buildings Detection Code (RBTEIE-2013) [17] was recently developed exclusively for use within the urban transformation initiative (RBTEIE-2013 and the latest renewed document is now known as RBTEIE-2019). This specification also provides a score-based evaluation system for measuring the regional distributions of buildings, under seismic risk. The principles of RBTEIE are used in RC and masonry risky buildings with a height less than or equal to 25 m or several stories less than or equal to 8-story, otherwise, TEC-2007 is taken into consideration for RC and masonry buildings outside this phenomenon as mentioned previously. For the considered data in this study, the specification of RBTEIE-2013 was used in both RC and masonry-mixed buildings. The seismic performance analyses were conducted using structural design and analysis software of STA4CAD for RC buildings and STATICAD-Masonry for masonry-mixed buildings. In this way, the performance analyses conducted with the current status of buildings were compared to the provided graphs (i.e., bar and pie charts) and performed as the risky building data incorporating the most recent data available for Istanbul.

So far, to the knowledge of the authors, such comprehensive data assessed here are unique and beneficial for the studies on the hazard and risk assessment strategies to mitigate seismic damage in 29%–66% possible strong earthquake ($M_w \geq 7.0$) affecting the south of Istanbul with rupturing beneath the sea of Marmara in the next 14 years [18–19]. When viewed from this aspect, this work will be a remarkable contribution to the existing knowledge base for the engineers about the estimation of buildings damage levels after a large-scale earthquake disaster [20–25].

2. DESCRIPTION OF REINFORCED CONCRETE (RC) AND MASONRY-MIXED BUILDINGS

In this section, a general statistical evaluation was performed for the examined buildings within the scope of urban transformation, and then they were classified separately as RC and masonry-mixed buildings. The risky building data were evaluated with the graphs obtained from the analysis of construction year, the number of stories, total building height, and total construction area to track changes (i.e., the structural irregularities, structural deficiencies, and material strength capacities) over long periods for the building stock. Istanbul province is distributed into a total of 39 major districts, of which 25 of those are falling on the European side, while the remaining 14 districts fell on the Asian side [26]. The RC and masonry-mixed buildings identified in this paper are located on both the Asian (7-district) and European (12-district) sides of the Marmara coast. The bar chart in Figure 1 shows the percentage of RC building data by districts of Istanbul. Concerning this figure, a significant number, 79%, of 150-RC buildings (e.g., 29% in Atasehir, 22% in Kartal, 10% in Maltepe, etc.) are located in the Asian side of Istanbul, 21% of RC buildings (e.g., 5% in Sisli, 4% in Bakirkoy, etc.) are located in the European side. Similarly, as given in Figure 2, 40% (e.g., 15% in Atasehir, 13% in Maltepe, etc.) and 60% (e.g., 24% in Sisli, 9% in Bayrampasa, etc.) of 250-masonry-mixed buildings are located in the Asian and European sides, respectively. In addition to this, a total of 20 districts of Istanbul from which the data of masonry-mixed buildings have been collected consists of 11 on the European side and the other 9 on the Asian side.

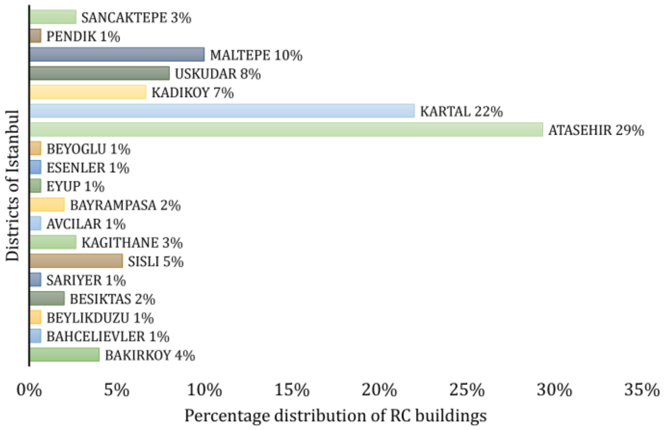

Figure 1. Percentage distribution of identified 150-RC buildings in the districts of Istanbul

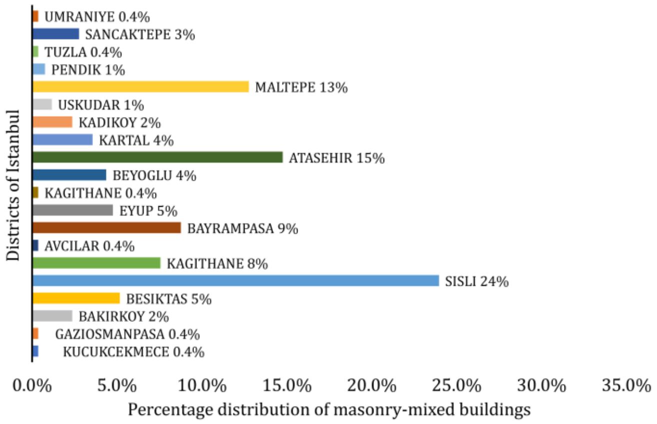

Figure 2. Percentage distribution of identified 250-masonry-mixed buildings in the districts of Istanbul

