Earthquakes and Structures, *Vol. 9, No. 4 (2015) 893-910*
DOI: http://dx.doi.org/10.12989/eas.2015.9.4.893

Performance based assessment for existing residential buildings in Lake Van basin and seismicity of the region

Ercan Işık*[1] and Mustafa Kutanis[2a]

[1]Department of Civil Engineering, Faculty of Engineering and Architecture, Bitlis Eren University, TR-13100, Bitlis, Turkey
[2]Department of Civil Engineering, Faculty of Engineering, Sakarya University, TR-54100, Sakarya, Turkey

(Received December 2, 2014, Revised February 21, 2015, Accepted April 20, 2015)

Abstract. Earthquake safety of existing buildings has gained considerable importance after earthquakes which have occurred in our country especially in the last 30 years. Performance based assessment methods have been widely used for existing reinforced concrete structures. This study aims to investigate the earthquake performances of the building stock located in Van Lake basin in Eastern Anatolia of Turkey. The case study of buildings has been modeled on and the structural performances have been determined by employing the non-linear methods described in the latest Turkish Earthquake Code published in 2007. The Van lake basin is located on the very seismically active in a region. On October 23, 2011, a magnitude of Mw 7.2 earthquake struck the Van province in eastern Turkey. The earthquake ground motion was recorded as about 0.1g in Bitlis province. Performance evaluations have been performed by taking samples from each district consisting urban building stocks of Bitlis. A total of 16 reinforced concrete buildings have been evaluated. Among them, 53% of those buildings were determined in the Fully Operational performance level; 13% of them in the Life Safety performance and 34% of them could not be evaluated because of the ratio of the effective mass of first mode to the total mass of the buildings was smaller than 0.70. Therefore, incremental equivalent seismic load methods, which are a part of Turkish Earthquake Code -2007, cannot be used.

Keywords: seismicity; performance based assessment; Bitlis; Lake Van

1. Introduction

The seismic risk of building stock is of growing interest for academia as well as for governments due to the increasing urbanization and concentration of population in earthquake prone and earthquake vulnerable areas. Turkey, since 1999, is known as one of the most earthquake prone regions in the world. This is somewhat true considering that the most of the country is under the threat of an earthquake. There are frequent moderate to large magnitude earthquakes striking not only in the western part Turkey but also in the rest of the country. This paper states that in a case of a large magnitude earthquake, a similar one to those which occurred

*Corresponding author, Assistant Professor, E-mail: ercanbitliseren@gmail.com
[a]Assistant Professor, E-mail: kutanis@sakarya.edu.tr

http://www.techno-press.org/journals/eas&subpage=7 ISSN: 2092-7614 (Print), 2092-7622 (Online)

in the past hits the region, the death toll could rise up to dramatic numbers. It should be noted that the recent Van Earthquakes of Mw=7.2 and Mw=5.6 in 2011 caused 641 deaths in the city of Van and its proximity.

Lake Van basin is located in Eastern Turkey, a region which has suffered very severe tectonic deformation (Horasan *et al*. 2007, Toker *et al*. 2007). Destructive earthquakes that might occur in Lake Van Basin in the future will affect the city of Bitlis as it happened during the 2011 Van earthquakes.

The province of Bitlis lies in Lake Van Basin in the eastern Anatolian Region of Turkey, which is considered to be one of the most important provinces of that strategic corridor in Turkey. Bitlis is the capital of Bitlis Province which has a total population of 70,000. The town is located at an elevation of 1,400 meters, 15 km from Lake Van, in the steep-sided valley of the Bitlis River, a tributary of the Tigris River. A popular folk etymology explanation, without any historical basis, is that it is derived from “Batlis”, the name of a Commander, said to have built Bitlis castle on the command of Alexander the Great (Armenian Soviet Encyclopaedia 1976).

In order to reduce the damages of the earthquakes in the Lake Van region, which are also likely to affect residential areas, firstly the performance of existing buildings needs to be determined. The most affective damage reduction method of an earthquake is to strengthen the buildings, which are under the risk of collapsing collapsed or being damaged. If strengthening is not efficient, then the building needs to be demolished and rebuilt (Sucuoglu 2006). In recent years, with the effect of an increasing consciousness on earthquakes, the society has started to think more rationally about the dangers related to earthquakes and they want to learn about the performance of their buildings against a possible earthquake. This consciousness is coming both from individuals and companies. Turkish Earthquake Code 2007 (TEC-07), Section 7 has the characteristics of responding to those needs.

