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A PRELIMINARY SEISMIC ASSESSMENT PROCEDURE FOR REINFORCED CONCRETE BUILDINGS IN TURKEY

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SUMMARY

Reinforced concrete buildings are predominant type of construction in developing countries like Turkey. Seismic performance of these buildings, however, is not predictable through techniques based on scientific and technical know-how alone, because the performance of this construction type depends highly on secondary factors such as the soft story, short column, irregularities in plan and elevation, the material quality, workmanship and compliance to the designed detailing and sizes. The devastating scene after many destructive earthquakes in Turkey had re-emphasized the role of the secondary factors in the severity of damage observed. Although many procedures have been proposed in the literature to evaluate the performance of existing RC buildings, the influence of the secondary factors has not been included adequately. This study has been undertaken to develop an assessment procedure that takes into account the influence of structural configuration as well as the secondary factors. In this procedure, a basic capacity index is computed considering the assessed orientation, size and material properties of the components comprising the lateral load resisting structural system. This index is then modified by several coefficients that reflect the quality of workmanship, detailing and architectural factors. The procedure has been developed based on the data compiled from damage surveys conducted after the earthquakes that occurred within the last decade in Turkey. The method uses attributes of each building to rank their vulnerability within a given inventory. As a result, buildings with high vulnerability are classified as unsafe indicating that they would perform unsatisfactorily under a strong earthquake. The procedure is quite attractive for assessing the vulnerability of a large inventory of buildings because of the ability of arriving at decisions rapidly.

INTRODUCTION

After recent earthquakes of destructive nature in Turkey, significant research has been tailored towards assessing seismic risk in earthquake prone areas. The city of Istanbul, the largest city in the country, has been the center of most of these investigations because of a large earthquake that is expected to hit the area. Due to large scale of the building inventories in hand, the need for quick and reliable procedures is vital. There have been several attempts and recommendations for such procedures. There are generally three levels of vulnerability assessment procedures available in the literature; Rapid screening procedures,

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preliminary assessment methodologies and detailed assessment techniques. The selection of the procedure depends on the degree of accuracy and reliability required as well as the size of the building stock in hand. Rapid screening procedures aim on assessing the vulnerability using information and data that can be collected from the inspection of the building without entrance to it. The information on the building attributes such as number of stories, post benchmark year, soft story, plan and vertical irregularities, apparent material and construction quality, and type of structural system are acquired. A scoring system is generally employed to include the influence of each factor on the expected seismic performance. These procedures generally intend to identify the buildings that need further investigation. FEMA 154 [1] is a well-known rapid visual screening procedure developed for buildings in the US. Similar procedures [2,3] have also been developed for Turkey. A recent study carried out by Sucuoglu and Yazgan [3] resulted in a simple procedure recommended to identify highly vulnerable reinforced concrete buildings in Turkey, using observed damage patterns compiled in Duzce after the 1999 earthquakes. The relative significance of each parameter included was determined from regression analyses of nearly 500 buildings [3].

A more reliable and thorough option is to employ preliminary assessment procedures that require detailed information on the structural components of the building. A study by Hassan and Sozen [4] used the sizes and orientation of columns, structural walls and infill walls to determine the relative vulnerability of a class of buildings. This procedure suggests two indexes to be computed based on the column and wall areas present on the ground floor of the building. The column index (CI) and wall index (WI) are computed from Equation 1. In Equation 1, A_c represents the summation of column cross-sectional areas on the ground floor, A_{mw} and A_{sw} correspond to the total cross-sectional area of the masonry infill walls and concrete shear walls in one orthogonal direction at base, respectively. The total area of all floors above the ground level is denoted by A_{ft}.

$$
\begin{aligned}
CI &= \frac{0.5A_c}{A_{ft}} x100 \\
WI &= \frac{A_{sw} + 0.1A_{mw}}{A_{ft}} x100
\end{aligned}
\qquad (1)
$$

The summation of wall and column indexes is defined as Priority Index (PI). The column and wall indexes of a given inventory are plotted on a two dimensional graph to determine the boundary of high vulnerability levels. An alternate evaluation can be based on the PI values that are compared to a cutoff determined for the inventory in hand. Gulkan and Sozen [5] used the same concept of wall and column indexes explaining the theoretical relationship between these indexes and the drift demands. A statistical approach was employed by Ozcebe et al. [6] to develop a preliminary assessment procedure for reinforced concrete buildings in Turkey. The procedure is based on the field observations carried out after the 1999 Duzce Earthquake. A comprehensive database that encompass detailed information on 484 buildings suffering various degrees of damage after the earthquake was compiled. In addition to architectural parameters, several indexes that take into account size and orientation of the vertical members and their stiffness are used in an equation obtained from discriminant analysis to compute a damage score. This score is compared with a cutoff value to classify the buildings. A major drawback of the procedure is its limited applicability confined to Duzce or a similar region that is likely to be hit by a similar earthquake. Besides that, the amount of data needed and the level of computations involved are considerable.

