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RESEARCH PAPER

Evaluation of Structural Properties of Existing Turkish RC Building Stock

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Abstract

The huge number of structures in which the major portion of the population resides will be seriously damaged if there is an earthquake on a medium or a large scale. For this reason, it has become a necessity to determine the structural characteristics in order to assess the seismic performances of existing RC buildings. However, the enormous size of the building stock to be assessed is the biggest problem for this evaluation. Therefore, it is necessary to make evaluations on all stock by making generalizations over the sample buildings for reflection of building stock. From this perspective, the building models used to reflect the exact building stock is of great importance. This study aims to generate statistics about structural properties of Turkish RC building stock using a detailed archive investigation. The inventory data set contains 8850 beams, 26,963 columns and 2311 shear walls from 506 existing residential buildings for comprehensive assessment. In this study, important structural parameters which are effective on the seismic response of existing RC building stock are investigated for proper modeling. The buildings are subgrouped according to embedded and emergent beam systems, absence and presence of shear walls and number of storeys. The statistical information such as average values, standard deviation and coefficient of variation has been investigated for the considered parameters. The findings of the present study were compared with past studies depending on the average values of parameters. The comparison emphasizes that the values of some parameters may be affected by construction date and number of storeys.

Keywords Existing buildings · Low- and mid-rise buildings · Reinforced concrete · Seismic performance · Structural irregularities · Building stock

1 Introduction

In the last 30 years, large- and medium-scale earthquakes causing massive casualties and material damage have occurred in Turkey. The resulting damaged buildings and casualties are concentrated in "low- and mid-rise" buildings, which are under eight storeys (Inel et al. 2008, 2013; Ozmen et al. 2014a). It has been reported that these buildings did not have sufficient performance due to inadequate structural characteristics of reinforced concrete buildings (Bayraktar et al. 2013a, b; Kocak et al. 2015; Oyguc 2016; Yazgan et al. 2016). Common observations of the studies have reported structural inadequacies such as weak and soft storeys, strong beam–weak columns, short columns, heavy overhang, inadequate shear wall ratio, inadequate transverse reinforcement, non-ductile detailing of members, poor concrete and poor steel quality (Sucuoglu 2000; Celebi et al. 2013; Ozmen et al.2013; Tama et al. 2013; Yon et al. 2013; Sayin et al. 2014; Yon et al. 2015).

Another common view in the studies is that there are thousands of structures that will be seriously damaged if there is an earthquake on medium or large scale (Adalier and Aydingun 2001; Sezen et al. 2003; Dogangun 2004). Therefore, it has become a necessity to determine the structural characteristics in order to assess seismic performances of the existing buildings. However, the enormous size of the building stock that needs to be examined is the main problem for this evaluation. For this reason, it is necessary to make evaluations on all stock by making generalizations over the sample buildings assumed to represent the building stock. In this case, the models used to reflect the building stock exactly are of great importance. There are many studies about seismic performance of RC buildings in the

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literature (Akkar et al. 2005; Meral 2010; Dogangun and Sezen 2012; Cakir and Uysal 2014; Ozmen et al. 2014b, Isik and Kutanis 2015; Korkmaz et al. 2015; Siddiqui et al. 2015; Ucar et al. 2015; Inel and Meral 2016).

Structural and architectural blueprints of existing low- and mid-rise RC buildings were gathered from structure inspection firms and construction offices. Statistics of various parameters such as storey number, material features, plan dimensions, storey area, storey elevations, quantity of heavy overhangs and infill walls, number of continuous frames and reinforcement arrangements from the blueprints were transferred to a Microsoft Excel worksheet. Statistical assessments depended on the obtained parameters. The inventory data contained 8850 beams, 26,963 columns and 2311 shear walls from 506 buildings for comprehensive assessment.

This study aims to determine the distribution and values of the various parameters in the inventory which will reflect the structural characteristics of existing structures. By evaluating this information, it is aimed to obtain an important source of building culture and construction. Through the building models to be prepared in accordance with these data, the existing building stock can be evaluated more accurately and consciously. The collected data consist of residence and residence plus workplace buildings which consist of 90% of the stock (Building Census 2000 2001). Other building types such as schools, hospitals and public structures are excluded from the scope of this study.

2 Past Studies

Since the number of reports is limited about inventory studies, this work is believed to contribute to structure source by increasing the quantity of information about the issue. There are inventory studies related to northwest (Bal et al. 2008; Ay 2012), southeast (Bal et al. 2007) and southwest (Ozmen et al. 2015) zones of Turkey.

The Inventory database of 211 reinforced concrete buildings which were damaged after 1998 Adana–Ceyhan Earthquake has been composed for study of Adana region by Bal et al. (2007). The detailed statistical data have been given about structural characteristics and cost of retrofitting for loss assessment studies to Adana region.

Approximately 1400 buildings obtained from Marmara region have been used to assess parameters such as beam depth, floor area and storey height of building stock by Bal et al. (2008). The buildings have been divided into two main groups as non-compliant and compliant according to Turkish Earthquake Code (TEC 1998).

A ground-motion selection and scaling procedure have been researched by verifying the seismic response of 3-, 4- and 8-storey buildings that were developed from a statistical study that collected the general characteristics of Turkish RC building stock by Ay (2012). The database includes geometrical properties such as storey height, floor plan dimensions, number of continuous frames, span lengths and dimensions of columns.

Important structural parameters effective on the structural response of the Turkish RC building stock have been investigated by Ozmen et al. (2015). Buildings have been classified according to 1975 (TEC 1975) and 1998 (TEC 1998) Turkish Earthquake Codes as their construction year and number of storeys. A total of 475 low- and mid-rise buildings, 40,351 columns and 3128 beams from these buildings were taken into consideration for member properties.

The previous studies have given information about parameters such as number of storeys, storey elevation, plan dimension, floor area, dimensions of columns and beams, material properties, slab type and construction year of Turkish RC building stock. Ozmen et al. (2015) also investigated the quantity of heavy overhang and infill walls, number of continuous frames, number and area of columns per ground storey area and arrangement of beams and columns for their study. All past studies about building stock are related to just frame with load carrying systems. In addition to above-mentioned studies, detailed values about slab thickness for different beam types, dimensions and arrangement of shear walls were obtained for different building databases in relationship with the number of storeys in this study.

3 Procedure

The previous studies related to the current issue used 1975 (TEC 1975) and 1998 (TEC 1998) Turkish Earthquake Codes as construction year. For this reason, buildings are classified per TEC (1975) and TEC (1998) for assessment of existing buildings. 2007 Turkish Earthquake Code (TEC 2007) has been published recently by modifying the TEC (1998). However, changes in the new code are connected with performance evaluation of existing buildings, and differences in design of the new buildings are limited between TEC (1998) and TEC (2007). The code considered as modern is TEC (2007) for this study since the selected buildings were constructed after 2007. The buildings were divided into three representative groups as 2 storeys, 3–5 storeys and 6–8 storeys. One-storey buildings were kept out of the scope of this study.

Firstly, structural and architectural blueprints of RC buildings were obtained from private archives of civil engineers. Then, features of the buildings were received from the blueprints and transferred to Microsoft Excel worksheets for assessment and analyses. The inventory study which collected information of buildings was considered to consist of the applied buildings' projects and to reflect the construction characteristics. The structural properties such as storey elevations, plan dimensions, floor areas, dimensions of columns and beams and material properties were directly employed as applied in the original buildings' projects.

4 Database

The outcomes of detailed archive investigation included 506 existing residential RC buildings, 8850 beam, 26,963 column and 2311 shear wall elements for the data set. All columns in the buildings were evaluated for further examination of the column elements. On the other hand, the numbers of beams and shear walls were lower because the selected representative elements were used for beams and shear walls.

