
# Evaluation of Changing Building Characteristics in Turkey

**B. Ö. Ay[1], T. Eroğlu Azak[2], M A. Erberik[3]**

[1]Department of Architecture, Middle East Technical University, Ankara, Turkey, ozer@metu.edu.tr
[2]Department of Civil Engineering, Akdeniz University, Antalya, Turkey, tubaeroglu@akdeniz.edu.tr
[2]Department of Civil Engineering, Middle East Technical University, Ankara, Turkey, altug@metu.edu.tr

## Abstract

Seismic risk combines earthquake induced hazard with structural response and determines loss that is equaled or exceeded over some time period. In this sense, it is of prime importance to utilize proper earthquake loss models that are able to consider local characteristics of building stock in a realistic way. The aim of this study is to compile changing characteristics of Turkish buildings that is believed to be necessary to develop representative models for loss estimations. Accordingly, a statistical survey will be carried out on the general properties of Turkish buildings using building permit statistics given by Turkish Statistical Institute (TSI). Previous studies on general characteristics of Turkish building stock is based on relatively small regions, limited number of buildings or old data. However, design characteristics of Turkish buildings have been altered within the last decade because of changing socioeconomic factors and regulations related with earthquake safe design. Thus, by including information of relatively new building stock, this study aims to perform a broader statistical survey about Turkish buildings in terms of use of building, occupancy, number of dwellings, number of stories, structural system, and geometrical properties. Making use of this information, this study is deemed to be a source for earthquake damage and loss estimation studies in urban areas in Turkey.

***Keywords:*** *Turkish buildings; Aim of use; Structural systems, Number of stories, Infill wall materials*

## 1 Introduction

Building inventory statistics are crucial for loss assessment studies. Not only the number of dwellings, but also their design characteristics are of prime importance for risk management. In addition to the particular challenges of analyzing such an extensive dataset, the changing socioeconomic conditions lead continuous transformation of building stock as the non-stationary nature of built environment. In light of these considerations, this study evaluates changing characteristics of Turkish building stock, particularly reinforced concrete (RC) residential buildings which constitutes about 80% of the whole inventory.

Previous studies in this topic has provided statistics on structural characteristics but for a relatively smaller scale either in terms of number of buildings or the region under consideration. For instance, Bal et al. (2007) provides information about design and material characteristics of buildings in Marmara region. Their study gives statistics on height and floor area of both ground and regular stories, dimensions of structural elements as well as nonstructural infill walls, and material properties of load bearing members. Less detailed information about these properties were also presented by Bal et al. (2008). Having a similar region, Eroğlu Azak et al. (2014) investigated 33773 RC buildings from city of Düzce and Zeytinburnu, Küçükçekmece, and Bakırköy districts of Istanbul in terms of geometrical dimensions in elevation and plan. By making use of Düzce (461 buildings) and Bakırköy (333 buildings) inventories, Eroğlu Azak et al. (2014) provided detailed information about frame continuity, average span length, and column dimensioning. Besides these studies, The 2000 Building Census Survey (TSI, 2000) provides data for the entire country about use of building, number of stories, construction year and typology. More recently, Building Permit Statistics 2010 (TSI, 2011) released building occupancy permit (BOP) statistics from 2002 to 2010. Although TSI has collected BOP information since 1964, the statistics has been standardized in 2002. Making use of TSI's BOP data from 2002 to 2015, this study evaluates the characteristics of Turkish building stock, with a particular interest in parameters influencing seismic performance of this inventory.

## 2 Building Database

The data analyzed in this study were taken from BOP statistics that are released annually by TSI. TSI compiles BOP information from municipalities and governorships (the data doesn't include unauthorized buildings) by occupancy permit forms (http://www.nvi.gov.tr/Files/File/AKS/Formlar/Yapı Kullanma İzin Belgesi.pdf) that have to be filled by law since 6 October 2001 (TSI, 2011). TSI (2011) reports that occupancy permits represent partially or fully completed buildings. According to the publicly available BOP statistics, the number of buildings taken occupancy permit from 2002 to 2015 is 1135452. Assuming that authorized buildings constitutes the majority of buildings, this study analyzed BOP data for Turkey at the level of districts. Nevertheless, statistics in this paper are relatively generalized for the whole country because of the limited space. Within this context, primary parameters under consideration are the use of building, structural system, number of stories and infill wall material.