The distribution of the observed building stock statistics in Istanbul within the scope of urban transformation by the year of construction is presented in Figure 3. Although the construction year had been recorded using the range between 1929 and 2000 in the report of TUIK-2000, the data for the identified risky buildings in this study would be more wide-ranging for the years of construction vary from 1930 to 2010. For example, 3%, 5%, 15%, and 19% of masonry-mixed buildings were constructed between 1930–1940, 1940–1950, 1950–1960, and 1960–1970, respectively. An important part, 26%, of masonry-mixed buildings was constructed between 1970 and 1980 in Istanbul. 2% of the RC buildings were constructed after 2000. 99% of RC buildings that underwent urban transformation were constructed between 1960 and 2010. From this investigation can be assumed that the increase in the number of risky building's applicants claimed by homeowners for the urban transformation in Istanbul was significantly high since most risky buildings were constructed according to the 1975 Turkish Earthquake Code (TEC-1975) [27] and 1998 Turkish Earthquake Code (TEC-1998) [28]. However, it is very well known that a large number of risky building stocks in this high seismicity region still pose a significant risk in terms of urban transformation. With the urban transformation, much attention has been drawn that many buildings in Istanbul have been constructed illegally without fulfilling design codes, furthermore, even in those cases where codes have been used to some extent, they are likely to express a lack of critical seismic design concepts (e.g., capacity design).

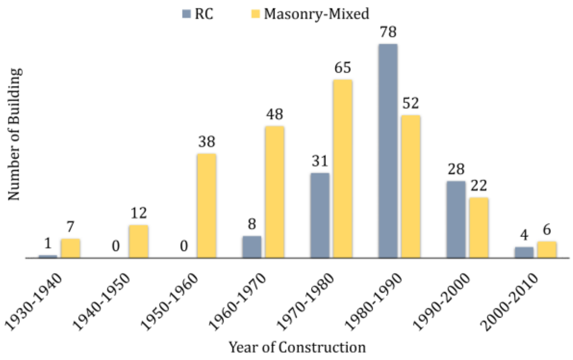

Figure 3. The year of construction for examined RC and masonry-mixed buildings

The height of buildings is an important characteristic in that combined with the local soil conditions it may have a strong influence on the level of seismic base shear and hence the level of damage and loss [29–30]. The total height of the selected RC and masonry-mixed buildings evaluated within the scope of urban transformation can reach up to 25 m. The maximum building heights here, both in the minimum and maximum ranges, are between 2.60–23.85 m for RC, and 2.20–23.20 m for masonry-mixed buildings. As given in Figure 4, the total building height of 40% of the masonry-mixed buildings varies between 5 m and 10 m, while those of 37% of RC buildings vary from 10 m to 15 m in urban areas due to high population density and scarcity of land for construction. The maximum number of stories in the 400 buildings, for which the urban transformation was applied, varies between 1-story and 8-story. As seen in Figure 5, 31% of the masonry-mixed buildings, which consist of one floor, and 26% of the RC buildings comprise 6 floors. 13% of the noteworthy masonry-mixed buildings had more than 5 floors. The total construction area reaches a maximum of 10345.77 m^2 in the 150-RC, and 4685.41 m^2 in the 250-masonry-mixed buildings. Likewise, the minimum values of the total construction area are 71.47 m^2 and 11.69 m^2 for RC and masonry-mixed buildings, respectively.

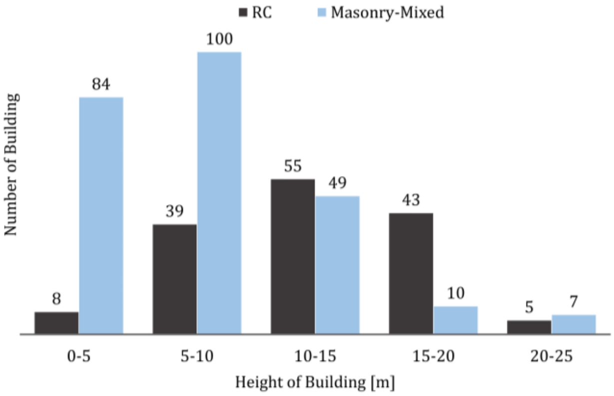

Figure 4. Number of RC and masonry-mixed building differentiated according to heights

When Figure 6 was reviewed, it was observed that 56% of total construction areas of masonry-mixed buildings were between 0–200 m^2, and 38% of the RC buildings were between 200 m^2 and 600 m^2. In this context, it can be said that the total construction areas of the buildings, for which the urban transformation has been applied, are small. The details of RC and masonry-mixed buildings are also separately evaluated and discussed in the next section.