In performance based design and assessment method it is possible to determine in quantities the damage levels that may arise under the design ground motion within the structural system elements. It is checked whether this damage stays under the acceptable damage levels for each related element. Acceptable damage limits are defined in a way to be consistent with the foreseen performance targets at various earthquake levels (Aydınoğlu 2007, Doran *et al*. 2011, Kutanis and Boru 2014).

2. Tectonics setting and seismicity of bitlis and surrounding areas

General tectonic setting of Eastern Anatolia is mainly controlled by the collision of northerly moving Arabian plate against the Anatolian plate along a deformation zone known as Bitlis Thrust Zone (Fig. 1). The collision leads to the westward extrusion of the Anatolian plate along the two notorious transform faults with different sense of slip, the dextral North Anatolian Fault and the sinistral East Anatolian Fault zones, which join each other in Karlıova Triple Junction (KTJ) in the Eastern Anatolia (Fig. 1). In the eastern side of KTJ; however, the collision deformation is largely accommodated within the Eastern Anatolian Block through distributed NW-SE trending dextral faults and NE-SW trending sinistral faults representing escape tectonics, and shortening of the continental lithosphere along the Caucasus thrust zone. East-west trending Mush-Lake Van and Pasinler ramp basins constitute other conspicuous tectonic properties within the Eastern Anatolian border (Sengor *et al*. 1985, Barka and Kadinsky-Cade 1998, Mc Clusky *et al*. 2000, Reilinger *et al*. 2006, Utkucu 2013).

The East Anatolian Fault Zone is a 550 km-long, approximately northeast-trending, sinistral strike-slip fault zone (Fig. 1) that comprises a series of faults arranged parallelly, sub-parallelly or obliquely to the general trend. The Bitlis Suture is a complex continent-continent and continent-ocean collisional boundary that lies north of fold-and-thrust belt of the Arabian platform and extends from south-eastern Turkey to the Zagros Mountains in Iran (Homke 2007, Bonnin *et al*. 1996, Piper *et al*. 2008, Stern *et al*. 2008, Lyberis *et al*. 1992). The area to the east of Karlıova triple junction is characterized by an N–S compressional tectonic regime (Fig. 2). Conjugate strike-slip faults of dextral and sinistral character paralleling to North and East Anatolian fault zones are the dominant structural elements of the region. Some of these structures include Agrı Fault, Bulanık Fault, Çaldıran Fault, Ercis¸ Fault, Horasan Fault, Iğdır Fault, Malazgirt Fault, Süphan Fault, Balıklıgölü Fault Zone, Baskale Fault, Çobandede Fault Zone, Dumlu Fault Zone, Hasan Timur Fault Zone, Kavakbası Fault, Kagızman Fault Zone, Doğubayazıt Fault Zone, Karayazı Fault, Tutak Fault Zone, Yüksekova–Semdinli Fault Zone and the Northeast Anatolian Fault Zone (Fig. 2) (Bozkurt 2001).

The faults are seismically active and form the source for many earthquakes. Some of the major earthquakes in the 20th Century are 13 September 1924 Pasinler (M=6.8), 1975 Lice (M=6.6), 24 November 1976 Çaldıran (M=7.3), 30 October 1983 Horasan-Narman (M=6.8), 5 May 1986 (M=5.8) and 6 June 1986 Doğanşehir (M=5.6) earthquakes (Bozkurt 2001).

Bitlis Centre is in first degree of seismic zones in current seismic hazard map of Turkey (Fig. 3). Fig. 3 indicates first and second degree of seismic zones.

Lake Van basin has been a seismically active region as indicated by historical sources. Table 1 tabulates significant earthquakes which occurred in Bitlis and its surrounding area before and after 20th century.