## 3 Buildings Statistics

### 3.1 Use of Building

After the standardization of the statistics in 2002, use of building in BOP data have been classified into two categories as residential and non-residential. A mixed-type use of building has been classified as residential if at least half of it is being used for residential purposes, otherwise as non-residential. For the case of non-residential buildings; commercial, industrial, educational, cultural, social and administrative buildings as well as buildings related with health, sport, religion and agriculture are taken into account. Last column of Table 1 shows the percentage (%) of Turkish residential and non-residential buildings completed between 2002 and 2015.

### 3.2 Structural System

An important parameter available in BOP statistics has been designated as the structural system by TSI. Table 1 lists the frequency of buildings with respect to their type of use and structural system.

**Table 1.** The percentage (%) of buildings with respect to building use and structural system

| 2002-2015 | Masonry | Steel Frame | Wood Frame | RC Frame | Composite | Prefabricated | Total |
|---|---|---|---|---|---|---|---|
| Residential | 5.001 | 0.196 | 0.196 | 78.726 | 0.551 | 0.551 | 84.988 |
| Non-residential | 0.530 | 0.977 | 0.058 | 12.004 | 0.389 | 0.389 | 15.012 |

For what concerns seismic performance of buildings, the structural system that resists lateral loads is of prime importance. Note that, it is difficult to assign all the subcategories shown by bold letters in Table 1 to a specific structural system. They can rather be grouped as construction methodology (in-situ or prefabricated), load bearing material (RC, steel, wood, composite, etc.) or load bearing system (masonry and frame). Nevertheless, this study uses the same terminology of the source for the sake of consistency. TSI (2011) explains masonry and frame as structural systems where the weight of the structure is carried directly by means of the walls and frames, respectively. However, taking lateral loads into consideration requires further classification since the structural system designated as frame by TSI includes also shear wall – frame interacting (i.e., dual) and shear wall (i.e. tunnel-form) systems. Since previous studies and post-earthquake observations highlighted distinct seismic performance of moment resisting frame (RF), shear wall – frame interacting (SF) and shear wall (SW) systems, further disaggregation of the building stock in terms of RF, SF and SW systems is necessary which is a topic currently being studied by the authors.

Figure 1 represents the annual variation of structural system percentages with respect to residential (left panel) and non-residential use (right panel). The number of buildings of each type has been normalized with the annual total to calculate annual percentages since the number of occupancy permits per year is fluctuating. Figure 1 depicts a decreasing trend in masonry residential building percentage and RC frame non-residential building percentage within last 10 years. On the other hand, both for residential and non-residential case, there is an increase in steel frame and prefabricated building percentages. For other types of structures, the trend between 2006 and 2015 is relatively vague.