The building database was selected to represent low- and mid-rise buildings located in the high seismicity southeast part of Turkey as Osmaniye, Adana, Kahramanmaras, Gaziantep and Hatay provinces. The inventory study consisted of 2–8-storey RC buildings for comprehensive assessment.

TEC (2007) was taken into consideration as a critical date because the buildings were constructed after 2007. The number of buildings, beams, columns and shear walls employed in the study is shown in Table 1.

The damage of existing buildings was concentrated especially in 3–8-storey buildings during the past earthquake events in Turkey (Bayraktar et al. 2013b, Ozmen et al. 2014a). The distribution of the buildings changes was inversely proportional to the number of storeys (Table 1). The representative RC buildings were selected based on the residential buildings located in town centers and the vulnerability of existing buildings obtained in the past earthquakes.

5 Construction Types

The structural system of buildings was divided into four types as frame construction, load-bearing wall construction, tunnel model system and prefabricated by Building Census 2000 (2001). The buildings with and without shear wall as load carrying systems were considered for the current study. The number of buildings was given for frame with and without shear wall per number of storeys which is shown in Table 2.

Table 1 Number of buildings, beams, columns and shear walls employed in the study

Storey	Building	Beam	Column	Shear wall
2	240	1566	6203	65
3–5	158	2196	9578	727
6–8	108	5088	11,182	1519
Total	506	8850	26,963	2311

The presence of shear walls can considerably affect some parameters such as number and area of columns per storey area. Therefore, the buildings were subgrouped according to whether or not they had shear wall in numerical assessment. As the number of storey increases, the distribution of the number of buildings with shear wall within the inventory increases as shown in Fig. 1.

6 Assessment of Building Features

Material properties, area and dimensions of plan, storey elevations, quantity of heavy overhang and infill walls, number of continuous frames, number and area of columns per ground storey area, slab thickness, dimensions and arrangement of beams, columns and shear walls are crucial parameters for assessment of seismic performance and design of RC buildings. Mathematical and statistical assessments depend on the achieved parameters. The average, standard deviation (SD) and the coefficient of variation (CoV) of parameters were calculated and are shown in their respective tables (Tables 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16). In addition, the data obtained in the present study were compared with the previous studies to determine eligibility or diversity.

The beams of selected buildings were distinguished as embedded beams and emergent beams for slab systems in

Table 2 Number of buildings in the scope with frame and shear walls

Storey	Frame	Frame with shear wall	Total
2	222	18	240
3–5	94	64	158
6–8	18	90	108
Total	334	172	506

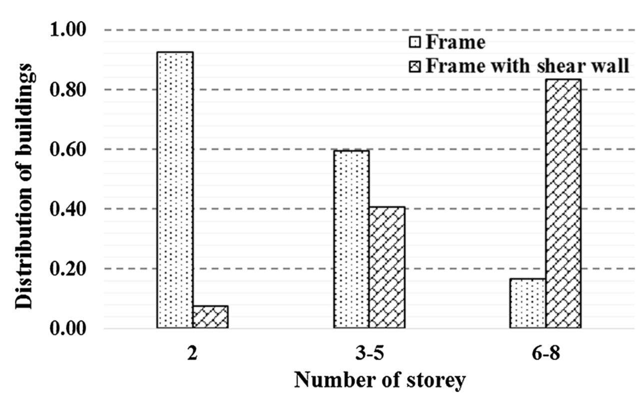

Fig. 1 Proportion of buildings in terms of frame with and without shear wall

this study. Since the embedded beams are not as rigid as emergent beams, these embedded beams are objectionable about seismic performance. However, they are preferred by the designers because the slab systems with embedded beams have advantages such as heat and sound insulation, low mold cost and easy workmanship.

7 Material Characteristics of the Stock

The concrete characteristic compressive strength of selected buildings was obtained using a database for building stock, which had 506 buildings in Osmaniye and its surrounding provinces as shown in Table 3. The average concrete strength of the older stock has been given 17 MPa with a CoV of 51% regardless of the number of storeys by Bal et al. (2008). Ozmen et al. (2015) found the average concrete strength of the buildings as 24.0 MPa for 1–2-storey, 25.2 MPa for 3–5-storey and 28.7 MPa for 6–8-storey buildings with a CoV of 13%, 15% and 13% for existing buildings after TEC (1998), respectively.

It was found out through this study that the S420 type steel was used for all buildings constructed according to TEC (2007). The findings of Ozmen et al. (2015) have shown the average characteristic steel strength of the buildings as 420.0 MPa for 1–2-storey, 405.3 MPa for 3–5-storey and 415.7 MPa for 6–8-storey buildings with a CoV of 0%, 13% and 7% for existing buildings after TEC (1998), respectively.

It has also been determined that the concrete which had lower strength than C20 (20 MPa) and the reinforcement steel which had higher strength than S420 were not used in all reinforced concrete buildings built in seismic zones in TEC (2007).

Table 3 Average, standard deviation (SD) and coefficient of variation (CoV) for identified typical material features

Storey	Average	SD	CoV
Identified typical concrete strength (MPa)			
2	23.38	2.63	0.11
3–5	23.91	3.05	0.13
6–8	25.60	2.12	0.08

8 Area and Dimensions of Plan

The plan dimensions are examined by considering the lengths of short and long plan dimensions as well as their ratios in Table 4. The plan area has also been researched in terms of ground storey area. The ground storey area and dimensions were investigated according to the number of storeys. When the ground storey area of buildings increases, the number of buildings in the inventory data decreases as illustrated in Fig. 2.

Bal et al. (2008) indicated an average ground storey area of 1144 buildings as 222 m^2 with a CoV of 85%. Ozmen et al. (2015) reported an average ground storey area of 475 buildings as 136.2 m^2 for 1–2-storey, 161.2 m^2 for 3–5-storey and 296.8 m^2 for 6–8-storey buildings with a CoV of 54%, 43% and 69% for existing buildings constructed per TEC (1998), respectively.

Ozmen et al. (2015) demonstrated an average long and short plan dimensions as 13.05 m and 10.24 m for 1–2-storey, 16.00 m and 10.84 m for 3–5-storey, 19.82 m

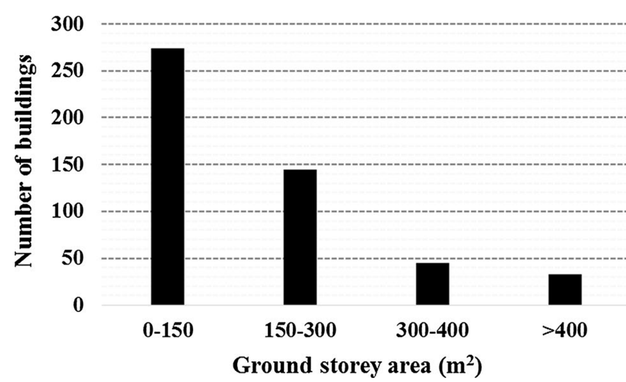

Fig. 2 Distribution of ground storey area for all RC buildings

Table 4 Average, standard deviation (SD) and coefficient of variation (CoV) for plan dimensions, ground storey area and ratio of long/short plan dimension

Storey	Average	SD	CoV	Average	SD	CoV
	Long plan dimension (m)			Short plan dimension (m)		
2	13.77	4.61	0.33	10.25	2.88	0.28
3–5	16.96	6.71	0.40	11.67	3.48	0.30
6–8	23.13	7.21	0.31	14.21	3.98	0.28
	Ground storey area (m^2)			Ratio of long/short dimension for ground storey		
2	136.37	48.36	0.35	1.38	0.38	0.28
3–5	181.80	93.69	0.52	1.49	0.54	0.36
6–8	297.71	122.84	0.41	1.71	0.66	0.38

and 13.84 m for 6–8-storey buildings with a CoV of 24% and 27%, 23% and 25%, 33% and 39% for TEC (1998) buildings, respectively. The average long and short plan dimensions have been given as 13.24 m and 9.20 m for 3–5-storey buildings with a CoV of 63% and 41% by Ay (2012), respectively. These dimensions have been reported as 15.42 m and 10.30 m for 6–9-storey buildings with CoV of 46% and 39% by Ay (2012), respectively.