The third and the most comprehensive methods of assessment require elaborate data collection and analyses efforts. Detailed information on the components such as the reinforcement amount and arrangement and actual strength of concrete are acquired. This procedure is usually applied to specific buildings, which either have special occupancy, unusual features or are classified unpredictable by the preliminary assessment procedures. Intensive structural analyses including static and dynamic nonlinear analyses may be necessary. FEMA 273 [7], FEMA 310 [8] and ATC-40 [9] recommend widely used detailed assessment procedures.

The objective of this study is to develop a simple, reliable and practical preliminary seismic assessment procedure that can be used to predict seismic vulnerability of a group of low- to mid-rise reinforced concrete buildings satisfactorily and rapidly. The wealth of existing damage survey data and past earthquake experience in Turkey are used to include peculiar construction practice and the observed performance in the procedure proposed. Unlike its counterparts, this procedure takes into account the influence of strength of concrete, regional seismicity, the effect of soil condition, the negative influence of some prevalent architectural features and the common practice of substandard construction.

DESCRIPTION OF THE PROCEDURE

The central point of the procedure is to approximate the elastic base shear capacity of the building using the dimensions, size, orientation and concrete strength of the components at the ground floor comprising the lateral load resisting system.

The following summary outlines the steps involved in the proposed procedure:

Step 1: Calculation of the total concrete shear capacity on the ground floor

The shear capacity of each structural component is computed based on the cross-sectional areas of the members and the strength of the concrete using Equation 2.

$$Vc_i = \alpha f_{ctk} b_w h \qquad (2)$$

Where Vc_i denotes the shear strength of the cross-section due to concrete contribution only, f_{ctk} is the direct tensile strength of concrete, b_w and h are the dimensions of the rectangular cross-section. This equation is incorporated in many reinforced concrete design codes to compute shear strength of the concrete members. The coefficient α is nothing but the product of strength reduction factor and the empirical coefficient that relates the tensile strength to the shear strength, and is given as 0.65 in the Turkish Design Code [10]. The total shear capacity (Vc) of the members at the ground floor is calculated from Equation 3.

$$Vc = \sum k\, Vc_i \qquad (3)$$

In Equation 3, the coefficient k is used to account for the orientation of the columns, which is taken as 2/3 when the capacity in the longitudinal direction of the member is calculated, and 1/3 if transverse shear capacity is desired. For shear walls k is taken as 1 when the in-plane direction is considered. It is generally not too practical to take concrete core samples for determining the compressive strength of concrete used to compute f_{ctk}. In such cases, the compressive strength of concrete can be approximately taken as 8, 12 and 16 MPa if the visual inspection of its quality is assessed to be poor, average and good, respectively. These values are recommended based on the general practice in Turkey; the minimum permitted concrete strength in the regions of high seismicity is specified as 16 MPa in the Turkish Seismic Code [11].

Step 2: Estimation of the base shear capacity of the building

The basic idea here is to establish a relationship between the total concrete shear capacity (Vc) and the expected yield base shear (V_y) of the building. In order to develop this relationship, forty reinforced concrete buildings, which are typical low- and mid-rise buildings were selected from several building databases compiled by the researchers at Middle East Technical University [12]. Majority of these buildings have masonry infill walls encased by the frames. Three dimensional models of each building were created with and without the inclusion of infill walls using guidelines given in FEMA 273 [7] and Turkish Design Code [10]. Each model was subjected to the pushover analyses to obtain a pushover curve in the two orthogonal directions. The pushover curves were idealized per FEMA 273 [7] procedure and two yield base shear values (V_y and V_{yw}) corresponding to the models with and without infill walls were obtained. Then by comparing V_y with Vc the relationship given in Equation 4 that represents the general trend of the data is established.

$$V_y = \frac{V_c}{1.4e^{0.065n}} \tag{4}$$

Where n indicates the number of stories. Figure 1 illustrates the mean of data points for number of stories used to obtain Equation 4.