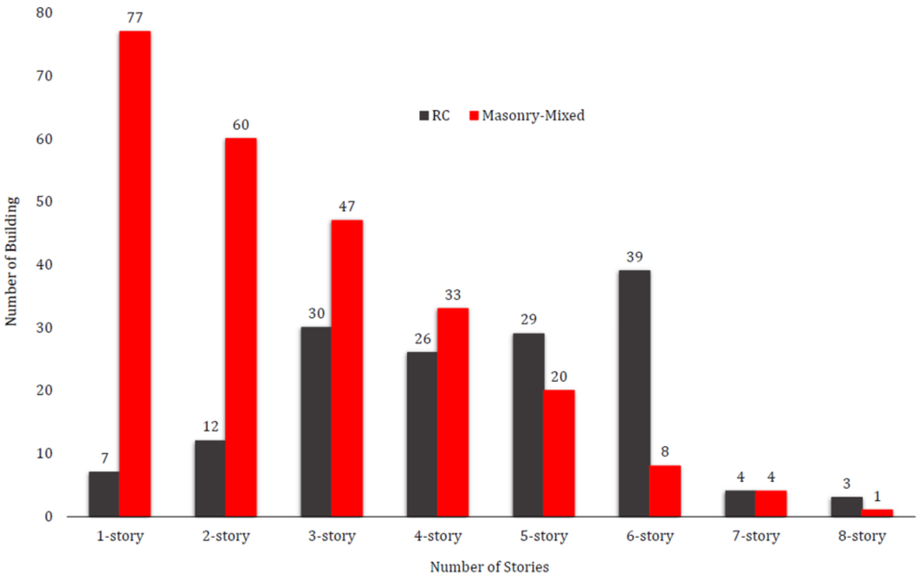

Figure 5. The maximum number of stories for RC and masonry-mixed buildings

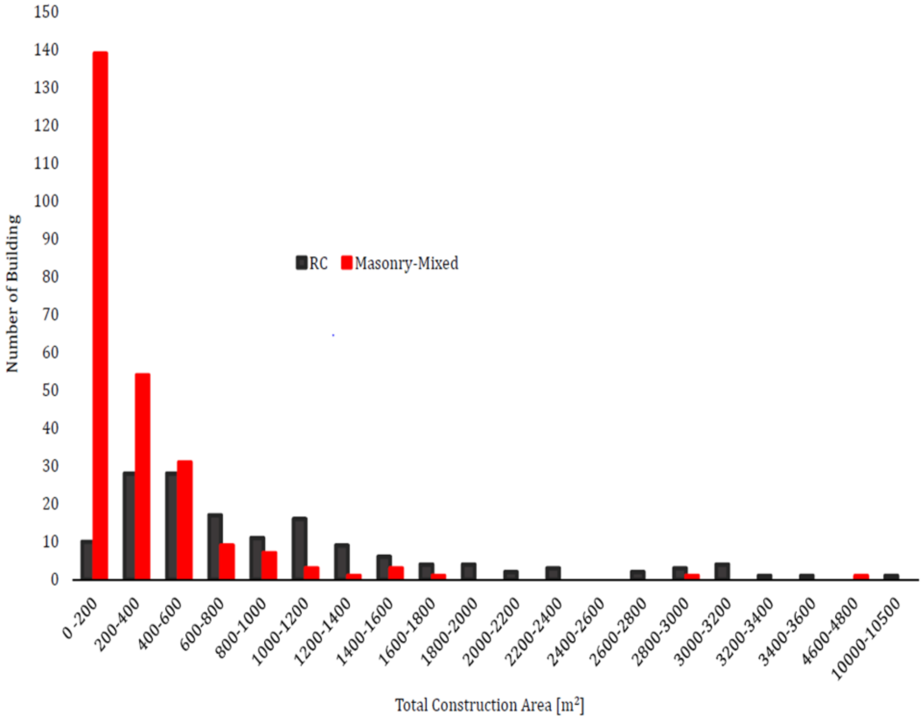

Figure 6. Total construction areas of examined RC and masonry-mixed buildings

3. EVALUATION OF COLLECTED BUILDING PERFORMANCE DATA

3.1. Masonry-mixed Buildings

The load-bearing wall and slab types of the masonry-mixed buildings discussed here are given in Figure 7 and Figure 8. In the masonry-mixed buildings examined within the scope of urban transformation, it was found that the load-bearing walls consisted of blended bricks by 52%, concrete briquettes by 18%, and fabricated bricks by 10%, respectively. Because most of these buildings, as stated before, were built between 1970 and 1980 in Istanbul, the common intensive use of blended bricks and concrete briquettes caused these wall types to be encountered more substantially. In order of frequency, a significant number of masonry-mixed buildings constructed with full blended bricks by 5%, briquettes by 5%, vertically perforated bricks by 4%, and hollow fabricated bricks by 2% were seen in distorted old urban settlements and slum areas of Istanbul’s districts. The vulnerability of unreinforced masonry buildings to impaired performance is a serious problem facing structural engineers today. Generally speaking, the compression strength is high and tension strength is low at materials such as briquettes, bricks and stone walls, etc. These materials are brittle, which leads to a rigid or flexible behavior, so, they have high deformation problems when exposed to reversed compression and tension loads. Unreinforced masonry walls usually constructed from these materials were designed primarily to resist gravity loads with little or no consideration for lateral loads. Although masonry-type buildings perform satisfactorily under service loads, there is evidence that they may suffer serious damage under high lateral loads such as earthquake inertia forces. Besides seismic loads, masonry-mixed buildings may require upgrading due to abnormal loads, environmental loads, or other causes of deterioration. Moreover, it was seen in previous earthquakes that the buildings with these types of load-bearing walls were single-floor and small structures; but, they had no capability of moving during an earthquake, which resulted in severe damages and losses in these buildings. Most of the masonry-mixed