Ozmen et al. (2015) showed the ratio of long/short dimension as 1.32 for 1–2-storey, 1.53 for 3–5-storey and 1.49 for 6–8-storey buildings with a CoV of 21%, 28% and 30% for TEC (1998) buildings, respectively. Ay (2012) has also reported the ratio of short/long dimension as 0.73 for 3–9-storey buildings with a CoV of 25%. It should be noted that the values of ground storey area and plan dimensions presented in this study are similar to those observed in Ozmen et al. (2015).

The current study confirmed the storey area by Building Census 2000 (2001). The storey area is used 75–149 m^2 for 68% of 2-storey buildings. This area value is commonly 100–299 m^2 for 58% of 3–5-storey buildings. For 6–8-storey buildings, the storey area value is employed extensively 150–399 m^2 by 53% of them. Our analyses suggested that the ground storey area values in Table 4 were in compliance with the abovementioned storey area information.

9 Storey Elevation

The storey elevation database was obtained as ground storey and upper storey elevation for statistical assessment (Table 5). The ground storeys are usually employed for commercial aims for residential buildings in Turkey. This is the main reason why ground storeys may be higher than the upper storeys' elevation for the Turkish building stock. This phenomenon is taken into account for the statistical evaluations described in this study.

The average ground and upper storey elevations have been given between 2.77 m and 3.40 m independent of construction year and number of storeys by Ozmen et al. (2015). The average upper storey elevation has been found 2.84 m with a coefficient of variation of 8% for Marmara region by Bal et al. (2008). Bal et al. (2007) found an average upper storey elevation of 221 buildings as 2.86 m with a coefficient of variation of 5% for Adana region.

The average ratios of the ground storey elevation to the upper storey elevation (being higher than 1.00) point out the presence of soft storeys in the buildings. These values were obtained approximately as 1.20 for all storey buildings in this study. The average ground/upper storey elevation values have been given between 1.18 and 1.41 by Ozmen et al. (2015). This ratio has been reported as between 1.04 and 1.16 for Marmara region by Bal et al. (2008). Bal et al. (2007) showed the average ratio as 1.19 with a coefficient of variation of 13% for Adana region. The values in the current study are fairly close to the similar studies mentioned above.

10 Quantity of Heavy Overhang

Heavy overhangs reduce the lateral stiffness and increase the weight of structure. As the weight of the structure increases, the distance between the center of mass and the center of rigidity also increases. This negatively changes the behavior of the structure against an earthquake. There are multiple reports about effects of heavy overhangs to RC buildings (Meral 2010; Ozmen 2011; Ozmen et al. 2011).

The average ratios of the heavy overhang area to the upper storey area are shown in Table 6. Ozmen et al. (2015) given

Table 6 Average, standard deviation (SD) and coefficient of variation (CoV) for quantity of heavy overhang

Storey	Average	SD	CoV
	Heavy overhang area/storey area ratio (%)[a]		
2	7.22	5.47	0.76
3–5	8.47	6.19	0.73
6–8	7.88	6.45	0.82

[a]Only for the 208 buildings with heavy overhangs

Table 5 Average, standard deviation (SD) and coefficient of variation (CoV) for plan dimensions, ground storey area and ratio of long/short plan dimension

Storey	Average	SD	CoV	Average	SD	CoV	Average	SD	CoV
	Ground storey elevation (m)			Upper storey elevation (m)			Ground storey/upper storey elevation ratio[a]		
2	3.01	0.13	0.04	2.98	0.16	0.05	1.56	0.74	0.48
3–5	3.00	0.14	0.05	2.98	0.10	0.04	1.12	0.12	0.10
6–8	2.99	0.16	0.05	2.95	0.14	0.05	1.09	0.13	0.12

[a]Only for situations (37 buildings) for different ground and upper storey elevations

Table 7 Average, standard deviation (SD) and coefficient of variation (CoV) for quantity of infill walls

Storey	Average	SD	CoV	Average	SD	CoV
	Infill wall length/ground storey area for long dimension (%)			Infill wall length/ground storey area for short dimension (%)		
2	7.45	7.32	0.98	7.91	7.04	0.89
3–5	5.97	6.35	1.06	5.86	6.22	1.06
6–8	4.90	4.92	1.00	4.17	4.21	1.01

the ratio of overhang area/storey area as 4.53 for 1–2-storey, 10.78 for 3–5-storey and 8.05 for 6–8-storey buildings with a CoV of 89%, 70% and 93% for TEC (1998) buildings, respectively. The coefficient of variation values were calculated reasonably higher according to other parameters as the findings of Ozmen et al. (2015). Our results suggest that the comparison of the current study with the past observed values have similar tendency.

11 Quantity of Infill Walls

Infill walls increase lateral strength and reduce displacement demands of structures comparing to buildings without infill walls (Korkmaz et al. 2013; Inel and Meral 2015; Meral 2015). The infill walls satisfying TEC (2007) criteria should be modeled as load carrying elements. In the structure model, infill walls arranged in a reinforced concrete frame and having a ratio of diagonal length to thickness less than 30 shall be taken into consideration per TEC (2007). Another criterion, infill walls with spaces that do not exceed 10% of the wall surface area may be permissible to include into the building model, provided that the position of the spaces does not obstruct the formation of the diagonal pressure bar. The characteristics of infill walls are given in Table 7 in terms of infill wall lengths for long and short dimension, respectively. The thickness of infill walls was taken into account as 200 mm in this study. The wall elements are constructed independent of storey number, and their amounts are generally the same on each storey. However, the ratio of infill wall length/ground storey area decreases (as shown in Table 7) due to the increase in the storey area based on the number of storeys.

12 Number of Continuous Frames

The presence of continuous frames is one of the important properties of the Turkish building stock due to lateral load transfer between elements (Fig. 3). Therefore, the number

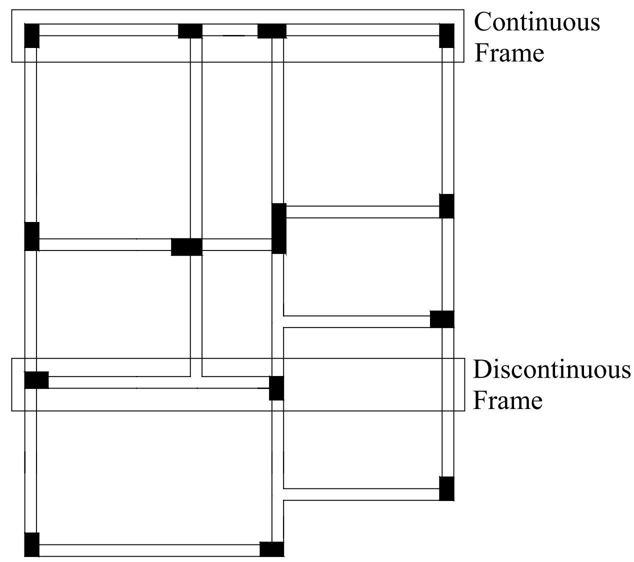

Fig. 3 Continuous and discontinuous frame

of continuous frames per ground storey area along the long and the short dimensions of buildings is also shown in Table 8 to reflect one of the other characteristics of the Turkish building stock. The continuity of frames increases with the decreasing number of storeys as demonstrated in Table 8.