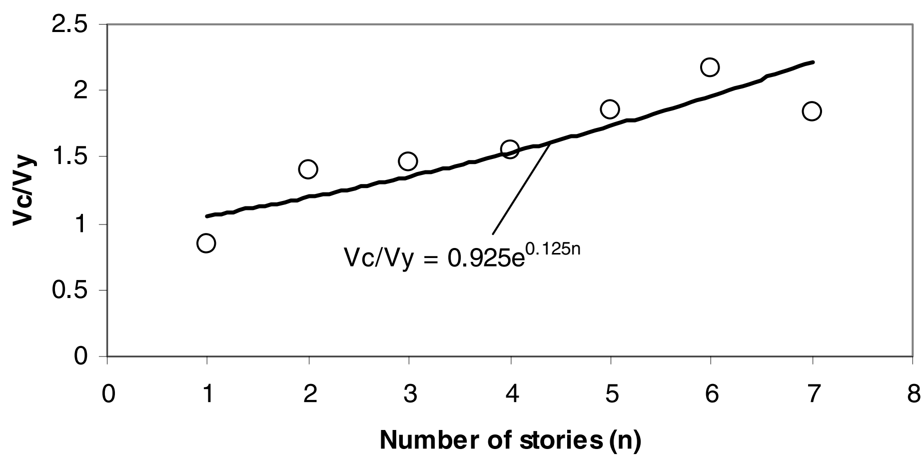

Figure 1. Relationship of Total Concrete Shear and the Yield Base Shear

It is well accepted that the presence of masonry infill walls in RC structures increases their lateral load capacity. Previous studies [4,5,6] account for this effect by assuming that the capacity of the infill walls is equivalent to 10 percent of the capacity of the shear wall that has the same size as the masonry wall. In the procedure proposed, however, this contribution is accounted for based on the results of nonlinear static analyses of the selected buildings. This way, a relationship between the increase in the yield base shear of bare frame (V_{yw}/V_y) and the total area of the infill walls on the ground floor was derived. Equation 5 shows how the yield base shear of a building with infill walls (V_{yw}) is computed if its value without infill walls (V_y) is known. Note that only infill walls without openings must be considered because of the inefficiency of the ones with openings. A_{mw} in Equation 5 corresponds to the total area of the infill walls in the direction of interest at the ground floor.

$$V_{yw} = V_y\,(46\frac{A_{mw}}{A_{tf}} + 1) \qquad (5)$$

Step 3: Calculation of Basic Capacity Index (BCPI)

An index called the basic capacity index (BCPI) is calculated dividing V_{yw} computed from Equation 5 by the code required base shear (V_{code}) used in the design of the building (Equation 6). Therefore for a building with known year of construction V_{code} needs to be computed according the code of practice at the time of its design.

$$BCPI = \frac{V_{yw}}{V_{code}} \qquad (6)$$

This index reflects the seismic region and the soil property at the site the building is located through V_{code}. There is reason to believe that the magnitude of this index gives an indication of the relative vulnerability of RC buildings in Turkey. The index is a measure of the strength capacity of the building so is a good indicator of the expected performance of buildings that do not have adequate ductility, as is the case in Turkish building stock.

Step 4: Modification of BCPI to include Architectural Features and Construction Quality.

The BCPI can properly be used for buildings that are rather regular and are constructed in compliance with the code and the design calculations. The buildings with irregularities in plan and in elevation the response is amplified as revealed by many studies and post earthquake observations. This amplification might play important role on the seismic performance of buildings that have moderate base shear capacity. In other words, buildings that have BCPI in the vicinity of unity would possess high risk if they have certain architectural features that would make them structurally irregular. In order to include this effect in the proposed procedure, BCPI is modified by applying a reduction factor (C_A). This factor reflects the influence of architectural features like soft story, short column, vertical irregularity, torsion and plan irregularities. Additionally, for regions where code compliance is not enforced and technical inspection is not properly ensured due to lack of accountability substandard buildings are constructed. This is a common problem in many developing countries including Turkey. In these regions, the effect of construction quality plays a significant role on the seismic performance of the RC buildings. For this reason, a second reduction factor, C_M, is applied on BCPI to account for the inferior quality of construction. The modified index is called capacity index, CPI and calculated from Equation 7.

$$CPI = C_A C_M BCPI \qquad (7)$$

The irregularity factor C_A serves to encompass the influence of several features and is computed using Equation 8.

$$C_A = 1.0 - 1.5(C_{AS} + C_{ASC} + C_{AP} + C_{AF}) \qquad (8)$$

where C_{AS} reflects the soft story feature and takes the value of 0.036 if soft story exist, 0 otherwise. C_{ASC} takes into account the vulnerability due to presence of short column and is assigned 0.018 when short columns are present. The effect of plan irregularity that results in horizontal torsion and significant amount of overhangs are represented through C_{AP}, which is taken as 0.019 when any of these features exist. The vertical and in-plan discontinuity of frames are incorporated through the coefficient C_{AF}. C_{AF} is assigned 0.027 to account for the effect of either type of frame discontinuity. Although there is consensus on the definitions of these architectural features, the descriptions given in the Turkish Seismic Code [11] are adopted here.

The values for the coefficients in Equation 8 are approximate and recommended to reflect relative significance of each factor. When assigning these relative scores weighting coefficients of each selected factor were determined by taking into consideration the recommendations of FEMA 154 [1].