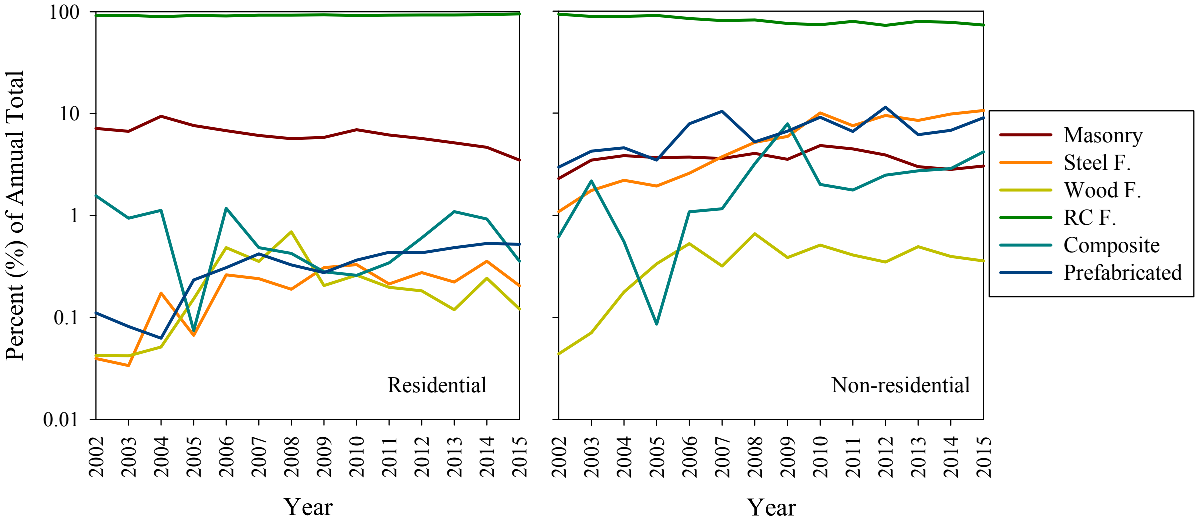


**Figure 1.** Variation of annual structural system percentages with respect to use of building

In addition to number of buildings data, BOP provides number of dwelling units and total floor area as the sum of floor areas within the outer walls of the building. Among these, the latter is especially important for loss assessment whereas the former is useful for social vulnerability studies. Thus, analyses for number of buildings have been repeated for total floor area and number of dwelling units. However the analysis of number of dwellings for non-residential case has been excluded since the dwelling unit has been defined by TSI (2011) as an independent enclosure used for residence. Total floor area of buildings and number of dwellings in the last 14 years is 1159x10$^6$ m$^2$ and 5950962 respectively. Table 2 shows the percentage results of total floor area and dwelling units with respect to structural systems under consideration. Further calculations show that the average area of a single residential unit is 124 m$^2$, 155m$^2$ and 148 m$^2$ for masonry, steel frame and RC frame structures, respectively. The trend of dwelling unit area as a function of years is found as stable especially for masonry and RC frame systems with a coefficient of variation value of 0.02.

**Table 2.** The percentage (%) of total floor area and number of dwelling units with respect to structural system for residential buildings

| Residential Use | Masonry | Steel Frame | Wood Frame | RC Frame | Composite | Prefabricated | Total |
|---|---|---|---|---|---|---|---|
| Total Floor Area | 1.291 | 0.092 | 0.065 | 97.776 | 0.731 | 0.045 | 75.494 |
| Dwelling Unit | 1.536 | 0.088 | 0.061 | 97.448 | 0.797 | 0.069 | 99.655 |

### 3.3 Number of Stories

Number of story information has been used as a primary classification parameter by previous studies (e.g., Erdik et.al, 2003; Akkar et.al, 2005; Ay and Erberik, 2008; Erberik, 2008a, etc.) as this parameter strongly influences seismic performance of buildings particularly RC frame structures. Nevertheless, the aforementioned studies had chosen different cut-off values to classify low-rise, mid-rise, high-rise and tall buildings. BOP gives number of story information as the sum of basement, ground, regular and roof stories. The resolution of post 2002 number of story data is distinctly available from 1 to 9 story buildings whereas buildings with number of stories 10 and above fall in the same class designated as 10+. Considering the resolution of The 2000 Building Census Survey (TSI, 2000) and cut-off values of other studies, this study classifies 1 to 3, 4 to 6 and 7+ story buildings as low-, mid- and high-rise, respectively.

Figure 2 shows the relative variation in percentage of buildings with different number of stories through years. Right panel of this figure highlights the transition in Turkish residential building stock where the mid-rise buildings become majority of the inventory as of 2015. The number of high-rise buildings which have 7 or more stories is also increasing although the slope of the trend is relatively small compared to mid-rise buildings.