Beam deficiencies in buildings with heavy overhangs and architectural necessities affect the number of continuous frames negatively on the upper storeys. There are few or no continuous frames in buildings due to the deficiency of beams connecting columns which have brought the standard deviations and average values of this parameter close to each other. Therefore, the coefficient of variation of continuous frames is higher than most of the other parameters. There is information created with different definitions about the number of continuous frames for RC buildings in previous studies (Ay 2012; Ozmen et al. 2015).

Table 8 Average, standard deviation (SD) and coefficient of variation (CoV) for number of continuous frames

Storey	Average	SD	CoV	Average	SD	CoV
	Number of continuous frames/ground storey area for long dimension (%)			Number of continuous frames/ground storey area for short dimension (%)		
2	2.41	1.37	0.57	2.44	1.38	0.57
3–5	1.78	1.21	0.68	1.91	1.24	0.65
6–8	1.14	0.77	0.67	1.30	0.84	0.64

Table 9 Average, standard deviation (SD) and coefficient of variation (CoV) for number and area of columns according to ground storey area

Models	Storey	Average	SD	CoV	Average	SD	CoV
		Number of columns/ground storey area (%)			Total area of columns/ground storey area (%)		
Frames without shear walls	2	11.57	3.08	0.27	1.67	0.58	0.35
	3–5	10.61	3.01	0.28	1.82	0.62	0.34
	6–8	6.86	1.74	0.25	1.97	1.00	0.51
Frames with shear walls	2	9.50	2.79	0.29	1.40	0.51	0.36
	3–5	8.70	2.39	0.27	1.62	0.51	0.31
	6–8	7.26	2.17	0.30	1.58	0.51	0.32

13 Number and Area of Columns Per Storey Area

Number and quantity of columns according to storey area are connected with axial load carrying, shear and flexure capacities of the buildings. Vertical load carrying elements are crucial especially columns and shear walls for reliable assessment of the existing buildings. The statistics about columns for the ground storey are presented in Table 9. The number and total area of columns are given for frame with and without shear wall per number of storeys in Table 9. The presence of shear walls may considerably affect the quantity of columns as shown in Fig. 4. In accordance with the previous studies, obtained values for shear walls in the table are generally lower than the values belonging to the absence of shear walls with buildings since the presence of shear walls decreases the necessity for columns. However, Ozmen et al. (2015) calculated higher values of column cross-sectional area in buildings with shear wall than that of buildings without shear wall, unlike the values illustrated in Fig. 4.

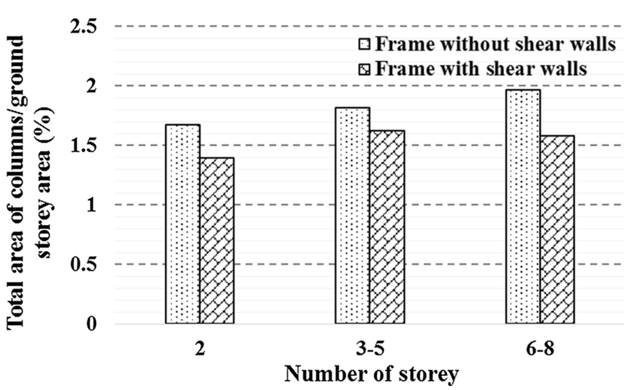

Fig. 4 Total area of columns/ground storey area (%) ratios depending on average values according to the absence and presence of shear walls

14 Element Properties

The structural properties of the considered RC buildings which have been investigated in this study contain slab thickness and dimensions along with longitudinal and transverse steel detailing of building elements such as beams, columns and shear walls. Average, standard deviation (SD) and coefficient of variation (CoV) obtained for the element parameters herein are shown in Tables 10, 11, 12, 13, 14, 15, 16.

14.1 Slab Thickness

The beams of selected buildings are considered as embedded beams and emergent beams for slab systems herein (Fig. 5). The thicknesses of slabs are given in Table 10 in terms of beam types for embedded and emergent beams. When the ratios of slabs with embedded beam and emergent beam are 85% and 15%, respectively (in the inventory), the average values of these slabs per number of storey are calculated as in Fig. 6. The average thickness for slab with embedded beams has been reported between 250 mm and 320 mm for study of Adana region by Bal et al. (2007). Bal et al. (2008) found that the average thickness for slab with emergent

Table 10 Average, standard deviation (SD) and coefficient of variation (CoV) for slab thickness

Storey	Average	SD	CoV	Average	SD	CoV
	Thickness for slab with embedded beam (mm)			Thickness for slab with emergent beam (mm)		
2	279.00	26.39	0.09	115.29	35.83	0.31
3–5	283.82	22.59	0.08	131.97	49.37	0.37
6–8	314.06	29.27	0.09	122.35	35.32	0.29

beams is 120 mm with a coefficient of variation of 9% for Marmara region. The outcomes of both studies are compatible with the current study.

14.2 Dimensions of Beams

The beams have been given in terms of their width, depth and clear length for embedded and emergent beam systems in Table 11. While the observed beam clear length is close for the embedded and emergent beams, the number of embedded beams is much more than the number of emergent beams in the inventory data (Fig. 7). Bal et al. (2008) obtained average beam depth as 600 mm for emergent beams and 300 mm for embedded beams with a CoV of 16% and 4% for buildings constructed in Marmara region before 1998, respectively. This value becomes 480 mm for emergent beams and 330 mm for embedded beams with a CoV of 14% and 19% for TEC 1998 [34] buildings, respectively. The cause of higher beam depth may be due to longer beam length in Marmara buildings. The average beam clear length has been calculated as 3.37 m with a CoV of 38% by Bal et al. (2008). Bal et al. (2007) found an average emergent beam depth of 450 mm with a CoV of 20% for buildings in Adana region. Bal et al. (2007) reported an average beam clear length of 2.84 m with a CoV of 29% for Adana buildings. The average span length (not clear beam length) has been computed as 3.55 with a CoV of 19% by Ay (2012).

Ozmen et al. (2015) also reported an emergent beam width of 261.3 mm for 1–2-storey, 295.8 mm for 3–5-storey and 274.5 mm for 6–8-storey buildings with a CoV of 20%, 32% and 22% for TEC (1998) buildings, respectively. The average emergent beam depth has been given as 497.2 mm for 1–2-storey, 456.8 mm for 3–5-storey and 500.2 mm for 6–8-storey buildings with a CoV of 8%, 22% and 15% by Ozmen et al. (2015), respectively. The average emergent beam clear length was 3.50 m for 1–2-storey, 3.35 m for 3–5-storey and 3.53 m for 6–8-storey buildings with a CoV of 31%, 37% and 33%, respectively. The statistics in the current study are similar to the aforementioned studies (Bal et al. 2007, 2008; Ay 2012; Ozmen et al. 2015).

14.3 Steel Detailing of Beams

The longitudinal and transversal reinforcement values are shown in Table 12 for embedded and emergent beams. Longitudinal steel ratio in the beam has effects directly on the fracture behavior of the beam. For this reason, amount of longitudinal reinforcement was obtained for the top and the bottom of the beams. Quantity of longitudinal was taken into account of percentage of cross-sectional area for beams.