buildings with few floors are not only in the urban areas of Istanbul but also in distorted old settlements and slums, for this reason, it is important to evaluate these buildings as a matter of priority in the urban transformation [31]. As shown in Figure 8, the existing statistical data mean that the most common slab type used in masonry-mixed buildings is the flat slab/mushroom slab system by 91% and the second most common type is the beam slab system by 9%. An insignificant number of waffled-slab floor buildings were also detected in the examined masonry-mixed buildings [32].

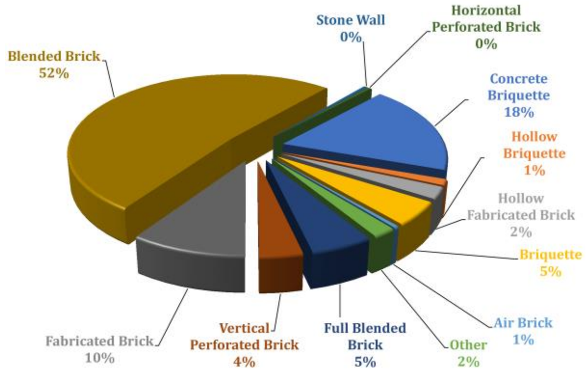

Figure 7. The percentage of each construction type in the masonry-mixed buildings

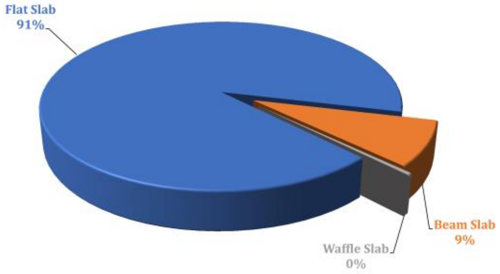

Figure 8. Distributions of slab characteristics in the masonry-mixed buildings

Indeed, the typical damage to masonry-mixed buildings can be caused by the in-plane failure of load-bearing walls, which are the main lateral earthquake-resistant elements, inadequate ties to parapets, out-of-plane failure of load-bearing walls, damage due to thrust from the roof, and pounding of adjacent buildings. Nevertheless, the documentation of damage to Turkish masonry-mixed buildings is not found extensively in the literature, though it may be because research groups generally focus on urban areas where RC construction dominates. Alternatively, as an explanation of the risk level, the structural analysis of masonry-mixed buildings can be conducted by comparing the shear strength of load-bearing walls as shear walls on the critical floor and the shear forces caused by the earthquake in both directions of the building, because one of the parameters for the masonry structures is wall ratio of building. So, if the contribution of the walls with insufficient strength to the floor shear force is above 50% in the X- or Y-direction, the building is considered a risky building [12, 30–31]. The contribution of the strength of walls with insufficient to floor shear force is presented in Figure 9, and this contribution is observed ranging from 0 to 100%. This ratio can be used for ranking of evaluated masonry-mixed buildings according to the level of seismic risk and their prioritization for further evaluation according to TEC-2007 Ch. 7.

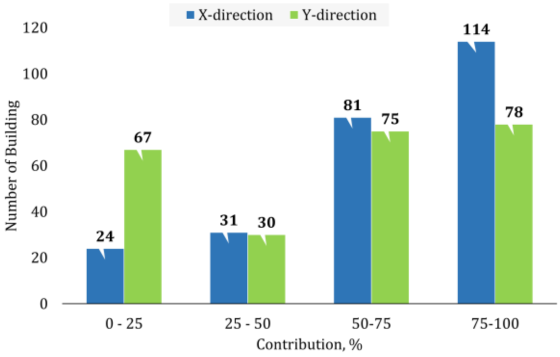

Figure 9. Contribution of the strength of insufficient walls to the floor shear force