The construction influence coefficient, C_M can be quantified based on the visual inspection of the building. Three levels of quality assessments, poor, average and good are converted to quantitative numbers. If the assessed quality is poor then C_M can be taken as 0.90, for average C_M =0.97 and for the good quality it is taken as 1.0. These numbers cannot be precisely determined, which is not necessary either. A number of researchers [2, 3] tried to quantify the effects of material quality and architectural features on the vulnerability of buildings. The outcome of their investigations is the relative significance scores between these parameters. FEMA 154 [1] recommends penalty scores for the architectural irregularities as well as the material quality. Table 1 summarizes the scores that are assigned to the selected irregularities and the material/construction quality recommended by FEMA 154 [1] and two previous studies [2,3]. The relative significance of construction quality suggested by [1], [2] and [3] is around 55, 44 and 10 percent of that of architectural features, respectively. Since the experience in Turkey clearly indicated the importance of C_M, its influence on the BCPI is assumed to be 10 percent, and that of C_A as 15 percent. A recent study that investigated the effect of vertical irregularities on the seismic response of buildings revealed that the average roof drift of regular buildings is generally not increased more than 15% [13].

Table 1. Comparison of Weighting Coefficients and Scores

Feature	Weighting Coefficients (Scores)		
	FEMA 154 [1]	Gulkan and Yakut [2]	Sucuoglu and Yazgan [3]
Soft Story	0.36 (2.0)	0.500 (2.0)	0.32 (15.00)
Short Column	0.18 (1.0)	0.250 (1.0)	0.11 (5.00)
Plan Irregularity	0.19 (1.0)	0.125 (0.5)	0.19 (9.13)
Frame Irregularity	0.27 (1.5)	0.125 (0.5)	0.38 (18.13)
Construction Quality	(0.5)	(1.75)	(25)

Step 5: Decision on the vulnerability of the building

The final step of the procedure is to prepare a plot that displays CPI computed for all buildings in the inventory. Then a cutoff limit needs to be set that will define a demarcation line to differentiate unsafe and safe buildings. In setting the cutoff, one should consider the sensitivity, accuracy and priority. If the purpose is to become conservative and to identify more buildings that are unsafe then several safe buildings will also be classified as unsafe. The applications that follow illustrate the delicacy in assigning this limit.

APPLICATION OF THE PROPOSED PROCEDURE

The benefit of existing data from the damage survey studies of some recent earthquakes in Turkey is used to test the efficiency of the proposed procedure. Three databases that have been compiled after recent earthquakes are employed. The procedure is also compared with Hassan and Sozen's [4] methodology, which is also applied to the same databases.

After the Erzincan earthquake of 1992, (Richter magnitude of 6.8), 43 institutional buildings were examined in Erzincan to document their damage and to provide repair/rehabilitation proposals if needed. This inventory formed the basis for Hassan and Sozen [4] as well as Gulkan and Sozen [5] studies. The author has updated this inventory to include architectural features as well as concrete strength and quality assessments.

On February 3, 2002 an earthquake of magnitude 6.5 occurred in Sultandagı district of Afyon. The earthquake caused significant damage to engineered buildings in Afyon. A team from METU was dispatched to document damage to reinforced concrete buildings along with the data on the structural system and architectural features. Table 2 summarizes the database that is comprised of eighteen reinforced concrete buildings.

The May 1, 2003 earthquake, magnitude 6.4 (M_w), struck the city of Bingöl causing considerable damage to the buildings and killing 168 people. After the earthquake a team from Middle East Technical University (METU) was deployed to investigate certain aspects of the earthquake and collect information on building damage using visual inspection, simple measurements, photographs, and GPS readings. Blocks of buildings (5 to 15 buildings each) were selected at different locations of the city to observe local and global distribution of damage. Each building was assigned a damage state based on the visual inspection of the structural as well as non-structural components. Twenty-eight buildings were surveyed and examined in detail to understand the reasons leading to the observed damage. Table 3 summarizes the collected information on these buildings.

The CPI and PI values computed for all buildings in these databases are displayed in Figures 2 and 3. The indexes plotted in these figures are the minimums of those computed for the two principal directions of the buildings, the information on the earthquake direction and building orientation is not reflected. A limit of 1.2 and a corresponding limit of 0.26 chosen for CPI and PI, respectively are also shown in these Figures. Out of 45 buildings judged to have had None/Light damage grades, 37 are classified safe by the CPI and 35 by PI (Figure 2a, 3a). On the other hand, 9 and 13 of the 26 moderately damaged buildings are identified unsafe by CPI and PI, respectively. Most of the buildings that were observed to experience heavy damage or collapse are captured by both indexes: out of 18 buildings only 3 are misclassified, not the same buildings, however, are identified by both procedures. The larger scatter observed using CPI clearly indicates the difference between the two approaches. CPI identifies more correctly the buildings with None/Light damage in Erzincan database. correct estimation rate for unsafe buildings is %80 using CPI and %90 based on PI. In Afyon database, %50 and %63 of safe buildings (Light and Moderate) were predicted wrong with CPI and PI, respectively. The influence of construction quality and architectural features had a minor effect on the CPI of buildings in Afyon inventory. The CPI offers a better estimate of the buildings that have suffered Heavy/Collapse damage in Bingol database; only 2 of 7 buildings were classified incorrectly based on the CPI limit of 1.2.