Longitudinal steel ratio at the upper of the emergent beam ends has been given as 0.44 for 1–2-storey, 0.51 for 3–5-storey and 0.72 for 6–8-storey buildings with a CoV's of 22%, 40% and 45% for TEC (1998) buildings by Ozmen et al. (2015), respectively. In the same way, longitudinal steel ratio at the underside of the emergent beam ends is 0.41 for 1–2-storey, 0.44 for 3–5-storey and 0.55 for 6–8-storey buildings with a CoV of 38%, 37% and 43% for 1998 buildings, respectively. Amount of longitudinal reinforcement in this study is less than that of Ozmen et al. (2015) due to different inventory databases used for the studies. The diameter of the transverse reinforcement reported as 8-mm bars with about 96% of emergent beams by Ozmen et al. (2015) seems to be almost the same values obtained in the current study. Average transverse reinforcement space at the confinement region has been calculated to

Table 11 Average, standard deviation (SD) and coefficient of variation (CoV) for width, depth and clear length of beams used in the study

Beam type	Storey	Average	SD	CoV	Average	SD	CoV	Average	SD	CoV
		Beam width (mm)			Beam depth (mm)			Beam clear length (m)		
Embedded beam	2	459.59	96.38	0.21	287.33	37.80	0.13	3.47	1.48	0.43
	3–5	507.13	102.23	0.20	309.28	53.90	0.17	3.39	1.48	0.44
	6–8	556.69	87.72	0.16	297.49	19.10	0.06	3.35	1.85	0.55
Emergent beam	2	301.48	35.01	0.12	466.27	76.84	0.16	4.02	1.34	0.33
	3–5	289.47	25.96	0.09	456.91	90.53	0.20	3.22	1.34	0.42
	6–8	322.05	106.01	0.33	567.39	145.77	0.26	3.50	1.60	0.46

Table 12 Average, standard deviation (SD) and coefficient of variation (CoV) for quantity and detailing of reinforcement in beams

Beam type	Storey	Average	SD	CoV	Average	SD	CoV
		Longitudinal steel ratio at the upper of the beam ends (%)			Longitudinal steel ratio at the underside of the beam ends (%)		
Embedded beam	2	0.48	0.29	0.61	0.38	0.21	0.55
	3–5	0.39	0.30	0.76	0.31	0.19	0.61
	6–8	0.32	0.24	0.73	0.28	0.12	0.45
Emergent beam	2	0.39	0.25	0.64	0.30	0.15	0.48
	3–5	0.28	0.17	0.60	0.27	0.15	0.53
	6–8	0.35	0.18	0.51	0.29	0.14	0.48
		Transverse reinforcement diameter at the confinement region (mm)			Transverse reinforcement space at the confinement region (mm)		
Embedded beam	2	8.05	0.32	0.04	89.10	26.56	0.30
	3–5	8.01	0.14	0.02	91.65	31.29	0.34
	6–8	8.00	0.07	0.01	78.16	14.83	0.19
Emergent beam	2	8.07	0.37	0.05	83.25	14.21	0.17
	3–5	8.00	0.00	0.00	84.36	22.05	0.26
	6–8	8.00	0.00	0.00	113.23	39.30	0.35

be around 90 mm for TEC (1998) buildings by Ozmen et al. (2015). The findings about the transverse reinforcement space in this study are very close to the values obtained by Ozmen et al. (2015).

14.4 Dimensions of Columns

The columns as part of the carrying system are of the important parameters which affect the seismic behavior of buildings. The short and the long dimensions of the columns are shown in Table 13 for sample buildings with and without shear walls. All of the columns have square and rectangular cross-sectional areas.

Bal et al. (2007) given the average column depth as 480 mm for equal or less than 3-storey, 550 mm for 4-storey and 710 mm for 5-storey and more storey frame buildings with a CoV of 31%, 18% and 27%, respectively. The average column depth has been found as 680 mm for equal or less than 3-storey, 700 mm for 4-storey, 710 mm for 5-storey and 830 mm for 6-storey and more storey frame buildings constructed according to TEC (1998) with a CoV of 45%, 35%, 26% and 30% by Bal et al. (2008), respectively. For frames with shear walls, Bal et al. (2008) obtained the average column depth as 650 mm for equal or less than 3-storey, 650 mm for 4-storey, 660 mm for 5-storey and 780 mm for 6-storey or more storey frame buildings with a CoV of 31%, 25%, 24% and 54%, respectively. The average column dimensions have been calculated as between 452 mm and 603 mm for 4–8-storey buildings with a CoV of 19–32% by Ay (2012).

Ozmen et al. (2015) also reported the average short dimension of columns as 301.4 mm for 1–2-storey, 311.7 mm for 3–5-storey and 332.7 mm for 6–8-storey frame buildings with a CoV of 18%, 15% and 19% for TEC (1998) buildings, respectively. The average long dimension of columns is given as 579.5 mm for 1–2-storey, 663.2 mm for 3–5-storey and 746.1 mm for 6–8-storey buildings with a CoV's of 22%, 32% and 35% by Ozmen et al. (2015), respectively. For frames with shear walls, the average short dimension of columns was 301.4 mm for 1–2-storey, 312.2 mm for 3–5-storey and 333.6 mm for 6–8-storey buildings with a CoV of 18%, 15% and 19%, respectively. Ozmen et al. (2015) found the average long dimension of columns as 579.5 mm for 1–2-storey, 648.9 mm for 3–5-storey and 724.1 mm for 6–8-storey frame buildings with a CoV of 22%, 26% and 27%, respectively. The values shown in

Table 13 Average, standard deviation (SD) and coefficient of variation (CoV) for short and long dimensions of columns considered in the study

Models	Storey	Average	SD	CoV	Average	SD	CoV
		Short dimension (mm)			Long dimension (mm)		
Frames without shear walls	2	291.83	45.87	0.16	553.67	125.76	0.23
	3–5	304.25	59.46	0.20	591.21	162.42	0.27
	6–8	365.48	153.11	0.42	754.31	370.63	0.49
Frames with shear walls	2	301.83	85.46	0.28	525.43	107.02	0.20
	3–5	319.31	58.42	0.18	654.02	240.92	0.37
	6–8	329.97	70.04	0.21	684.76	180.51	0.26

Table 13 are compatible with the values in the past studies mentioned above.

14.5 Steel Detailing of Columns

Longitudinal steel quantity and detailing affect the moment capacity of columns, while transverse reinforcement influences shear capacity and ductility of columns. Information about longitudinal and transversal reinforcement is shown in Table 14.

Number of steel series throughout the long direction of columns has been reported as 4.27 for 1–2-storey, 4.87 for 3–5-storey and 5.27 for 6–8-storey buildings with a CoV of 21%, 29% and 33% for TEC (1998) buildings by Ozmen et al. (2015), respectively. The longitudinal steel ratio has been found around 1% by Ozmen et al. (2015). They have obtained the transverse reinforcement diameter at the confinement region as approximately 8 mm bars, similar to the data in Table 14. They have computed average transverse reinforcement space at the confinement region as 92.39 mm for 1–2-storey, 95.51 mm for 3–5-storey and 93.62 mm for 6–8-storey buildings with a CoV of 11%, 20% and 29%, respectively.

14.6 Dimensions of Shear Walls

Shear walls are elements of vertical load carrying system with a ratio of long dimension to short dimension in building plan which is equal to the least seven (TEC 2007). Shear walls as columns contribute to carrying lateral loads and restricting lateral deformations in buildings. The values of shear walls were presented in terms of short and long dimension for the number of storeys in Table 15. Although especially long dimension of shear walls does not increase as the number of storeys increases, it should be kept in mind that a large number of shear walls may be used with increasing number of storeys. It is hard to reach a proportional evaluation between number of storeys based on minimum and maximum values for short and long dimensions of shear walls (that are given in Fig. 8).

