OVERVIEW OF SEISMIC PERFORMANCE ASSESSMENT PROCEDURES FOR RC BUILDINGS IN TURKEY

A. Yakut
Middle East Technical University, Department of Civil Engineering, Ankara, Turkey
Email: ayakut@metu.edu.tr

ABSTRACT:

Seismic performance assessment of existing buildings is carried out to determine expected response of a building under a given earthquake. Several procedures have been proposed over the last decade to assess seismic performance of existing reinforced concrete buildings. These procedures have varying degree of accuracy and complexity thus their selection depends on the need and the objective. In general, seismic performance assessment procedures have three levels. Rapid screening procedures are generally employed to determine vulnerability ranking of a group of buildings based on rapid assessments carried out from the street survey. Preliminary procedures are proposed to assess the buildings using more data and some simple calculations for prioritization ranking of a group of buildings. Detailed assessment procedures aim to determine either weaknesses and retrofit needs or to decide whether a building satisfies a certain performance criteria. This paper provides an overview of several seismic performance assessment procedures proposed for buildings in Turkey from all three tiers to determine their efficiency and adequacy along with their weaknesses. Applications of these procedures to sample RC buildings are discussed and a comparative evaluation on relative efficiency of the procedures is presented.

KEYWORDS: performance assessment, RC buildings, performance levels

1. INTRODUCTION

Reinforced concrete buildings are among the most populated construction types in Turkey as well as in many developing countries. Their seismic performance in Turkey has been observed to be inadequate as observed after recent moderate to severe earthquakes. Considering the large existing RC building stock in Turkey and their poor seismic performance, majority of relevant research in Turkey, especially after 1999 earthquakes, has been devoted to determining their seismic performance and mitigating the losses expected. In this framework, a number of procedures have been proposed over the last twenty years to assess seismic performance of existing reinforced concrete buildings. Rapid assessment and preliminary assessment procedures have been developed to handle large building stocks for ranking and prioritizing their seismic risk (Sucuoğlu and Yazgan 2003, Sucuoğlu et al 2007, Hassan and Sozen 1997, Ozcebe et al 2004, Yakut 2004, Temur 2006, Tezcan et al 2011). Additionally, detailed assessment procedures have been developed and recommended to assess seismic performance and retrofit of existing buildings (Erduran and Yakut 2007, TEC 2007, TBEC 2019). The level of assessment depends on the need and objective so for large building stocks three-tier procedures are applied (FEMA 310, ATC 31-03). Rapid screening procedures are generally based on visual inspection from the street to determine vulnerability ranking of a group of buildings. A more detailed assessment is carried out using preliminary assessment procedures using more data and some simple calculations for approximate vulnerability assessment of individual buildings. Detailed assessment procedures aim to determine weaknesses and retrofit needs for existing buildings. The objective and effort to be given plays an important role in the selection of the most appropriate procedure. Table 1 provides a summary of all three levels of performance evaluation process along with the objective, applicability and content of data needed.

Table 1. Seismic vulnerability assessment procedures

<table>
<tr><th>Level of Assessment</th><th colspan="2">Rapid Visual Screening</th><th>Preliminary Evaluation</th><th>Detailed Assessment</th></tr>
<tr><td>Purpose</td><td colspan="2">Ranking/Prioritization</td><td>Prioritization/Performance</td><td>Performance/ Rehabilitation</td></tr>
<tr><td>Data</td><td colspan="2">Street survey/ Visual attributes</td><td>Street survey + simple building survey</td><td>Detailed building survey/drawings / sample tests</td></tr>
<tr><td>Method</td><td>Theoretical</td><td>Statistical analyses of observed behavior</td><td>Hybrid</td><td>Linear or Nonlinear analysis</td></tr>
<tr><td>Application</td><td colspan="2">Building Stock</td><td>Group of buildings or individual buildings</td><td>Individual buildings</td></tr>
</table>

Several studies have been carried out to assess efficiency and adequacy of these procedures in determining seismic performance of existing RC buildings (Gulay et al 2008, Gunes et al 2006, Kalem 2010). In order to compare the results and investigate the variability among these procedures, typical building sets and sample buildings have been employed and assessed by the most common approximate and detailed procedures. The results are then combined with the results presented in the literature to evaluate and discuss efficiency and adequacy of the procedures.