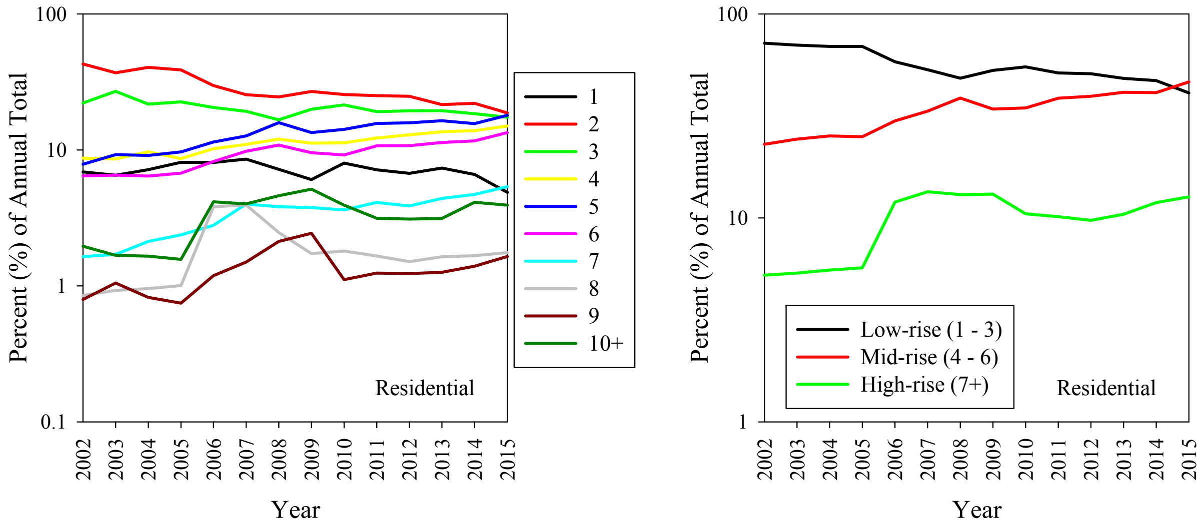


**Figure 2.** Annual variation of residential building number of stories percentages

Figure 3 and 4 present the percentages of low-rise and mid-rise buildings at province level, respectively. Low-rise buildings constitute about 53% of the inventory whereas mid-rise buildings correspond to 36% of the buildings taken occupancy permit between 2002 and 2015. Figure 3 and 4 indicate the majority of low-rise buildings in Turkish building stock. Nevertheless, recent data shown in right panel of Figure 2 expresses a changing trend.