It should be noted that the presence of all negative features in a building is very rare; None of the buildings in the databases employed in this study posses all selected architectural features and poor construction quality. The combined effect of these secondary factors reduces BCPI by 25 percent, which is quite critical for the buildings in the vicinity of the cutoff. For buildings in the near this demarcation line, a more detailed evaluation might be necessary unless a conservative approach of classifying them as unsafe is not preferred.

Interpretation and Discussion

The procedure developed in this study introduces significant improvements to other similar procedures. It has been developed and calibrated under conditions specific to Turkey. However, the concept used is equally applicable to any other region provided that certain steps need to be modified to reflect region specific practice. The current construction practice in Turkey reveals that typical longitudinal reinforcement ratio for a column is about 0.01, which is implicitly taken into consideration in the pushover analyses. For regions where construction quality is uniform and code compliance is implemented properly then the effect of construction quality may be ignored, i.e. CM = 1.0 may be assumed. The coefficients used in Equations 7 and 8 to modify BCPI are assigned certain values based on the recommendations given in the literature and the past earthquake experience in Turkey. Therefore, they may need to be adjusted for other regions as well. The precise magnitudes of these coefficients are not vital, because the purpose of the proposed procedure is to rank the vulnerability within a group of buildings so approximate reasonable values are adequate.

A challenging step of the procedure is to set a cut-off that is essential to classify the buildings. This cut-off strongly depends on the assessors compiling the data, therefore case specific cut-offs are more reliable. The application of the procedure to several earthquake damage databases indicated that a limit of 1.2 provided reasonable results. Another round of re-evaluation is recommended for the buildings that are near the limit of CPI.

It is believed that as more research on quantifying the effect of the architectural features becomes available, their influence could be reflected better leading to improved results. Additionally, more analyses of the buildings would lead to improvements of Equations 4 and 5.

Table 2. Afyon Database

BUILDING ID	Number of Stories	ΣFloor Area (m^2)	ΣA_{col} (m^2)	ΣA_{col}-x (m^2)	ΣA_{col}-y (m^2)	ΣA_{cw}-x (m^2)	ΣA_{cw}-y (m^2)	ΣA_{mw}-x (m^2)	ΣA_{mw}-y (m^2)	f_{ci}* (MPa)	Construction Quality	Short Column	Plan Irregularity	Frame Irregularity	Soft Story	Damage
AFY-B-01	4	1853	7.74	2.67	5.07	1.05	0.00	1.47	6.35	22.1	Average	yes	no	no	yes	Moderate
AFY-B-02	3	1042	6.37	0.30	6.07	0.00	0.00	1.05	1.81	31.5	Good	no	no	no	no	Light
AFY-C-02	3	386	1.50	0.90	0.60	0.00	0.00	0.90	0.00	16.0	Poor	no	no	yes	yes	Heavy
AFY-C-03	3	358	1.10	0.00	1.10	0.00	0.00	0.00	0.00	13.6	Poor	yes	no	no	yes	Heavy
AFY-C-05	4	561	1.60	0.50	1.10	0.00	0.00	0.51	1.71	28.9	Average	yes	no	no	no	Moderate
AFY-C-06	3	359	1.60	0.20	1.40	0.00	0.00	0.33	4.37	20.4	Average	no	no	yes	yes	Moderate
AFY-C-07	4	544	2.22	0.72	1.50	0.00	0.00	0.00	1.01	22.1	Average	no	yes	no	yes	Heavy
AFY-C-11	4	1335	7.81	2.33	5.49	0.00	0.00	0.00	2.58	13.6	Average	no	no	yes	yes	Light
AFY-C-12	4	649	2.75	0.00	2.75	0.00	0.00	0.00	3.15	13.6	Average	yes	no	no	yes	Moderate
AFY-C-13	3	350	1.36	0.17	1.19	0.00	0.00	0.00	0.78	25.5	Average	no	yes	no	yes	Heavy
AFY-CO-01	3	745	3.30	1.95	1.35	0.00	0.00	2.45	0.79	17.0	Poor	no	no	no	no	Collapsed
AFY-CO-02	4	1029	3.72	1.63	2.09	0.00	0.00	0.00	2.20	16.1	Average	no	no	no	yes	Heavy
AFY-CO-03	5	2304	7.65	3.42	4.23	0.00	0.00	1.79	10.08	17.0	Average	no	no	no	yes	Heavy
AFY-CO-04	4	964	5.28	1.92	3.36	0.00	0.00	2.87	3.17	15.3	Poor	no	no	no	yes	Light
AFY-CO-05	3	353	1.58	1.00	0.58	0.00	0.00	0.00	0.76	14.4	Poor	no	yes	yes	yes	Heavy
AFY-M-02	4	2551	5.76	0.66	5.10	0.00	0.00	0.00	5.36	20.4	Good	yes	no	no	no	Light
AFY-S-01	3	522	2.63	0.25	2.38	0.00	0.00	0.00	3.46	18.7	Average	yes	yes	no	yes	Heavy
AFY-Y-01	3	806	6.40	6.40	0.00	0.00	0.00	0.00	0.00	20.4	Average	no	no	no	yes	Heavy