2. RAPID AND PRELIMINARY ASSESSMENT PROCEDURES

The simplest, fastest and the most practical seismic assessment procedures, first level assessment, are generally based on determination of visual attributes of buildings that can be identified from a quick street survey. The data including irregularities, age, apparent quality, location and site are typically collected through a data collection form. Each attribute in the form is assigned a score that is then used to determine a performance score for the building. One of the most commonly known example of such procedures is ATC 21/FEMA 154 procedure that has been proposed for the buildings in USA.

A rapid assessment procedure that is applicable to low- to mid-rise RC buildings has been developed (Sucuoğlu and Yazgan 2003, Sucuoğlu et al 2007) for Turkish building stock based on statistical analysis of damage database compiled in Düzce after 1999 earthquakes (www.seru.metu.edu.tr). Similar to FEMA154, a street survey is carried out to determine several parameters related to the architectural and structural attributes of the buildings. The number of stories, soft story, short column, heavy overhangs, apparent quality, pounding and topographic effects are the parameters selected to reflect the seismic vulnerability. The seismic vulnerability of the building is reflected by a vulnerability score calculated based on the presence of the selected parameters. Location and number of stories are used to assign a basic score from which negative scores assigned to each attribute are deducted to compute the vulnerability score.

A significant effort has been put on preliminary assessment procedures for RC buildings in Turkey over the years (Hassan and Sozen 1997, Ozcebe et al 2004, Yakut 2004, Temur 2006, Tezcan et al 2011).

Almost all of these procedures use cross sectional areas of the columns, structural walls and infill walls generally at the ground floor. Hassan and Sozen (1997), Ozcebe et al. (2004) and P25 method (2011) use ratios of the cross sectional areas to the ground floor area as a parameter. Yakut (2004) and Temur (2006) use the cross sectional areas to predict base shear capacity of the building. Additionally, except Hassan and Sozen (1997) all other procedures account for the influence of architectural features on vulnerability. The material properties are directly used in Yakut (2004), P25 and DURTES (Temur 2006) procedures. All procedures result in a quantitative score that is used to assess the building vulnerability. The procedure recommended by Ozcebe et al. (2004) is based on statistical analysis of Düzce damage database whereas other procedures are based on either theoretical approximations and/or experience from past earthquakes. All of these procedures employed some past earthquake data for verification of the method. Despite similarities in parameters used in these procedures, the relative influence of each parameter in the resulting vulnerability is quite different in each procedure. Beside that the target performance level is also different in these procedures. Yakut (2004) classifies the buildings as Safe or Unsafe, Ozcebe et al. (2004), similar to Hassan and Sozen (1997) adds an intermediate level to that whereas P25 procedure aims to identify the buildings that are expected to collapse. DURTES, on the other hand, classifies the buildings into five different risk levels.

3. DETAILED ASSESSMENT PROCEDURES

Detailed performance assessment procedures rely on the concept of performance based design and thus use performance based criteria. The general steps included in detailed assessment procedures are summarized in Figure 1. The assessment starts with data collection, determination of site properties and seismic hazard after making decision on the performance objective. Based on data collected from the survey, the model of the building is obtained and the analysis is carried out to determine member internal forces and deformations using an appropriate procedure. The member forces and/or deformations are compared with acceptance criteria (force/deformation limits) to make decision regarding the expected performance of the building. The most common detailed assessment procedures are the ones provided in seismic assessment codes (EC8, ASCE41, TEC2007, TBEC2019).