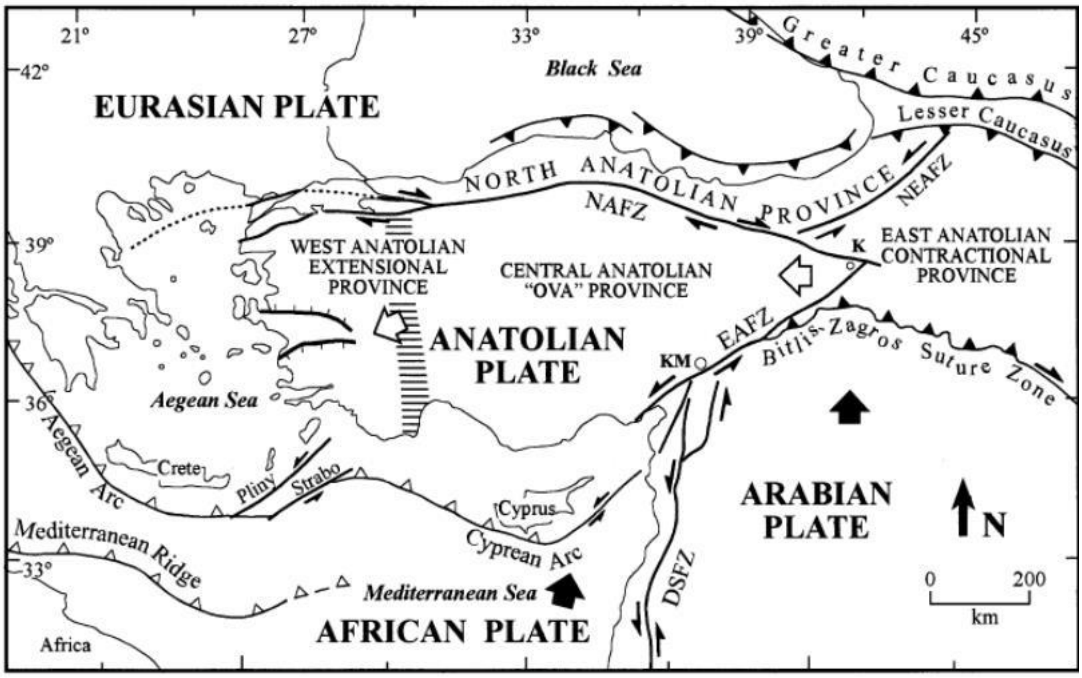

Fig. 1 Tectonic map of Turkey including major structural features (from Bozkurt 2001)

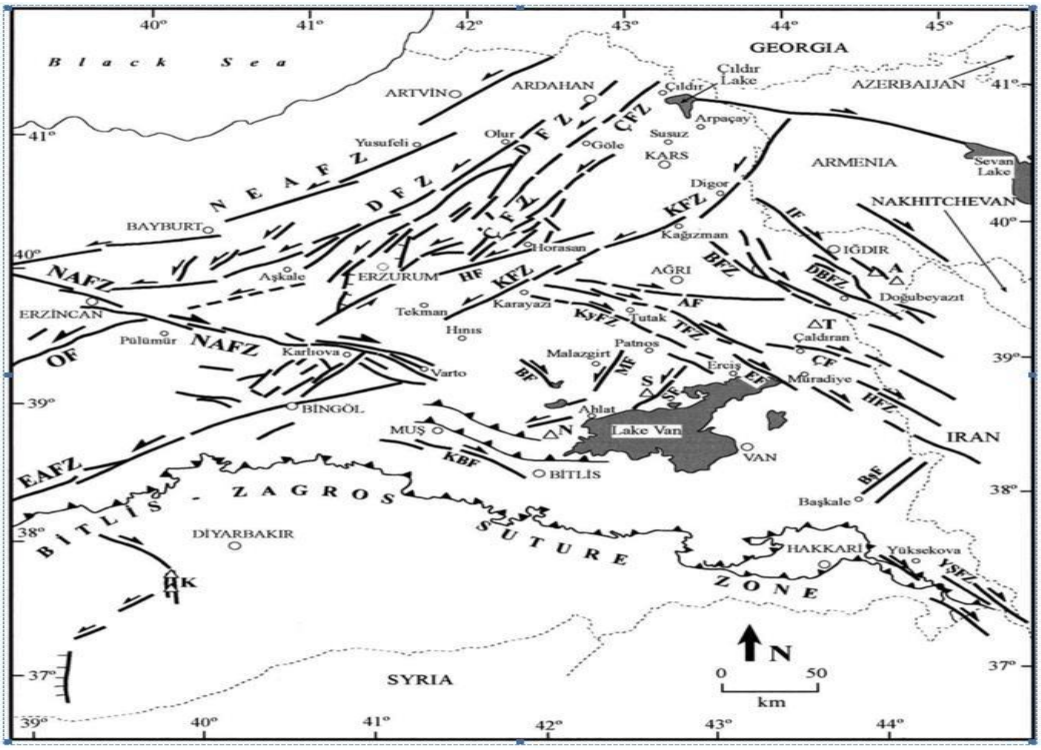

Fig. 2 Active faults of Eastern Anatolian Province (Bozkurt 2001)