The total shear force on any wall in the direction of the earthquake is calculated by multiplying the rate of rigidity of that wall to total rigidity in that direction. Similarly, total shear forces affecting the floors are distributed in the rates of rigidities of the walls on that floor. The walls in the X-direction are effective when the earthquake is effective in X-direction and the walls in the Y-direction are effective when the earthquake is effective in Y-direction. In the structural analysis of masonry-mixed buildings, the ratio of the total area of load-bearing walls in each orthogonal directions in the plan (excluding openings) to the gross floor area (GFA) is considered and presented in Figure 10. As shown in the figure, the ratio meaningfully varies between 2% and 16%, accordingly, it is understood that the density of load-bearing walls of observed masonry-mixed buildings was low percentages in both directions of considered ranges. Since these masonry-mixed buildings would not be able to sustain the demands from the earthquake shaking, all of those were evaluated as risky buildings within the scope of urban transformation.

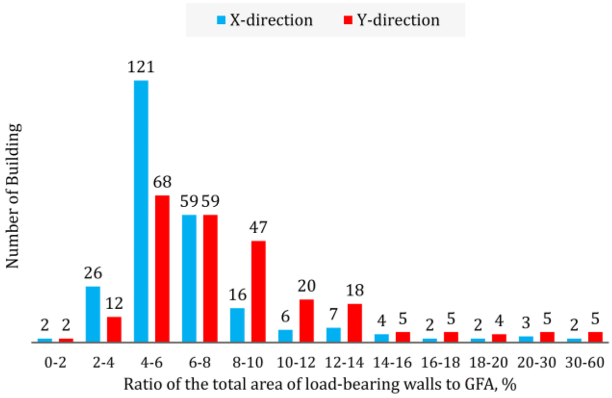

Figure 10. Ratio of the total area of load-bearing walls to GFA

3.2. RC Buildings

As observed in Figure 3, the properties of the concrete used in the Turkish building stock have been evaluated in terms of the concrete quality of the buildings constructed before and after 2000. According to TEC-1998, concrete with any strength below C16 class cannot be used in RC buildings to be constructed in earthquake zones, and C20 class must be the minimum concrete strength in 1st and 2nd-degree earthquake zones. Although TEC-1998, which requires the lowest concrete strength to be 20 MPa, the rigorous control of the concrete assembling process has been employed with the new set of construction supervising law (i.e., Law on Construction-Inspection (Law No. 4708 dated 2001)) introduced after 2000. Extensive use of ready-mix concrete started after that year; however, before 2000 when ready-mix concrete was used, the quality was poor. It is noted by [33] that half of the samples which were taken from the ready mix concrete process did not satisfy the requirements of the related standards. Note that the concrete characteristics presented here have been obtained from cored samples of the risky buildings tested within the scope of urban transformation. The statistical evaluation of concrete qualification is done according to the relative Turkish Standards [34–35]. The compression strength capacities of the RC buildings examined within the scope of urban transformation are shown by construction years in Figure 11. As shown in this figure, the average values of concrete compression strength results of the RC concrete buildings constructed in compliance with the TEC-1975, TEC-1998, and TEC-2007 (i.e., constructed between 1940–2010) were evaluated for the average of each constructed year of RC buildings, respectively. The average concrete quality of the risky building stock is about 10.36 MPa pre-1975, 9.00 MPa pre-1985, 7.82 MPa pre-2007, and 9.22 MPa in 2010, respectively. As shown in Figure 12, the minimum and maximum average values of concrete compression strengths for the examined RC buildings having a range of 1- to 8-story (see Figure 5), which represented the majority of taking cored samples, were found to vary from 7.51 MPa for 7-story to 9.75 MPa for 2-story, buildings, respectively.

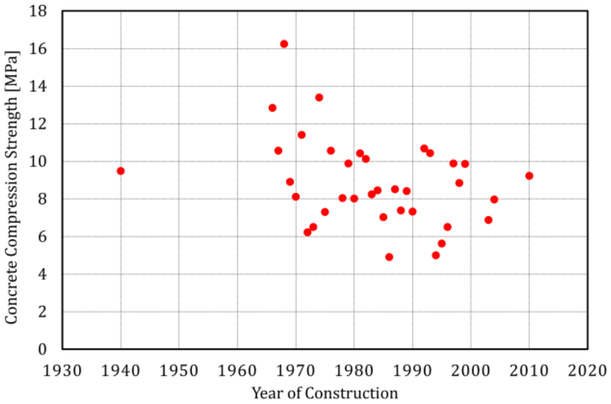

Figure 11. Distribution of concrete compression strengths according to building construction years

According to TEC-2007, the compression strength value of the concrete in buildings should be at least C20. According to the data presented here, none of the buildings has a concrete compression strength class upper than C20, which is unacceptable for the earthquake regions. In addition to this, there are high-rise buildings that do not fulfill the C20 concrete strength condition stated in TEC-2007, posing a huge risk. Although the buildings are constructed according to the rules specified in the earlier earthquake zones map and building earthquake codes, which are in effect on the date of construction, it is likely to be a risky building because the risk analysis is performed using the current earthquake hazard map and building earthquake code. For example, the C20 strength condition is designated as minimum C25 under the Building Earthquake Code of Turkey (TEC-2018) [36] which is based on a new Turkish accelerometric database and analysis system launched by the Turkish Disaster and Emergency Management Authority of Turkey (AFAD-TADAS) [37]. Hence, the older risky building inventory of urban transformation will also be covered with buildings that do not fulfill this condition as concrete quality.