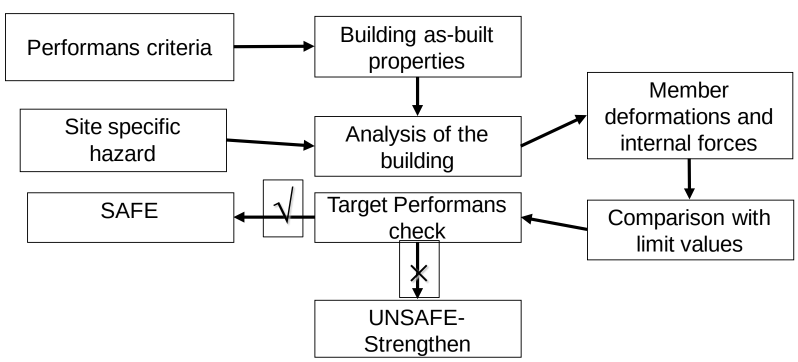

Figure 1. Detailed Performance Assessment Procedures

3.1. Turkish Earthquake Code Procedures

The first code that includes a methodology for detailed assessment of RC buildings in Turkey was released in 2007 (TEC 2007). In this code, two detailed assessment procedures namely linear and nonlinear are recommended. The procedures in 2007 code are mostly based on FEMA 356 approach incorporating different deformation parameters for assessment. Besides this, TEC 2007 has a global assessment for the whole building based on ratio of story shear forces carried by vertical members and percent of beams not satisfying the given performance criteria as compared to the member level assessment procedures in ASCE 41 (2006, 2014, 2017) and EC8-3 (2005).

In the linear assessment internal forces and drifts under earthquake loads are computed from a linear analysis. Similar to ASCE 41, the internal forces for ductile members are compared with the corresponding capacities to determine member demand capacity ratios, which are then compared with the corresponding performance based limit state values. Brittle members are required to be strengthened.

The nonlinear assessment procedure requires performing pushover or nonlinear time history analyses to compute strains in concrete and steel at the critical sections of the member ends. These strains are compared with the performance based limit values.

In parallel to revisions in ASCE41 (ASCE41-13, ASCE 41-17), Turkish earthquake code has also been revised in 2019 (TBEC 2019). The seismic assessment and retrofit of existing buildings are performed based on chapter 15 of the code where linear and nonlinear assessments are given. The major change is the use of strain and plastic rotation as the deformation parameter for member assessment in the nonlinear procedures where only simple relations for strain limits were given in the previous code. The performance based deformation limits in the new Turkish code are given in Equations 1 to 6.

$$\varepsilon_c^{(SH)} = 0.0025 \quad ; \quad \varepsilon_s^{(SH)} = 0.0075 \tag{1}$$

$$\varepsilon_c^{(KH)} = 0.75\,\varepsilon_c^{(GÖ)} \quad ; \quad \varepsilon_s^{(KH)} = 0.75\,\varepsilon_s^{(GÖ)} \tag{2}$$

$$\varepsilon_c^{(GÖ)} = 0.0035 + 0.04\sqrt{\omega_{we}} \le 0.018 \qquad \varepsilon_s^{(GÖ)} = 0.4\varepsilon_{su} \tag{3}$$

$$\theta_p^{(SH)} = 0 \tag{4}$$

$$\theta_p^{(KH)} = 0.75\,\theta_p^{(GÖ)} \tag{5}$$

$$\theta_p^{(GÖ)} = \frac{2}{3}\left[(\phi_u - \phi_y)\,L_p\left(1 - 0.5\,\frac{L_p}{L_s}\right) + 4.5\,\phi_u\,d_b\right] \tag{6}$$

where, ϕ_y is yield curvature, Lp is plastic hinge length and Ls is shear span. The near collapse total curvature, ϕ_u, is calculated through section analysis using the strain limits given in Eq. 3 and considering the axial load at the section.

3.2. Principles for Identifying Buildings with High Risk Buildings

Although, the existing seismic code was updated in 2007 to include a part on the assessment and rehabilitation of existing buildings, most of the vulnerable residential buildings received no attention and they are at high seismic risk. A new campaign was started with a new urban renewal law passed on May 16, 2012 (MEU 2012) to mainly address the vulnerable residential building stock. According to the law a building is classified as high risk or critical if the building is expected to experience collapse or heavy damage under the design earthquake level. The number of buildings in Turkey to be examined under this law in the next 10 years was estimated to be in the order of several millions. The time and budget required for the assessment of these buildings using existing code procedures is overwhelming. Thus, The Ministry of Environment and Urbanization set up a committee in 2013 to draft a relatively fast and acceptable procedure for assessment of residential buildings named as Principles for Identification of High Risk Buildings (PIHRB 2013). This code was then revised in 2019 (PIHRB 2019).