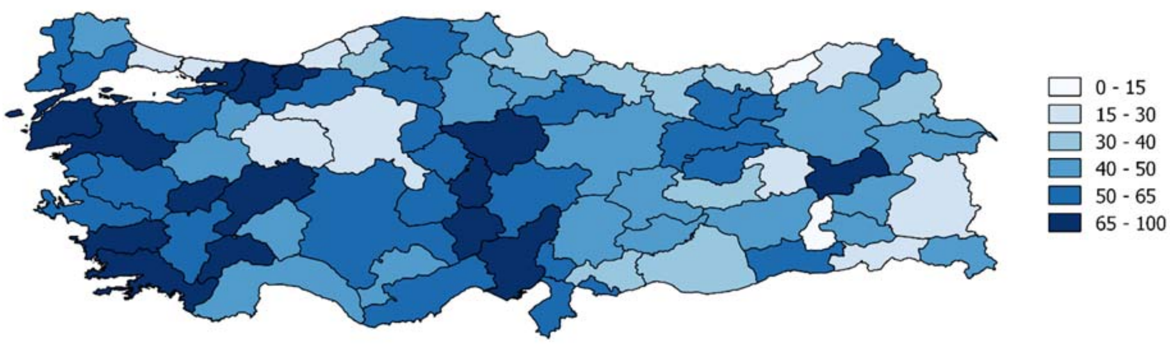


**Figure 3.** Percentages of low-rise buildings in Turkey at province level

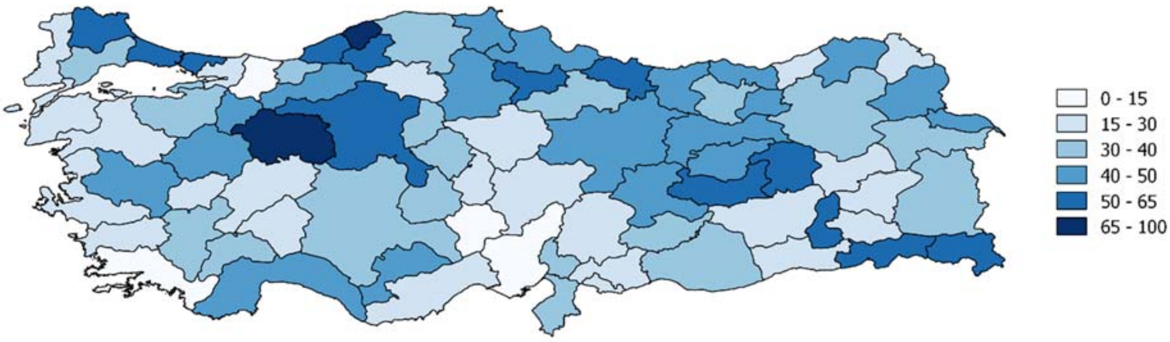


**Figure 4.** Percentages of mid-rise buildings in Turkey at province level

As one can infer from Figures 3 and 4, the mid-rise buildings in Ankara and İstanbul that are the most crowded cities in Turkey constitute more than half of the young building stock (the last 14 years). This observation fortifies the observed increasing rate of mid-rise buildings as a function of years as big cities mostly dominate the statistics of the entire building stock.

## 3.4 Material of Infill Wall

Another important information that can be derived from BOP statistics is the type of infill wall material. BOP data classifies infill wall material into 9 categories as hollow concrete block (HCB), brick, stone, wood, adobe, calcium silicate brick (CSB), concrete block (CB), light panel (LP) and other. Figure 5 displays the percentages of infill wall material with respect to structural systems given in BOP data for the last 14 years. The results show that brick is the primary infill wall material for all type of structures with the exception of wood structures. 90% of the whole inventory use brick as the infill material. Residential and non-residential buildings with brick infill correspond 92.4% and 82.9%, respectively. Considering the structural system, 93% of the RC frame structures use brick as the infill wall material. The vast majority of masonry structures use also brick where it serves as the load bearing material indeed. HCB is second most frequently used material for RC frame, masonry and composite structures. The frequency of light panels are more than 30% both for steel frames and prefabricated buildings. In prefabricated buildings concrete blocks are also used with a frequency of about 9%.