14.7 Steel Detailing of Shear Walls

Like the steel detailing of beams and columns, steel quantity and detailing were investigated for sample shear walls. Quantity of longitudinal reinforcement, transversal reinforcement diameter and space is given in Table 16 about

Table 14 Average, standard deviation (SD) and coefficient of variation (CoV) for quantity and detailing of reinforcement in columns

Models	Storey	Average	SD	CoV	Average	SD	CoV
		Number of steel series throughout long direction of columns			Longitudinal steel ratio of columns (%)		
Frames without shear walls	2	4.19	1.14	0.27	1.41	0.60	0.42
	3–5	4.76	1.33	0.28	1.30	0.55	0.42
	6–8	5.67	2.49	0.44	1.00	0.33	0.33
Frames with shear walls	2	4.28	0.96	0.22	1.09	0.13	0.12
	3–5	5.39	2.28	0.42	1.26	0.44	0.35
	6–8	5.60	1.49	0.27	1.33	0.49	0.36
		Transverse reinforcement diameter at the confinement region (mm)			Transverse reinforcement space at the confinement region (mm)		
Frames without shear walls	2	8.01	0.12	0.02	97.26	13.50	0.14
	3–5	8.00	0.00	0.00	96.42	13.92	0.14
	6–8	8.00	0.00	0.00	99.90	15.14	0.15
Frames with shear walls	2	8.00	0.00	0.00	89.13	18.93	0.21
	3–5	8.00	0.00	0.00	101.74	21.29	0.21
	6–8	8.00	0.00	0.00	106.01	22.73	0.21

Table 15 Average, standard deviation (SD) and coefficient of variation (CoV) for short and long dimensions of shear walls

Storey	Average	SD	CoV	Average	SD	CoV
	Short dimension (mm)			Long dimension (mm)		
2	235.94	22.48	0.10	2807.81	963.28	0.34
3–5	246.56	35.50	0.14	2556.33	966.86	0.38
6–8	254.72	17.50	0.07	2253.62	578.28	0.26

Table 16 Average, standard deviation (SD) and coefficient of variation (CoV) for quantity and detailing of reinforcement in shear walls

Storey	Average	SD	CoV	Average	SD	CoV
	Longitudinal reinforcement area of shear wall end regions/shear wall area (%)			Longitudinal reinforcement area of shear wall web regions/shear wall web area (%)		
2	0.41	0.21	0.52	0.41	0.17	0.43
3–5	0.50	0.20	0.39	0.49	0.22	0.46
6–8	0.49	0.21	0.43	0.54	0.24	0.45
	Transverse reinforcement diameter at the shear wall end region (mm)			Transverse reinforcement space at the shear wall end region (mm)		
2	8.00	0.00	0.00	126.25	38.06	0.30
3–5	8.14	0.73	0.09	122.76	40.47	0.33
6–8	8.24	0.96	0.12	108.38	28.13	0.26
	Transverse web reinforcement diameter (mm)			Transverse web reinforcement space (mm)		
2	8.00	0.00	0.00	153.44	27.63	0.18
3–5	8.30	1.03	0.12	158.53	34.37	0.22
6–8	8.51	1.36	0.16	155.70	28.98	0.19

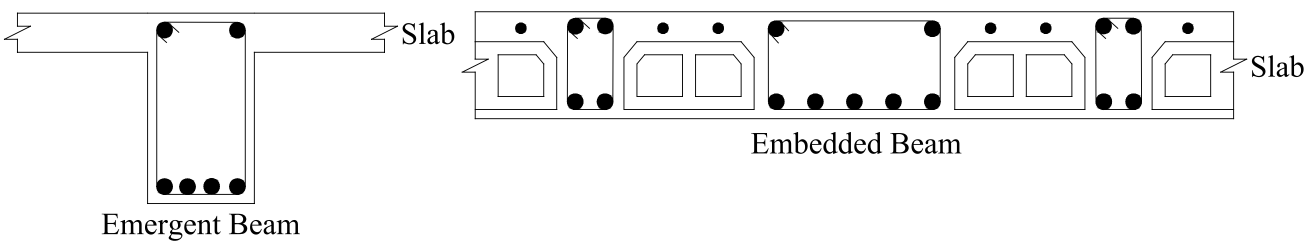

Fig. 5 Emergent and embedded beam

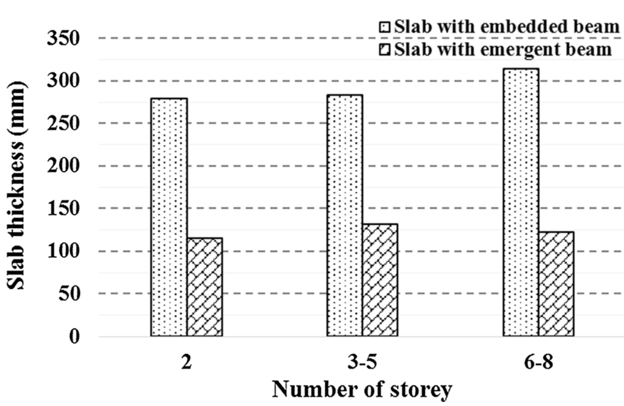

Fig. 6 Distribution of slab thickness for slabs with embedded beam and emergent beam

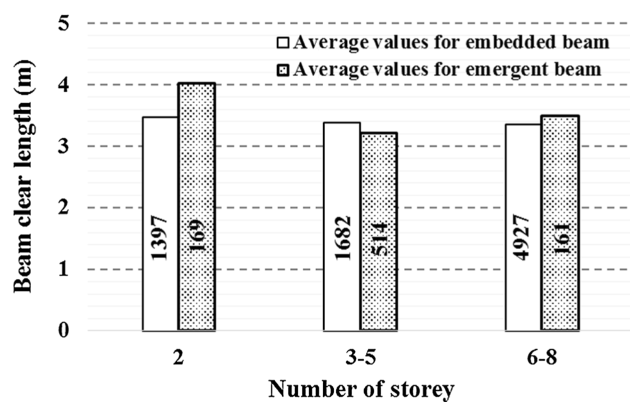

Fig. 7 Dispersion of beam clear length according to number of embedded and emergent beams

web and end region of shear wall (Fig. 9). In each of the shear wall end regions, it has been specified that the ratio of the longitudinal reinforcement total area to the shear wall gross cross-sectional area should not be less than 0.001 in TEC (2007). Besides, the ratio of the longitudinal reinforcement web total area to the shear wall gross cross-sectional area between shear wall end regions shall not be less than 0.0025 (TEC 2007). Transverse web reinforcement space had more than space at the shear wall end region as shown in Table 16. Transverse reinforcement diameter is around 8 mm bars for both web and end regions as being minimum requirement by TEC (2007). The values have given an idea about common trend for proper modeling of the existing building stock.

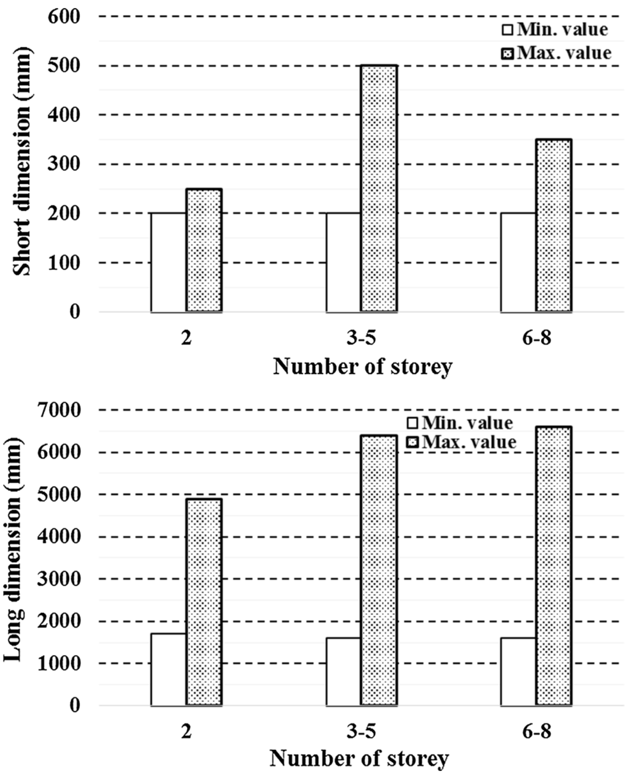

Fig. 8 Minimum and maximum values for short and long dimensions of shear wall

15 Comparison of the Present Study with Past Studies

The findings of the present study were compared to the previous studies about the properties of the existing buildings. Table 17 shows the values of structural parameters which were obtained from the current study and from the past studies (Bal et al. 2007, 2008; Ay 2012; Ozmen et al. 2015) on existing reinforcement concrete buildings in Turkey. Table 17 includes the average values of 3–5-storey and 6–8-storey buildings for the comparison. The 2-storey buildings are not shown in Table 17 since the values of 2-storey buildings were not obtained for some parameters in the evaluated studies.