The main steps involved and risk assessment in PIHRB are displayed in Figure 2. Three assessment procedures are given for three height classifications of RC buildings. The most popular building category is low rise buildings comprising buildings up to 10 stories or 30m height where a linear mod superposition procedure is applied. The details of the procedure for low rise RC buildings are elaborated here. The response spectrum is obtained for the building site from the seismic hazard map using an interactive web application (tdth.afad.gov.tr). The data collected through a relatively less complicated and practical field survey is used to generate a three dimensional model of the building. The building model is analyzed to obtain internal forces and inter-story drift ratios at member ends that are compared with the corresponding capacities and limits for columns and shear walls only. The members not satisfying the limits are classified as high risk (or not conforming). The column and wall demand capacity ratio limits (DCR_{limit}) and Inter-story drift ratio limits ($ISDR_{limit}$) have been determined employing existing experimental databases and analytical simulations. The proposed limits have also been compared with existing code limits as shown in Figures 3 and 4. For building level assessment, each floor is assessed based on the story shear force ratio calculated as the shear force carried by high risk members divided by the total story shear. The story shear force ratio is compared with the corresponding limit which is determined based on the average vertical stress in vertical member. When the average axial stress resulting from gravity loads in the considered floor exceeds 0.65, none of the members are allowed to exceed their performance limit to classify the building as High Risk. When the average axial load ratio is less than or equal to 0.1, columns/walls that carry up to 35 percent of the story shear are allowed to exceed their performance limits in order to classify the building as High Risk.

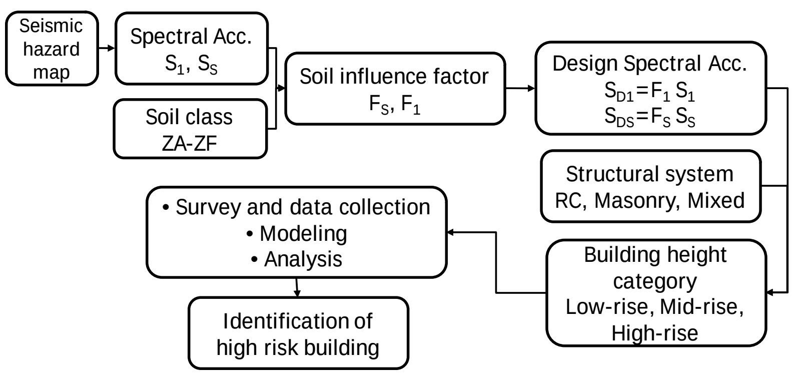

Figure 2. Risk Assessment Procedure in PIHRB

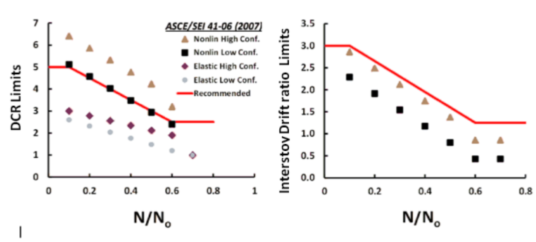

Figure 3. Comparisons of DCR and Interstory Drift Ratio Limits for Class A Columns

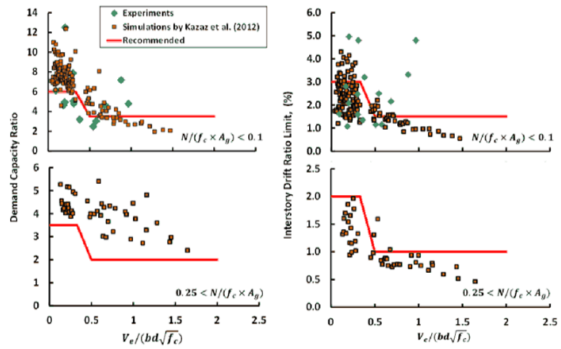

Figure 4. Comparisons of DCR and Interstory Drift Ratio Limits for Class A Walls

4. APPLICATION OF ASSESSMENT PROCEDURES TO SAMPLE BUILDINGS IN TURKEY

4.1. Assessment of An Existing Building Database

The database consists of 131 reinforced concrete buildings that were evaluated by detailed assessment procedures and decisions were made regarding the type of action that needs to be taken to improve the performance of the vulnerable buildings (Gunes 2006). The detailed assessment results reveal that thirty six of these buildings were found to have enough capacity according to Turkish Seismic Code (TEC 2007) and were classified as “Adequate”. Eighty eight buildings were determined to be in need of rehabilitation and classified as “To be strengthened”. The remaining seven buildings were classified as “To be demolished” since they were found to be seismically deficient. The properties related to structural and architectural features of the building stock were also investigated considering, plan irregularity, apparent quality, soft story and/or short column. Most of the buildings had 2 to 6 stories.