* Measured compressive strength of concrete

Table 3. Bingol Database

BUILDING ID	Number of Stories	ΣFloor Area (m^2)	ΣA_{col} (m^2)	ΣA_{col}-x (m^2)	ΣA_{col}-y (m^2)	ΣA_{sw}-x (m^2)	ΣA_{sw}-y (m^2)	ΣA_{mw}-x (m^2)	ΣA_{mw}-y (m^2)	f_{ck}^{*} (MPa)	Construction Quality	Short Column	Plan Irregularity	Frame Irregularity	Soft Story	Damage
BNG-10-3-10	3	1958	10.13	3.38	6.75	0.00	0.00	1.23	11.58	14.0	Poor	no	no	yes	yes	Heavy/Collapse
BNG-10-3-3	3	918	6.72	2.99	3.73	0.00	0.00	0.00	1.76	18.0	Poor	no	no	no	no	Moderate
BNG-10-4-4	4	3149	11.50	4.27	7.23	0.00	0.00	4.89	16.68	18.0	Average	no	yes	yes	yes	Moderate
BNG-10-4-6	4	2408	13.78	8.39	5.40	0.00	0.00	8.72	0.00	30.0	Average	yes	yes	no	no	None/Light
BNG-10-4-7	4	3311	16.42	5.82	10.61	0.00	0.00	0.00	4.59	20.0	Average	no	no	yes	yes	None/Light
BNG-10-4-9	4	2201	5.37	2.33	3.04	3.15	3.85	3.63	12.52	22.0	Good	no	yes	yes	yes	None/Light
BNG-10-5-1	5	2918	8.12	4.82	3.30	0.00	2.78	6.87	8.19	18.0	Average	no	yes	no	yes	Moderate
BNG-10-5-11	5	460	2.65	0.99	1.67	0.00	0.00	1.42	4.01	32.0	Average	no	yes	no	yes	None/Light
BNG-10-5-2	5	3363	5.31	1.77	3.54	1.44	0.78	0.00	8.04	20.0	Good	no	yes	no	no	None/Light
BNG-11-2-3	2	260	2.40	1.00	1.40	0.00	0.00	1.32	0.00	8.0	Poor	no	yes	yes	yes	Moderate
BNG-11-4-1	4	1033	3.26	1.46	1.80	0.70	0.00	3.57	1.00	18.0	Poor	no	yes	no	yes	Heavy/Collapse
BNG-11-4-2	4	580	2.13	0.92	1.22	0.00	0.00	1.68	3.80	20.0	Poor	no	yes	yes	yes	Heavy/Collapse
BNG-11-4-4	4	486	2.10	1.05	1.05	0.00	0.00	1.10	1.71	16.0	Poor	no	yes	yes	yes	Moderate
BNG-11-4-5	4	583	3.00	1.45	1.55	0.00	0.00	1.83	2.42	13.0	Average	no	yes	yes	no	None/Light
BNG-3-4-1	4	1954	8.50	4.15	4.35	0.00	0.00	2.12	5.48	18.0	Poor	no	no	yes	no	None/Light
BNG-3-4-2	4	1869	5.25	2.63	2.62	0.00	1.12	6.08	8.14	18.0	Average	no	no	no	no	None/Light
BNG-3-4-4	4	1910	8.05	3.50	4.55	1.12	0.00	3.72	1.76	26.0	Average	no	no	yes	no	None/Light
BNG-5-5-1	5	1974	5.79	3.27	2.52	0.00	0.00	2.54	7.62	26.0	Average	no	yes	yes	yes	None/Light
BNG-6-2-8	2	233.1	1.5	0.5	1	0.00	0.00	2.95	0	12	Poor	no	yes	no	no	Heavy/Collapse
BNG-6-3-1	3	821.3	3.78	1.74	2.04	0.00	0.00	5.2	3.4	20	Average	yes	yes	no	yes	Moderate
BNG-6-3-10	3	365.6	2	0.875	1.125	0.00	0.00	1.22	4.59	20	Good	no	yes	yes	yes	None/Light
BNG-6-3-11	3	705.3	3.9	1.95	1.95	0.00	0.00	1.61	2.97	14	Average	no	yes	yes	yes	None/Light
BNG-6-3-12	3	443.8	2.94	1.04	1.9	0.00	0.00	0	6.18	13	Average	no	yes	yes	yes	None/Light
BNG-6-3-4	3	343.9	1.8	1.05	0.75	0.00	0.00	3.1	0	18	Average	no	yes	no	no	None/Light
BNG-6-4-2	4	2021	6.3	2.7	3.6	0.00	0.00	3.31	14.92	18	Poor	yes	yes	yes	yes	Heavy/Collapse
BNG-6-4-3	4	662.3	1.92	0.76	1.16	0.00	0.00	1.25	3.48	30	Poor	no	yes	no	yes	Heavy/Collapse
BNG-6-4-5	4	398	2.25	0.8	1.45	0.00	0.00	0.58	4.16	20	Good	no	yes	no	no	None/Light
BNG-6-4-7	4	948.5	3.9	1.5	2.4	0.75	0.00	2.08	2.07	18	Poor	no	yes	no	no	Moderate