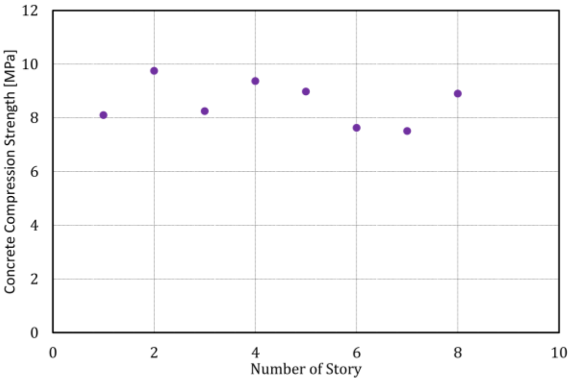

Figure 12. The values of concrete compression strength according to the number of stories

To check the current concrete compression strength, nondestructive methods will be used in at least 10 elements from the columns and shear walls of the critical floor, and cored samples will be taken from 5 places where the lowest result is obtained. If the floor area is more than 400 m^2, the cored sample will be increased by one for each 80 m^2 exceeding 400 m^2 [17]. Consequently, the building is considered a risky building if the average concrete compression strength value is below 20 MPa in the results obtained from these samples. In Figure 13, the distribution of RC buildings analyzed within the scope of urban transformation is given according to the number of cored samples. It was found in the analysis that 5 cored samples were taken in approximately 138 of 150 buildings. It covers 92% of the total number of RC buildings. However, when TEC-2007 is examined, it is stated that one cored sample from every 400 m^2, not less than three columns or shear walls on each floor and not less than 9 in total in the building, must be taken per the conditions specified in TS-10465 [34]. Furthermore, according to TEC-2018, the number of cored samples has been determined as a minimum of three on the ground floor, a minimum of two on other floors, and a minimum of nine in the whole building for detailed information. The number of cored samples can be said to be low in these analyses according to the earthquake codes mentioned previously and it is seen that most of the results do not fulfill these values as well.

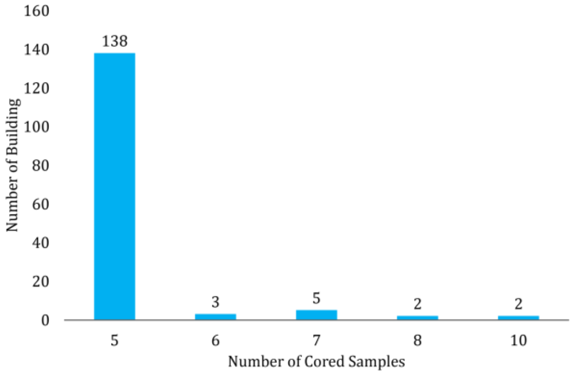

Figure 13. Observation values according to the number of cored samples

The concrete compression strengths of examined RC buildings under urban transformation are presented in Figure 14. It is seen that the examined RC buildings do not fulfill the current rules of concrete quality since RC buildings have poor concrete compression strengths by 67% between 6 and 9 MPa, by 42% between 9 and 12 MPa, and 25% between 3 and 6 MPa, etc., respectively.

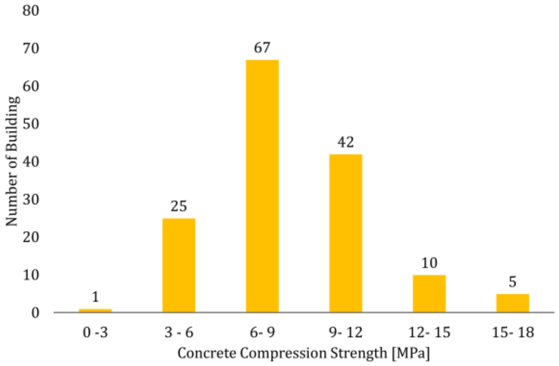

Figure 14. Concrete compression strengths of RC buildings

Two types of reinforcement steel/reinforcing bar/rebar have mainly been used in the Turkish building stock and they are referred to according to their 5% yield strength characteristics: S220 and S420 MPa (Bal et al., 2008). As summarized in Table 1, it was known that the S220-type steel was used for 141 out of the 150-RC building and S420-type steel for the remaining 9 out of those. However, it was stated that in Table 1, it is seen that the available reinforcement steel type in buildings was S220, but this steel type is not currently used. According to TEC-2018, B420C-type and B500C-type steels can be used in RC buildings. A total of 150 RC buildings, which comprise the types of beam slab by about 99% (e.g., emergent beams) and hollow block slab by 1% (e.g., embedded/hidden/concealed beams or asmolen slabs) is briefly tabulated in Table 1. In hollow block slab systems, nonstructural materials are used between joints. The hollow block slab usually consists of a wide and shallow beam. Because of the low beam height in this system, its lateral stiffness is less than beam floor systems. Because the hollow block slab has low lateral stiffness, using this slab type increases soft-story risk in buildings that have soft-first story risk [38].