The rapid visual screen procedure and some of the preliminary assessment procedures presented in Table 2 were applied to the database. These results reveal that there are significant differences between the final outcomes of the procedures. ATC 21 and, Sucuoglu and Yazgan (2003) give inconsistent results; Sucuoğlu and Yazgan (2003) tends to classify buildings as safe whereas ATC21 predicts otherwise. Yakut (2004) and Hassan and Sozen (1997) procedures that are primarily based on the sizes of the lateral load resisting members yield consistent results. This is also evidenced in the high correlation of vulnerability scores computed with these procedures versus the member area density ratios per total floor area as depicted in Fig. 5. Ozcebe et al.’s procedure that relies on the parameters representing the stiffness, strength and the architectural features and is based on statistical analysis yields unexpectedly poor predictions. This is in part due to sensitivity of this method more to other features than member sizes (Fig. 5).

Table 2. Results of assessments for existing building database

		Percentage of buildings assessed				
		Yakut 2004	**Hassan and Sozen 1997**	**Ozcebe et al. 2004**	**Sucuoglu and Yazgan 2003**	**ATC 21**
Adequate (36 buildings)	Unsafe	17	14	22	0	81
	Intermediate	-	-	14	-	-
	Safe	83	86	64	100	19
Needing strengthening (88 Buildings)	Unsafe	74	67	48	7	93
	Intermediate	-	-	27	-	-
	Safe	26	33	25	93	7
Demolished (7 Buildings)	Unsafe	71	43	57	29	100
	Intermediate	-	-	0	-	-
	Safe	29	57	43	71	0

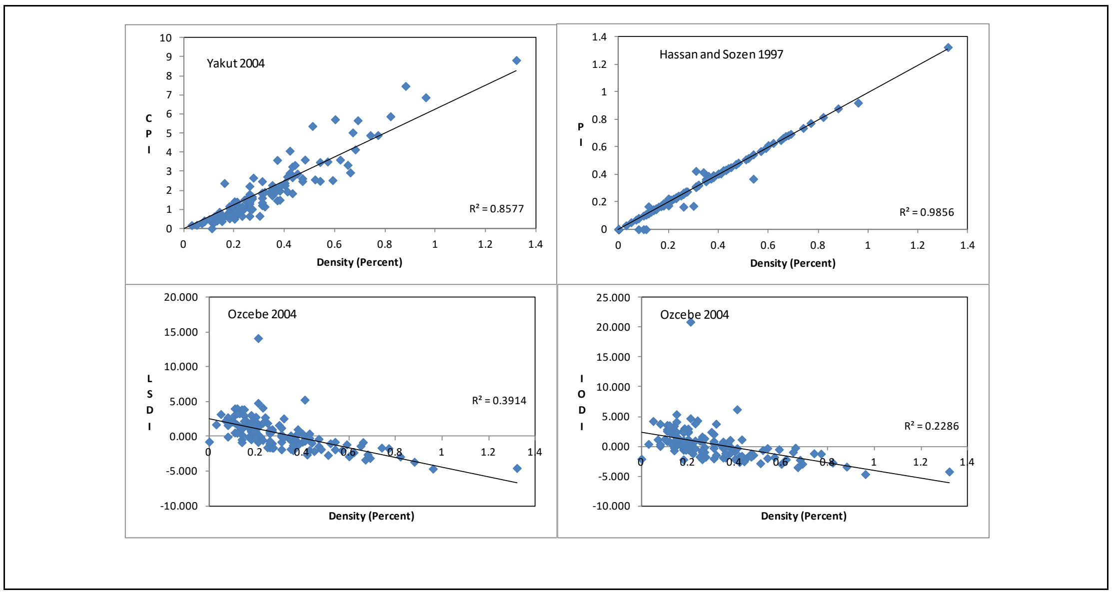

Figure 5. Correlation with member area and density ratio.