* Measured compressive strength of concrete

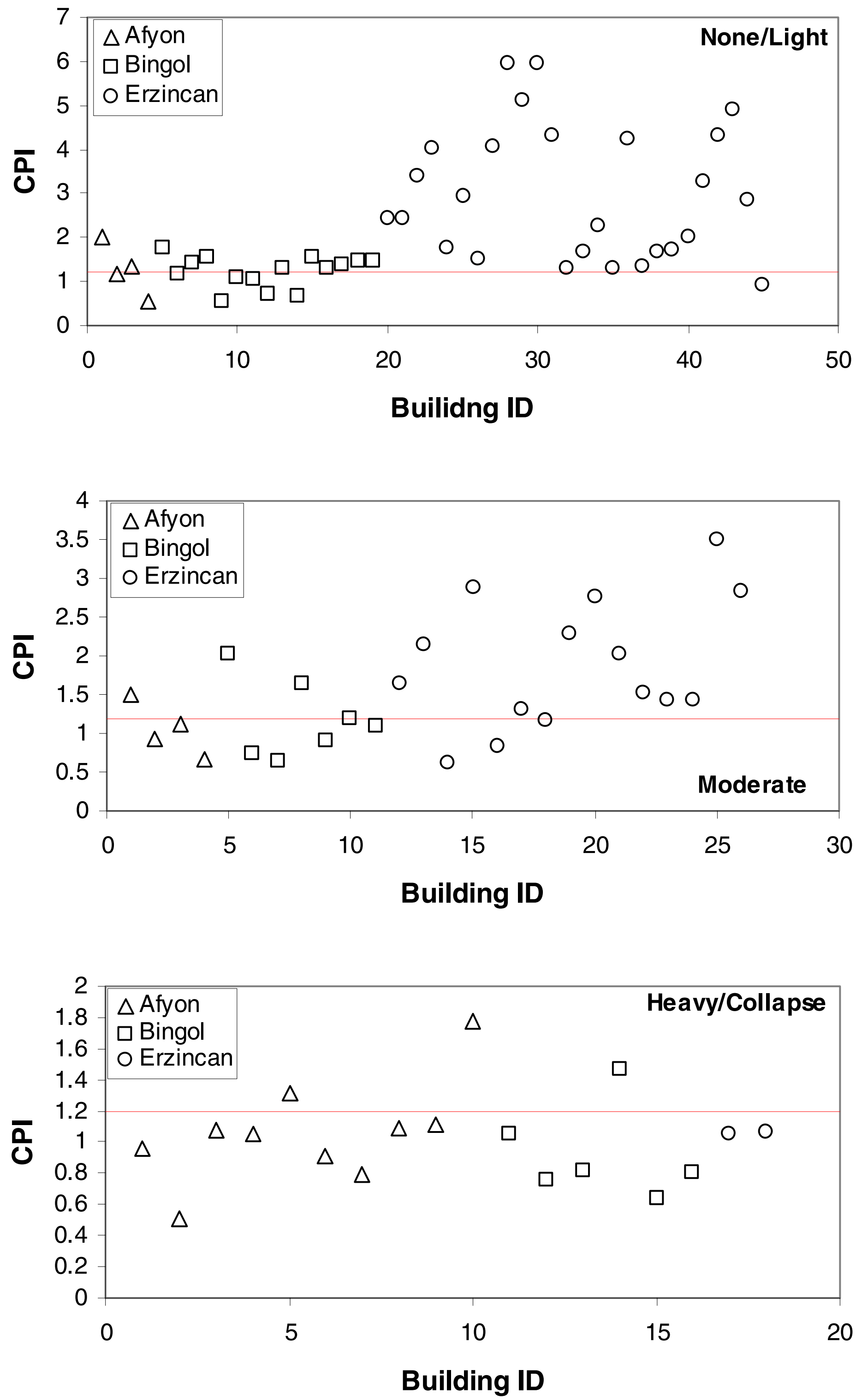

Figure 2. Capacity of the buildings in the Damage Databases

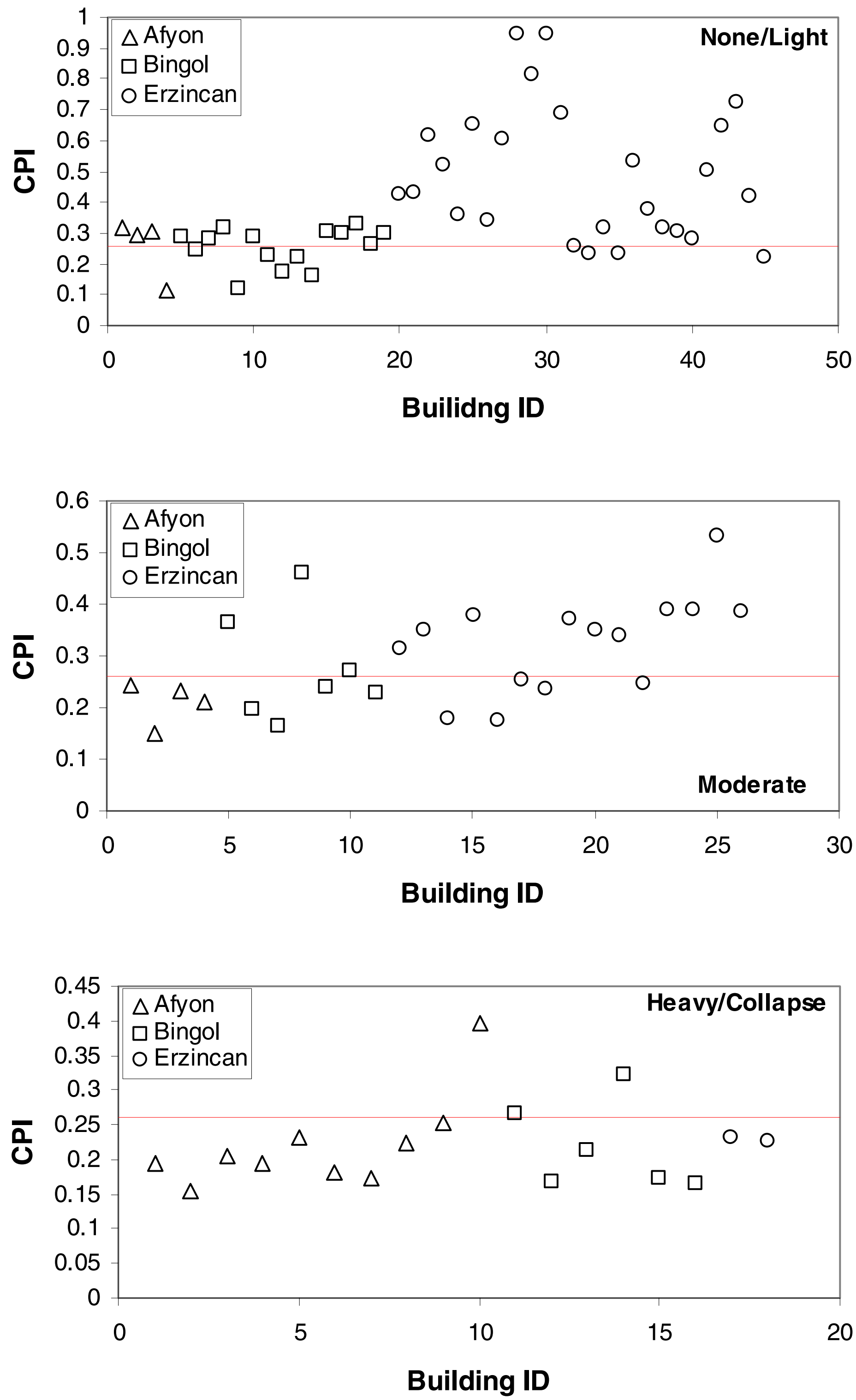

Figure 3. Priority Index of the buildings in the Damage Databases

CONCLUSIONS

The proposed procedure aims to assess rapidly the likely vulnerability of a group of low- to mid-rise reinforced concrete buildings that have moderate ductility. The procedure differs from other similar procedures in that it includes the effect of certain major parameters such as the presence of irregularities, the influence of regional seismicity, the type of underlying soil and the quality of construction. The procedure relies on the orientation, size and concrete strength of vertical load resisting components. Being a strength based assessment procedure, it is reasonably applicable to the buildings in Turkey which generally have moderate or low level of ductility. The procedure can easily be applied to other regions with a few minor modifications.

The magnitudes of the coefficients C_A and C_M are not precisely known. The values assigned to them in this study are based on the engineering judgment, past earthquake experience and the construction practice in Turkey.

The dependence on the as-built properties and on-site surveys makes it extremely important to employ a standard data collection when using the procedure. For decisions or classifications regarding the expected performance, a limit for CPI needs to be set. This limit is best determined for a population of buildings surveyed by the same assessors. When seeking for a rough assessment in Turkey than the limit might be set at 1.2. Buildings near the cut-off limit may need to be re-evaluated using detailed procedures.

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