Bal et al. (2008) obtained ground storey area, while Ay (2012) and Ozmen et al. (2015) reported plan dimensions and the ratio of long/short dimensions. The present study and Ozmen et al. (2015) contribute to plan dimensions, and the ratio of long/short dimensions and ground storey area for buildings constructed according to the diverse seismic codes for different number of storeys. Ay (2012) supports plan dimensions for 3–5-storey and 6–9-storey buildings, while the present study and Ozmen et al. (2015) show more information about 2-, 3–5-and 6–8-storey buildings.

Bal et al. (2008) calculated an average ground storey area of 1144 buildings as 222 m^2 with a CoV of 85%. The coefficient of variation (CoV) is higher as values of ground storey area were not given per number of storey. The value of the average ground storey area in the current study is close to the value obtained by Bal et al. (2008). The ground storey area has an increasing trend when the number of storeys increases.

Upper and ground storey elevations have been computed in almost all of the studies. Upper storey elevation value is around 2.8 m in previous studies, while this value in the current study is approximately 3.00 m. The ground storey elevation values in the current study are similar to the study of Ay (2012) and Ozmen et al. (2015). All studies excluding Ay (2012) have warned that this situation causes the presence of soft storey in the buildings if the ratio of ground storey elevation to upper storey elevation is higher than 1.00. Bal et al. (2007) and Bal et al. (2008) have found ground storey/upper storey elevation ratio of 19–25%, while Ozmen et al. (2015) reported that ground storey elevation values are 1.25 and 1.41 which are higher than upper storey elevation values. This ratio in current study was calculated as 10% for the existing buildings evaluated.

Ozmen et al. (2015) and the current study contribute statistics on heavy overhang to the data of the existing buildings. The overhang value was calculated as 8.18% of the storey area in this study, while Ozmen et al. (2015) found the average value as 8.37% of the storey area. The overhang values seem to be close for both studies in Table 17.

The ratio of infill wall length to 100 m^2 building area has been reported as 5.38% for the long dimension by Ozmen et al. (2015), while this ratio is 7.85% for the short dimension. In the current study, infill wall length/ground storey area was found as 5.53% and 5.17% for the long and for the short dimensions, respectively. Other studies excluding this

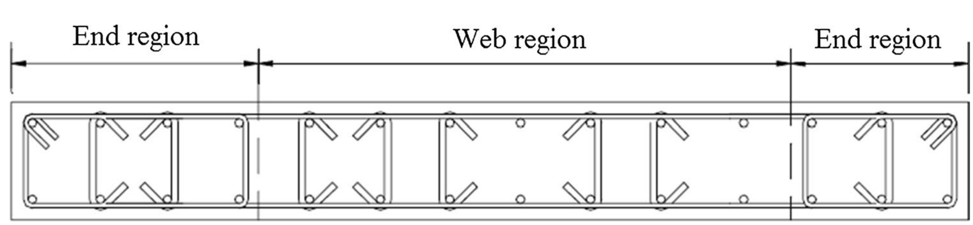

Fig. 9 Web and end region of shear wall

Table 17 Comparison of the present study with previous studies

Parameter	Current study			Ozmen et al. (2015)					Bal et al. (2007)	Bal et al. (2008)	Ay (2012)	Assessment
	After 2007		All	Before 1998		After 1998		All	All	All	All	
	3–5	6–8		3–5	6–8	3–5	6–8					
Specified steel strength (MPa)		420		222.10	242.60	405.30	415.70	***				
Specified concrete strength (MPa)	23.91	25.60	24.59	17.90	16.80	25.20	28.70	***				
Long plan dimension (m)	16.96	23.13	19.47	14.18	17.94	16.00	19.82	15.78			13.24*	*Obtained for 3–5 storey. 15.42 m is given for 6–9 storey
Short plan dimension (m)	11.67	14.21	12.70	9.81	12.42	10.84	13.84	10.96			9.20*	*Obtained for 3–5 storey. 10.30 m is given for 6–9 storey
Ground storey area (m^2)	198.95	313.26	245.11	131.50	223.80	161.20	296.80	171.50		222.00		
Ratio of buildings plan dimensions (long/short)	1.49	1.71	1.58	1.49	1.53	1.53	1.49	1.50			1.37	
Upper storey elevation (m)	2.98	2.95	2.97	2.78	2.78	2.77	2.79	2.78	2.86	2.84	2.71	
Ground storey elevation (m)	3.00	2.99	2.99	2.87	3.40	2.88	3.12	3.00	3.40*	3.29*	3.01	*Obtained from ground/upper storey elevation
Ground storey/upper storey elevation ratio*	1.12	1.09	1.10	1.28	1.31	1.25	1.41	1.28	1.19	1.25		*Only buildings with different storey elevations are shown
Heavy overhang area over storey area (%)*	8.47	7.88	8.18	7.18	7.35	10.78	8.05	8.37				*Only buildings with overhangs are calculated. Zero values are neglected
Infill wall length/ground storey area for long dimension (%)	5.97	4.90	5.53	6.21*	5.51*	4.86*	4.06*	5.38*				*Infill wall length/100 m^2 building area for long dimension (m/100 m^2)
Infill wall length/ground storey area for short dimension (%)	5.86	4.17	5.17	10.38*	6.88*	6.23*	6.38*	7.85*				*Infill wall length/100 m^2 building area for short dimension (m/100 m^2)
Number of continuous frames/ground storey area for long dimension (%)	1.78	1.14	1.52	2.18*	1.08*	1.61*	1.19*	1.71*			2.70**	*Per 100 m^2 and **per building, not per ground storey area
Number of continuous frames/ground storey area for short dimension (%)	1.91	1.30	1.67	2.28*	1.27*	1.62*	1.26*	1.82*			2.68**	*Per 100 m^2 and **per building, not per ground storey area
Number of columns/ground storey area for frames without shear walls (%)	10.61	6.86	10.00	13.37*	11.12*	11.43*	9.93*	12.20*				*Per 100 m^2, not per ground storey area
Number of columns/ground storey area for frames with shear walls (%)	8.70	7.26	7.85	13.17*	10.83*	11.18*	9.03*	11.71*				*Per 100 m^2, not per ground storey area

Table 17 (continued)