4.2. Damaged Building Database

Four buildings damaged to varying levels after recent earthquakes were employed for comparison purposes. The buildings were assessed using detailed assessment procedures and preliminary seismic assessment procedures. Typical properties of these buildings are presented in Table 3. Assessment results are summarized in Table 4. In general, detailed procedures except the TEC 2007 Linear capture the observed behavior better than other procedures. ASCE 41 procedure and TEC 2007 Nonlinear procedures give similar results. Although, results obtained from preliminary assessment procedures are similar, they are not adequately representing the observed behavior which is similar for TEC 2007 Linear procedure.

Table 3. Properties of buildings damaged after earthquakes

Building ID	**Number of stories**	**Concrete strength (MPa)**	**Plan area (m2)**	**EQ. Experienced**	**Global Damage**
BLD1	5	14	234	Ceyhan 1998	Light
BLD2	4	12	274	Dinar 1995	Moderate
BLD3	5	20	253	Düzce 1999	Heavy
BLD4	3	14	124	Bingöl 2003	Light

Table 4. Assessment of buildings damaged after earthquakes

Build. ID	**Observed**	**TEC 2007 Linear**	**TEC 2007 NLinear**	**ASCE 41**	**EC8**	**Yakut 2004**	**Hassan 1997**	**P25 (Tezcan et al. 2011)**
BLD1	Light	CP	IO	IO	LS	US	US	US
BLD2	Moderate	LS	CP	LS	LS	US	US	US
BLD3	Heavy	CP	CP	CP	LS	S	S	S
BLD4	Light	CP	IO	IO	IO	US*	US*	US*

US: Unsafe, S: Safe, *: Very close to limit of S

5. EVALUATION OF ASSESSMENT PROCEDURES

5.1. RVS and Preliminary Assessment

Seismic performance assessment procedures have limitations, assumptions and scope that, along with the content of data in hand, determines their applicability, adequacy, efficiency and reliability. It is critical to know that rapid screening procedures provide only a ranking to be used for further evaluations. For a large building stocks, carrying detailed assessment is not too reasonable due to time and economical constraints. In such cases, preliminary assessment procedures are preferred due to their practicality. However, in such cases, approximations, limitations and assumptions of the methods should be taken into account when using results of these procedures. It is also important to know what parameters are used and how the procedure was validated in order to evaluate its reliability. For example, Ozcebe et al.'s procedure was developed based on statistical analysis of field data and relies on structural as well as architectural features of the buildings. It was pointed out earlier that, when applied to the database of existing buildings, the correlation of this method with structural member areas was found to be relatively poor compared to other procedures. So one should expect inconsistent results as compared to the detailed assessment procedures that rely on analyses of building models. The other procedures which rely mostly on member cross sections provide consistent results. However, influence of other parameters may especially be very critical for buildings that have weak structural systems. For example, in Yakut (2004) procedure the building is expected to perform satisfactorily if member sizes and concrete strength are adequate thus presence of other features such as irregularities would not let the building alone to be classified as unsafe. Unlike this, P25 procedure can classify the building as having potential to collapse due to adverse effect of only one or a few parameters considered: such as pounding score alone lets the building be classified unsafe although the building might have significantly dense shear walls. Additionally, the combined effect of some of irregularity features such as torsion, vertical discontinuity, mass distribution and corrosion may reduce P1 score by 70 percent. One should also be careful when using Hassan and Sozen (1997) method which merely relies on member cross sectional areas ignoring earthquake level, irregularities and material properties.

In development of most of these procedures, verification and/or calibration using a database is performed to show the validity of the method. However, it is worth emphasizing that these databases generally do not contain data for heavily damaged or collapsed buildings as they rely on existing drawings which do not necessarily reflect as built properties.