Table 1. The types of reinforcement steel and slab

		Number of Buildings
Reinforcement steel type	S220	141
	S420	9
Slab type	Beam slab	148
	Hollow block slab	2

The corrosion can be different in the load-bearing parts of the building, e.g., frequently observed in the interaction areas of the building's ground floors. Also, it may change in different regions depending on the existence of gaps such as cracks [39–40]. In this research, the corrosion of the embedded reinforcement steel was observed in all examined RC buildings and thereby was assessed as a major risk. These corroded elements were marked in the floor layout plans, in this way, this situation was taken into account in the element capacity calculations. The corrosion conditions of RC buildings examined within the scope of urban transformation are provided in Table 2. Figure 15 shows captured photos from the field observations of some examined buildings into the worst corrosion condition. The negative effect of corrosion is heavily observed with the ranges of 3%–6% corrosion rates in 68 RC buildings (approximately 45% of RC buildings). The seismic performance of RC buildings examined here has been particularly proofed the poorness of the concrete quality including the heavily corroded rebar in risky RC building stocks. The reinforcement detailing and confinement of columns and beam-column joints are inadequate. A lack of lateral resistance of the framing system is common and irregularities in the strength, and stiffness with height occurs in the investigated RC buildings (see Figure 16). The foundations are usually shallow-type consisting of spread footings under individual columns or strips joining lines of columns, often with inadequate tie beams.

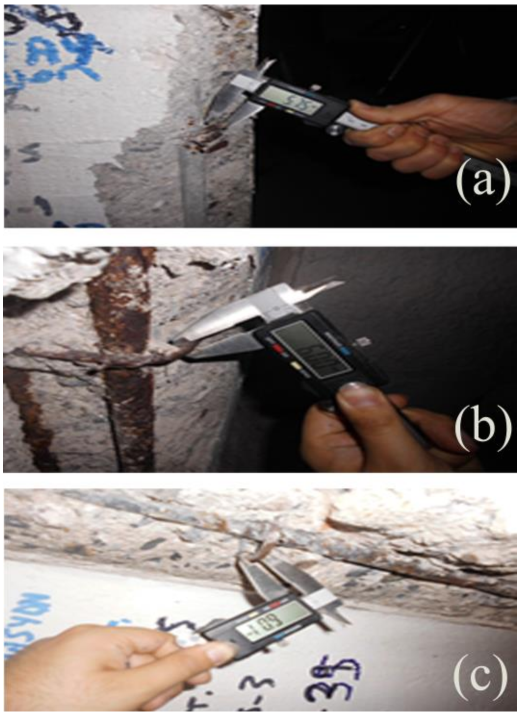

Figure 15. Views from measuring corroded reinforcements with Vernier Caliper

Table 2. The reinforcement corrosion rate of examined RC buildings

Reinforcement corrosion rates, %	Number of Buildings
0–1	2
1–3	25
3–6	68
6–9	47
9–12	8

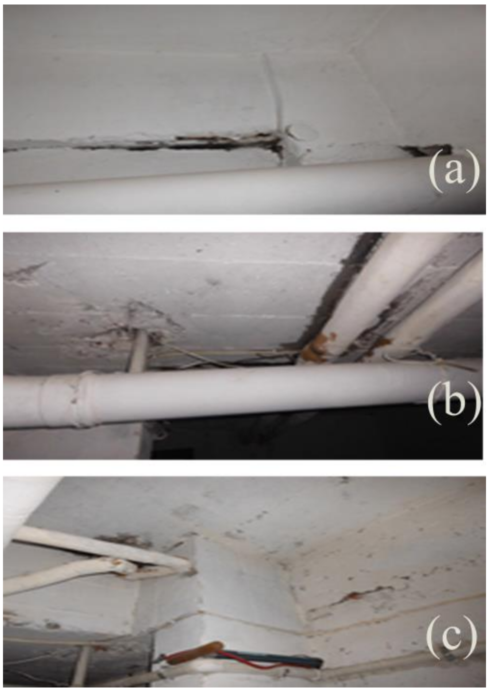

Figure 16. Close views from improper construction techniques and insufficient quality control and supervision examples for examined RC buildings