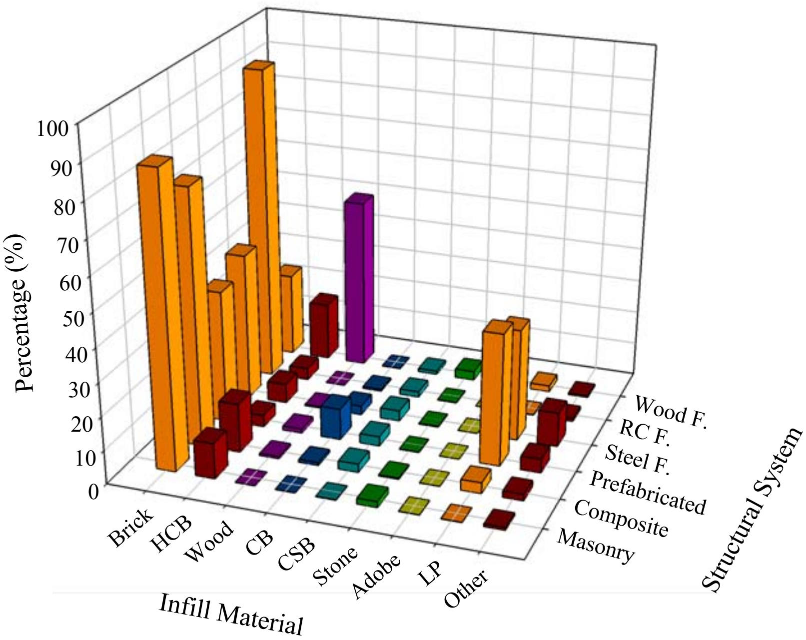


**Figure 5.** Percentages of infill wall material with respect to structural system

Infill walls in frame structures are not intended to carry any type of load. Nevertheless, the influence of infill walls and corresponding material on seismic performance of frame buildings, especially bare frame buildings where the inter-story drifts could become quite large, cannot be disregarded (Akhoundi et al., 2015; Erberik, 2008a; Bal et al., 2008; Dolšek and Fajfar; 2001 etc.). Besides, fragility curves derived for Turkish masonry buildings (Erberik, 2008b) show that, the seismic performance varies significantly with respect to alternative load-bearing wall materials. Thus, the infill wall material information is crucial for loss assessment studies especially for RC frame and masonry structures that constitute more than 95% of the whole inventory under investigation. Figure 6 presents the yearly changes of infill wall material use in masonry (left panel) and RC frame (right panel) buildings. This figure highlights once again the dominancy of brick use in Turkish construction practice. According to the trends shown in the right panel of Figure 6, the use of CSB in RC frame structures is increasing, although it is still less than 5%. According to the statistics given in Figure 5 and 6, masonry and RC frame structures with brick infill walls correspond 4.8% and 83.8%, respectively of the buildings taken permit between 2002 and 2015. These statistics have been given as 15% and 73.4% by Bal et al. (2007) for buildings in Marmara region. Infill wall material statistics with respect to total floor area and number of dwellings are quite similar with those given in Figure 5 and 6.

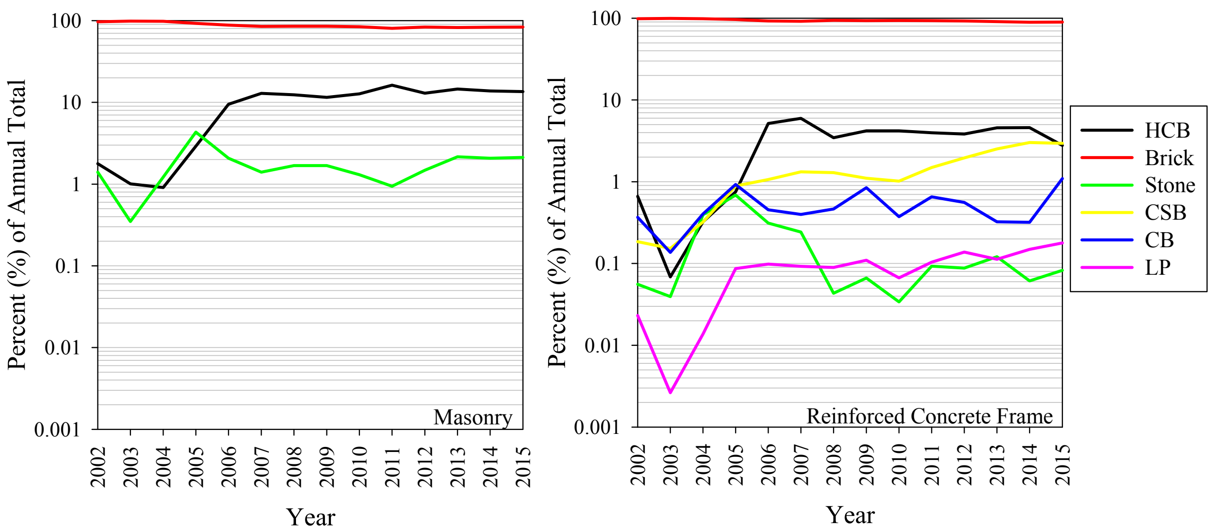


**Figure 6.** Annual variation of infill wall material of masonry and RC frame buildings

## 4 Summary and Conclusion

This study investigated changing characteristics of Turkish building stock by making the use of building permit statistics released by Turkish Statistical Institute. Four attributes of buildings - the aim of use, structural system, number of story and infill wall material - which are believed to have significant influence on loss assessment results have been examined.