Even detailed assessment procedures such as TEC2007 Linear may not adequately predict observed behavior in some cases. Although, it is expected that the detailed procedures based on linear analysis are more conservative then nonlinear ones the degree of conservatism needs to be reasonable. The cases discussed here revealed that preliminary assessment procedures are generally in agreement with the TEC 2007 elastic procedure.

5.2. Detailed Assessment Procedures

The progress of seismic assessment codes is obviously led by ASCE41 series over the past years (ASCE41-06, ASCE41-13, ASCE41-17). Eurocode 8 which employs chord rotation as the deformation parameter has not been revised since 2005. The first Turkish assessment code (TEC2007) has been significantly changed in 2019 (TBEC 2019) employing new deformation limits and parameters. Examination of these common codes reveals that the recent advances generally focus on deformation limits rather than other parts of the assessment including data collection and analysis methods. ASCE 41-06 that was similar to FEMA 356, has gone through changes of column classifications in ASCE 41-13 in which some of the plastic rotation limits were changed for beams. A significant change in column deformation limits was introduced in ASCE41-17 moving from tabularized values since FEMA 273 to equations. The changes in deformation limits of columns in these codes are summarized in Figure 6 that shows the comparison of rotation limits for various column cross sections. It is clearly seen that The limits in Turkish code have decreased for Collapse prevention whereas there is significant increase in ASCE41. It clearly seen that the codes have different limits; EC8 has the most conservative limits for Immediate Occupancy. TBEC 2019 limits are the most conservative for Collapse Prevention.

Several alternatives for linear and nonlinear procedures are given in these codes using detailed data collected and sophisticated models. On the other hand, PIHRB (2013, 2019) provide practical, fast and reliable assessment using a linear dynamic procedure for low rise RC buildings.

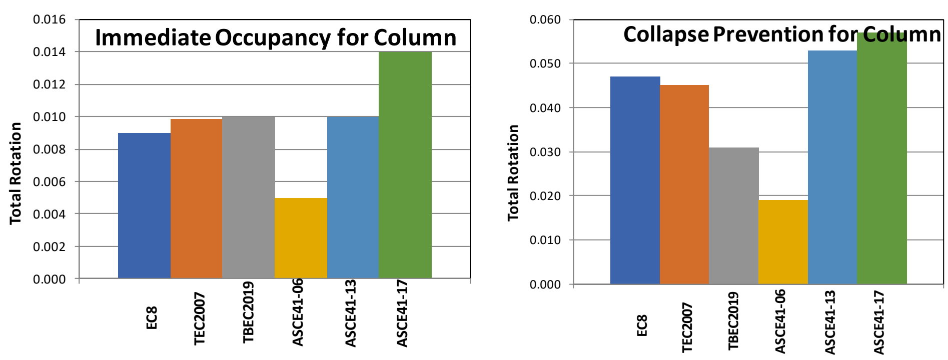

Figure 6. Comparison of Column Deformation Limits

6. CONCLUSIONS

The most common approximate and detailed assessment procedures proposed for RC buildings in Turkey were discussed here. Some of the RVS and preliminary assessment procedures were applied to some databases to evaluate their efficiency and reliability. It has been shown that all preliminary assessment procedures have inherent limitations and assumptions that strongly affect the results. The expected accuracy depends greatly on the quality of data, features of the buildings studied and applicability of the procedure. As expected, the comparisons revealed that preliminary assessment procedures relying mostly on structural features give consistent results with detailed assessment procedures. The users should be very careful about the limitations and assumptions in these procedures. The change in deformation limits of the members in ASCE41 indicates that these procedures were very conservative, despite this, the limits in Turkish code were decreased. In Turkey, PIHRB 2019 and TBEC2019 give procedures for seismic performance assessment of RC buildings, however, it should be noted that the objective between these codes is quite different.

REFERENCES

ASCE/SEI 41 (2006). Seismic rehabilitation of existing buildings. American Society of Civil Engineers, Reston, Virginia. USA.

ASCE/SEI 41-13 (2014). Seismic assessment and rehabilitation of existing buildings. American Society of Civil Engineers, Reston, Virginia.

ASCE/SEI 41-17 (2017). Seismic assessment and rehabilitation of existing buildings. American Society of Civil Engineers, Reston, Virginia.

ATC 31-03 (2003). Seismic Evaluation of Existing Buildings, American Society of Civil Engineers, Reston, VA.