4. CONCLUSIONS

In an attempt to provide quantitative data for assessing the urban transformation process and applications of RC and masonry-mixed buildings in the case of Istanbul within the scope of Law No. 6306, this paper describes and compares the results from the findings and thoughts developed in the previous sections. The following major conclusions are briefly drawn based on the findings as a result of examining 150 RC and 250 masonry-mixed buildings, via the individual application method in Istanbul from the date of entry of the law on urban transformation into force until 2020:

- In the present research, 26% of the total number of masonry-mixed buildings were constructed between 1970 and 1980 and 56% had the total construction area in the range from 0 to 200 m^2. 31% of masonry-mixed buildings were one floor, and 40% were buildings of total heights between 5 m and 10 m. Concerning the most masonry-mixed building construction on the European and Asian sides, 24 out of every 100 buildings were located in the district of Sisli, and 15 in the district of Atasehir, respectively.

- 99% of RC buildings were built between 1960 and 2010. The total construction areas were ranging from 71.47 m^2 to 10345.77 m^2, especially, with 38% of whole RC buildings in the range of 200 m^2 to 600 m^2. Generally, 26% of RC buildings were six-floor buildings, and 37% of those varied between 10 m and 15 m according to heights. While the district of Atasehir was the higher risky building’s owner applications among them with twenty-nine percent on the Asian side, 5 out of 100 of building owner's applications were conducted from the district of Sisli on the European side.

- When masonry-mixed buildings were evaluated, it was seen that 52 out of every 100 buildings, the blended bricks were used in the load-bearing walls. The other percentages of materials used in the masonry-mixed buildings were the concrete briquettes by 18% and fabricated bricks by

10%. The most common slab type used in masonry-mixed buildings was the flat slab by 91% and the second one was the beam slab system by 9%.

- Considering the structural analysis of masonry-mixed buildings, the number of buildings in which the contribution of the walls with insufficient strength to the floor shear force was above 50% in both directions. The ratio of the total area of load-bearing walls in each orthogonal directions in the plan (excluding openings) to GFA varied between 2% and 16%.

- The peak and minimum values of concrete compression strengths obtained from the examined RC buildings were equal to 16.24 MPa in 1968 and 4.90 MPa in 1986. According to the current earthquake code, it is necessary for the concrete compression strength of the buildings located in earthquake zones to be minimum 25 MPa. Most of the number of cored samples taken from the buildings was equal to 5. It was also noted that the reinforcement steels in the buildings were S220-type steel class, which are not used anymore. Very high-level corrosion was detected in the buildings. For this reason, corrosion formation in RC building elements should be controlled in the ground floors of the building with respect to interaction areas, where the groundwater level is high. In the present work, the negative effect of corrosion was heavily watched with the ranges of 3%–6% corrosion rates in 68 out of every 150 RC buildings. In another observation for this technical paper was that the beam slabs had been used in 148 out of every 150 RC buildings.

- In assessing the risk of RC buildings within the scope of urban transformation, the irregularities described in the existing earthquake code should also be taken into consideration. Besides, it is recommended to increase the number of cored samples by considering the position of the structural elements in the building.

Most buildings were designed to meet the building code in place at the time of construction. In addition, since codes only certify the minimum requirements for safety, when changing a building's use, a structural analysis of the strength of the existing materials must be completed. The seismic response of structures plays an important role in guiding the choice of the correct seismic retrofitting strategy. It is clear that a successful seismic retrofitting strategy requires a full understanding of the expected response mechanisms of the rehabilitated since the retrofitting measures can alter the complete existing building response. So, it is good for one building that may not necessarily be right for another to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. The selected method must be consistent with aesthetics, function, and strength, ductility, and stiffness requirements. It is required to make a true decision on whether to renew or seismic retrofitting of the risky buildings under urban transformation. It is recommended if the buildings with an earthquake risk cannot be renewed under urban transformation due to financial incapability, and, in that case, financial and technical support can be provided for such cases within the context of reinforcement under urban transformation. While the current practice of seismic retrofitting is predominantly concerned with structural improvements to reduce the seismic hazard of using the structures, it is similarly essential to reduce the hazards and losses from nonstructural elements. This work, along with the studies on risky buildings' material properties presented here, was originally in Turkish and so the authors have decided to summarize these studies, such that the information can be used by a wider, international audience. Hence, the important additional information is provided to a gap in the current knowledge based on the earthquake-induced damage evaluation and seismic damage mitigation strategies for future researchers.

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CONFLICTS OF INTEREST/COMPETING INTERESTS

All authors have no conflict of interest to declare the research described in this paper.

AVAILABILITY OF DATA AND MATERIAL

All raw/processed data are provided by Tektas Engineering authorized for determining risky buildings within the scope of Law No. 6306 by the Ministry of Environment and Urbanization in Turkey. The generated or used data required to reproduce these findings of this study will be made available from the corresponding author upon reasonable request.

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