Parameter	Current study			Ozmen et al. (2015)					Bal et al. (2007)	Bal et al. (2008)	Ay (2012)	Assessment
	After 2007		All	Before 1998		After 1998		All	All	All	All	
	3–5	6–8		3–5	6–8	3–5	6–8					
Total area of columns/ground storey area for frames without shear walls (%)	1.82	1.97	1.84	1.85	2.30	2.20	2.50	2.06				
Total area of columns/ground storey area for frames with shear walls (%)	1.62	1.58	1.60	1.82	2.14	2.16	2.16	2.02				
Slab thickness for buildings with embedded beams (mm)	283.82	314.06	293.50						250–320*			*It changes from 250 mm to 320 mm
Slab thickness for buildings with emergent beams (mm)	131.97	122.35	128.70						70–150*	120.00		*It changes from 70 mm to 150 mm
Embedded beam width (mm)	507.13	556.69	544.07									
Embedded beam depth (mm)	309.28	297.49	300.49							300–330*		*It changes from 300 mm to 330 mm
Emergent beam width (mm)	289.47	322.05	297.24	230.00	269.00	296.00	275.00	262.00				
Emergent beam depth (mm)	456.91	567.39	483.26	531.00	530.00	457.00	500.00	504.00	450.00	480–600*		*It changes from 480 mm to 600 mm
Embedded beam clear length (m)	3.39	3.35	3.36						2.84	3.37	3.55*	*Obtained as span length
Emergent beam clear length (m)	3.22	3.50	3.29	3.28	3.29	3.35	3.53	3.35				
Longitudinal steel ratio at the upper of the embedded beam ends (%)	0.39	0.32	0.34									
Longitudinal steel ratio at the upper of the emergent beam ends (%)	0.28	0.35	0.30	0.38	0.41	0.44	0.55	0.42				
Longitudinal steel ratio at the underside of the embedded beam ends (%)	0.31	0.28	0.28									
Longitudinal steel ratio at the underside of the emergent beam ends (%)	0.27	0.29	0.28	0.59	0.68	0.51	0.72	0.58				
Transverse reinforcement diameter for embedded beam at the confinement region (mm)	8.01	8.00	8.00									
Transverse reinforcement diameter for emergent beam at the confinement region (mm)	8.00	8.00	8.00	8.00	8.00	8.10	8.20	8.10				

Table 17 (continued)

Parameter	Current study			Ozmen et al. (2015)					Bal et al. (2007)	Bal et al. (2008)	Ay (2012)	Assessment
	After 2007		All	Before 1998		After 1998		All	All	All	All	
	3–5	6–8		3–5	6–8	3–5	6–8					
Transverse reinforcement space for embedded beam at the confinement region (mm)	91.65	78.16	81.59									
Transverse reinforcement space for emergent beam at the confinement region (mm)	84.36	113.23	91.24	169.00	173.00	91.00	91.00	***				
Short dimension of columns for frames without shear walls (mm)	304.25	365.48	321.83	255.00	276.00	312.00	333.00	284.00			261–284*	*It found from the average values of column depth/column width ratio and it changes with number of storey
Long dimension of columns for frames without shear walls (mm)	591.21	754.31	638.03	535.00	672.00	663.00	746.00	604.00	360–710**	450–1000**	452–603*	*It changes with number of storey. **It changes with number of storey and structural system type
Short dimension of columns for frames with shear walls (mm)	319.31	329.97	326.29	254.00	275.00	312.00	334.00	292.00				
Long dimension of columns for frames with shear walls (mm)	654.02	684.76	674.16	533.00	667.00	649.00	724.00	648.00		430–780*		*It changes with number of storey and structural system type
Number of steel series throughout long direction of columns for frames without shear walls	4.76	5.67	5.02	3.39	4.37	4.87	5.27	4.22				
Number of steel series throughout long direction of columns for frames with shear walls	5.39	5.60	5.53									
Longitudinal steel ratio of columns for frames without shear walls (%)	1.30	1.00	1.21	1.00	1.14	1.09	1.13	1.06				
Longitudinal steel ratio of columns for frames with shear walls (%)	1.26	1.33	1.31									
Transverse reinforcement diameter at the confinement region for frames without shear walls (mm)	8.00	8.00	8.00	8.00	8.00	8.20	8.60	8.10				
Transverse reinforcement diameter at the column confinement region for frames with shear walls (mm)												

Table 17 (continued)

Parameter	Current study			Ozmen et al. (2015)					Bal et al. (2007)	Bal et al. (2008)	Ay (2012)	Assessment
	After 2007		All	Before 1998		After 1998		All	All	All	All	
	3–5	6–8		3–5	6–8	3–5	6–8					
Transverse reinforcement space at the column confinement region for frames without shear walls (mm)	96.42	99.90	97.42	181.00	180.00	96.00	94.00	***				
Transverse reinforcement space at the column confinement region for frames with shear walls (mm)	101.74	106.01	104.54									
Short dimension of shear walls (mm)	246.56	254.72	252.07									
Long dimension of shear walls (mm)	2556.33	2253.62	2351.78									
Longitudinal reinforcement area of shear wall end regions/shear wall area (%)	0.50	0.49	0.49									
Longitudinal reinforcement area of shear wall web regions/shear wall web area (%)	0.49	0.54	0.52									
Transverse reinforcement diameter at the shear wall end region (mm)	8.14	8.24	8.21									
Transverse reinforcement space at the shear wall end region (mm)	122.76	108.38	113.05									
Transverse web reinforcement diameter (mm)	8.30	8.51	8.44									
Transverse web reinforcement space (mm)	158.53	155.70	156.61									

*First explanation about the parameters taken in previous studies

**Second explanation on the parameters taken in previous studies

***These average values are not given because they are not considered to reflect all of buildings by Ozmen et al. (2015)

study and Ozmen et al. (2015) reported no information about the quantity of the infill walls (Table 17).

This study, Ay's study (2012) and Ozmen et al. (2015) have reported statistics about the number of continuous frames for the long and for the short dimensions. Ay (2012) has obtained an average value for all buildings, while the current study and Ozmen et al. (2015) found average values according to the number of storeys of the buildings. Average values between 1.71 and 1.82 have been calculated for 100 m^2 ground storey area by Ozmen et al. (2015). For the current study, the numbers of continuous frames were 1.52 and 1.67 for the long and for the short dimensions per ground storey area of the buildings, respectively. The continuity of frames decreases, while the number of storey increases as shown in Table 17.

This study enhances the statistics about dimensions of slabs, beams, columns and longitudinal/transversal reinforcement arrangements for the assessment of the existing building properties. The current study includes RC buildings located in the different zones of Turkey based on previous studies. Unlike other studies, the buildings constructed after 2007 were selected for the inventory of this study. The current study also reports short and long dimensions of shear walls, and quantity of longitudinal and transversal reinforcement for the selected sample shear walls. For this purpose, number and total area of columns were obtained according to ground storey area for the number of storeys and for the presence of shear walls. The present study provides information with the number of steel series throughout the long direction of columns, transversal reinforcement diameter and space at confinement regions of beams and columns, width, depth and clear length of the embedded and emergent beams.

16 Conclusion

The current study aims to contribute to the literature about the properties of the existing buildings with respect to seismic performance evaluation. The inventory data contain 8850 beams, 26,963 columns and 2311 shear walls from 506 existing residential RC buildings for comprehensive evaluation. Structural and architectural blueprints of existing low- and mid-rise RC buildings were obtained from structure inspection firms, construction offices and private archives of civil engineers. The building database was selected to represent low- and mid-rise buildings located in the high seismicity southeast part of Turkey (Osmaniye and its surrounding provinces). Later, properties of the buildings were received from the blueprints and transferred to Microsoft Excel worksheets for evaluation. TEC (2007) was taken into consideration as a modern code since the buildings were constructed after 2007.

The structural properties such as storey elevations, plan dimensions, floor areas, slab thickness, dimensions of beams, columns and shear walls, material properties, quantity of heavy overhang and infill walls, number of continuous frames, number and area of columns per ground storey area, are directly employed as applied in the buildings' projects. Mathematical and statistical assessments were related to the achieved parameters. The average, standard deviation (SD) and the coefficient of variation (CoV) of parameters were computed for the considered parameters. The results of this study and the abovementioned studies are compared about structural parameters of the existing buildings. The comparison shows that the values of some parameters may be affected by construction date and number of storeys. Although coefficient of variation is high in some studies, the average values of the compared parameters have similar trends for all studies.

It is noticed that percentage of buildings with shear wall increases in the inventory when the number of storey increases. It is showed that the ground storey area has an increasing tendency when the number of storeys increases. In accordance with the past studies, it is noted that values of columns which obtained for buildings with shear walls have generally lower than the values belonging to buildings with the no shear wall because the presence of shear walls decreases the necessity for columns.

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