Binici, B., A. Yakut, G. Ozcebe, A. Erenler (2013). Provisions for the Seismic Risk Evaluation of Existing RC Buildings in Turkey under Urban Renewal Law, Earthquake Spectra, 31(3), December.

Erduran E, Yakut A (2007). Vulnerability Assessment of Reinforced Concrete Moment Resisting Frame Buildings. *Journal of Structural Engineering ASCE*; 133 (4): 576-586.

Eurocode 8 (2005). Design of Structures for Earthquake Resistance-Part 3: Assessment and Retrofitting of Buildings . BS EN 1998-3. Comité Européen de Normalisation, Brussels, Belgium; 2005.

FEMA 154/ ATC-21 (1988). *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook.* Federal Emergency Management Agency, Washington, D.C..

FEMA 273 (1997): NEHRP Guidelines for the Seismic Rehabilitation of Buildings. Federal Emergency Management Agency (FEMA). Washington, D.C.

FEMA 310 (1998). “Handbook for the Seismic Evaluation of Buildings - A Prestandard”, Federal Emergency Management Agency, Washington, DC.

FEMA 356 (2000). NEHRP Guidelines for the seismic rehabilitation of buildings. Federal Emergency Management Agency (FEMA), Washington DC.

Gülay FG, Bal İE, Gökçe T (2008). Correlation Between Detailed and Preliminary Assessment Techniques in the Light of Real Damage States. *Journal of Earthquake Engineering*; 12(S2):129–139.

Gunes B, Yakut A, Gunes O (2006). Approximate Seismic Evaluation Methods for Large Building Inventories with High Variability in Their Seismic Resistance. *8th National Conference on Earthquake Engineering (8NCEE)*; Paper No. 1606. EERI. San Francisco.

Hassan AF, Sozen, MA (1997). Seismic Vulnerability Assessment of Low-Rise Buildings in Regions with Infrequent Earthquakes. *ACI Structural Journal*; 94(1): 31-39.

Kalem İ (2010). *Capacity Related Properties and Assessment of School Buildings in Turkey*. MS Thesis. Orta Doğu Teknik Üniversitesi, METU. Ankara, Turkey.

Ministry of Environment and Urbanization (MEU), (2012). The Urban Renewal Law for Regions under Disaster Risk, Law No: 6306, Official Gazette: Date, 28(309), Volume 52, Turkey.

Ozcebe G. Yucemen MS, Aydogan V (2004). Assessment of Seismic Vulnerability of Existing Reinforced Concrete Buildings, *J. of Earthquake Engineering*; 8(5): 749-773.

PIHRB (2013, 2019). Principles for Identifying High Risk Buildings, Ministry of Environment and Urbanization (MEU), Ankara, Turkey

Sucuoglu H, Yazgan U (2003). Simple Survey Procedures for Seismic Risk Assessment in Urban Building Stocks. *In: Wasti ST, Ozcebe G, editors. Seismic Assessment and Rehabilitation of Existing Buildings, Earth and Environmental Sciences* -Vol 29: Kluwer Academic Publishers, London:97-118.

Sucuoglu H, Yazgan U, Yakut A (2007). A Screening Procedure for Seismic Risk Assessment in Urban Building Stocks. *Earthquake Spectra* 2007*;* 23(2): 441-458.

Temür R (2006). Hızlı Durum Tespit (DURTES). Yöntemi ve Bilgisayar Programının Geliştirilmesi. MS Thesis. İstanbul Üniversitesi, İstanbul.

Tezcan SS, Engin IB, Gulay FG (2011). P25 scoring method for the collapse vulnerability assessment of R/C buildings. *Journal of the Chinese Institute of Engineers* 2011; 34 (6) : 769–781.

TEC (2007). Turkish Earthquake Code. Ministry of Public Works, Ankara, Turkey, 2007(in Turkish).

TBEC (2019). Turkish Building Earthquake Code . Ministry of Interior, Disaster and Emergency Management Presidency (AFAD).

Yakut A (2004). Preliminary seismic performance assessment procedure for existing reinforced concrete buildings. *Engineering Structures* 2004; 26: 1447–1461.