Primary parameter which is the aim of use is simply categorized as residential and non-residential. The number of residential and non-residential buildings that have been investigated is 964995 and 170457, respectively. The cross-statistics between aim of use and structural system as well as number of story has been examined. Structural system classification of BOP statistics have been adopted as it is for the sake of consistency although there are several shortcomings of the sub-classification of TUIK data in terms of seismic performance of buildings. The results show that RC frame structures which include moment-resisting frame, frame-wall interacting (dual) and shear wall systems constitute the vast majority of the building stock. The frequency of RC frame structures is relatively stable for residential use whereas it is slightly decreasing for non-residential buildings. On the other hand, the frequency of steel frame and prefabricated buildings are increasing both for residential and non-residential use although this trend is much more pronounced for the latter case. Then, the statistics about the number of story have been evaluated for both types of use. As an important outcome of these comparisons, the number of 4-6 story residential buildings which have been designated as mid-rise in this study exceeded the number of residential low-rise (1-3 story) buildings. Similar to the mid-rise buildings, the yearly percentage of high-rise buildings in total building stock is also increasing. Final parameter that has been investigated in this study is infill wall material. The results highlighted that, brick has been used in every 9 out of 10 RC frame buildings whereas its use is more than 80% in masonry structures.

The statistics and comparisons given in this study are believed to be useful for loss assessment studies in Turkey. To this end, further research on cross-statistics with more detailed sub-categorization is an ongoing study of the authors.

## Acknowledgement

The authors would like to acknowledge the support of Middle East Technical University (BAP-08-11-2016-027). All results, findings and conclusions are solely those of the authors and do not necessarily represent the views of any organization.

## References

Akhoundi, F., Lourenço, P. B., and Vasconcelos, G. (2015). Numerically Based Proposals for the Stiffness and Strength of Masonry Infills with Openings in Reinforced Concrete Frames. *Earthquake Engineering and Structural Dynamics*, Vol. 41(11): doi:10.1002/eqe.2688

Akkar, S., Sucuoğlu, H., Yakut A (2005). Displacement-based fragility functions for low and mid-rise ordinary concrete buildings. *Earthquake Spectra* Vol. 21(4): pp. 901–927.

Akkar, S., Yazgan, U., and Gülkan, P. (2005). Drift Estimates in Frame Buildings Subjected to Near-Fault Ground Motions. Journal of Structural Engineering, Vol. 131 (7): pp. 1014–1024.

Ay, B.Ö., Erberik, M.A. (2008). Vulnerability of Turkish low-rise and mid-rise reinforced concrete frame structures. *Journal of Earthquake Engineering* Vol. 12(S2): pp. 2-11.

Bal, I. E., Crowley, H., Pinho, R., and Gülay, F. G. (2007). *Structural Characteristics of Turkish RC Building Stock in Northen Marmara Region for Loss Assessment Applications*. IUSS Press, Pavia.

Bal, I. E., Crowley, H., Pinho, R., and Gülay, F. G. (2008). Detailed Assessment of Structural Characteristics of Turkish RC Building Stock for Loss Assessment Models. *Soil Dynamics and Earthquake Engineering*, Vol. 28(10-11), pp. 914–932.

Dolšek M, Fajfar P. (2001). Soft storey effects in uniformly infilled reinforced concrete frames. *Journal of Earthquake Engineering*; Vol. 5: pp. 1–12.

Erberik, M.A. (2008a). Fragility-based assessment of typical mid-rise and low-rise RC buildings in Turkey. *Engineering Structures*, Vol. 30: pp. 1360-1374.

Erberik, M.A. (2008b). Generation of Fragility Curves for Turkish Masonry Buildings Considering in-plane Failure Modes. *Earthquake Engineering and Structural Dynamics*, Vol. 37(3), pp. 387–405.

Erdik, M., Aydınoğlu, N., Fahjan, Y., Sesetyan, K., Demircioğlu, M., Siyahi, B., Durukal, E., Özbey, C., Biro, Y., Akman, H., Yüzügüllü, Ö. (2003). Earthquake risk assessment for Istanbul metropolitan area. *Earthquake Engineering and Engineering Vibration* Vol. 2(1): pp. 1-23.

Eroğlu Azak T., Ay, B. Ö. and Akkar, S. (2014). A Statistical Study on Geometrical Properties of Turkish Reinforced Concrete Building Stock, *2nd European Conference on Earthquake Engineering and Seismology*, August 24-29, İstanbul, Turkey.

Turkish Statistical Institute, (2000), "*Building Census*", Ankara, Turkey

Turkish Statistical Institute, (2011), "*Building Permit Statistics 2010*", Ankara, Turkey