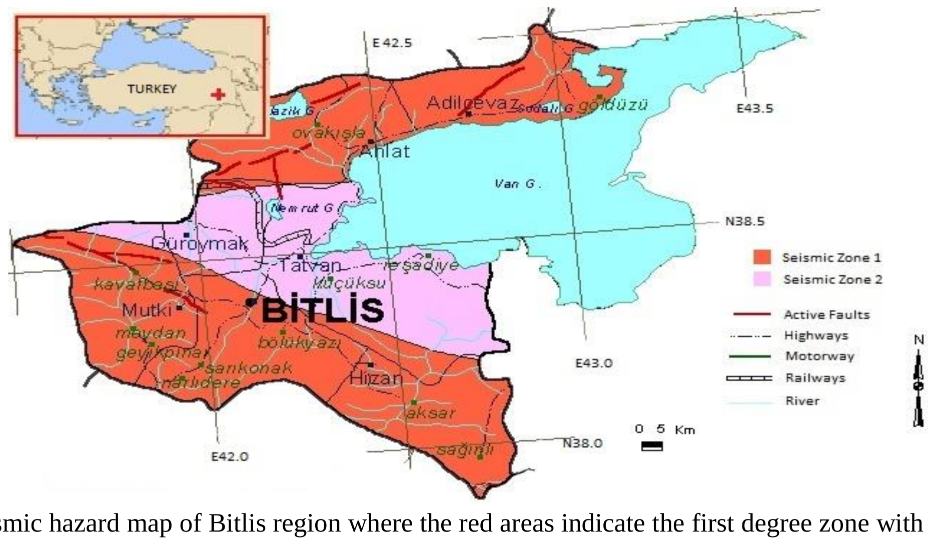

Fig. 3 Seismic hazard map of Bitlis region where the red areas indicate the first degree zone with a minimum effective acceleration of 0.40 g and the pink areas mark the second degree zone with a minimum acceleration of 0.30 g

The examination of historical and instrumental earthquakes in Bitlis and its surroundings proves that this region is constantly under the influence of micro and macro earthquakes. Thus, Bitlis remains under a great influence of large earthquakes (Işık et al, 2012). Therefore, its buildings must be constructed, especially in Lake Van Basin where earthquake resistant design has always been neglected, according to earthquake codes.

Table 1 Major earthquakes which occurred in Bitlis and its surrounding area between 461 A.D. and 2011

No	Date	Lat. (°)	Lon. (°)	Location	Magnitude	Intensity
1	461	39.10	42.50	Malazgirt		X
2	1012	39.10	42.50	Malazgirt		VII
3	1101	38.50	43.50	Ahlat - Van		VI
4	1110	38.50	43.50	Ahlat - Van		VIII
5	1111	38.50	42.70	Ahlat - Van		IX
6	1208	38.70	42.50	Ahlat-Van-Bitlis-Muş	6.5	
7	1245	38.74	42.50	Ahlat - Bitlis- Van - Muş		VIII
8	1246	38.90	42.90	Lake Van (Ahlat - Erçiş –Van)		VIII
9	1275	38.40	42.10	Bitlis- Ahlat -Erciş – Van		VII
10	1276	38.90	42.50	Bitlis- Ahlat -Erciş – Van		VIII
11	1282	38.90	42.90	Ahlat – Erçiş		VII
12	1345	39.10	42.50	Malazgirt		VIII
13	1363	38.70	41.50	Muş and surrounding		IX
14	1415	38.50	43.00	Van Gölü		V
15	1439	38.50	42.10	Nemrut		VI
16	1441	38.35	42.10	Nemrut		VIII
17	1444	38.50	43.40	Nemrut - Van		VI
18	1546	38.50	43.40	Van - Bitlis		V
19	1582	38.35	42.10	Bitlis and surrounding		VIII
20	1646	38.50	43.40	Van and surrounding		VII
21	1647	39.15	44.00	Van - Muş -Bitlis		IX
22	1648	38.30	43.70	Van and surrounding	6,7	VIII
23	1670	38.00	42.00	Hizan - Siirt	6.6	
24	1682	38.40	42.10	Bitlis		
25	1696	39.10	43.70	Çaldıran - Bitlis	6,8	X
26	1701	38.50	43.40	Van and surrounding		VIII
27	1704	38.50	43.40	Van		VII
28	1705	38.40	42.10	Bitlis	6,7	IX-X
29	1715	38.70	43.50	Van - Erçiş	6,6	VIII
30	1869	38.40	42.10	Bitlis and surrounding		VII
31	1871	38.50	43.40	Van -Nemrut	5,5	VII
32	30.05.1881	38.50	43.40	Van and surrounding	7,3	IX
33	1884	37.50	42.50	Bitlis - Pervari	6,9	
34	1891	38.80	42.50	Malazgirt- Adilcevaz-Bitlis	5,5	VIII

Table 1 Continued

No	Date	Lat. (°)	Lon. (°)	Location	Magnitude	Intensity
35	1892	39.10	42.50	Malazgirt - Muş		VII
36	1903	39.14	42.65	Malazgirt and surrounding	6,7	
37	1906	38.90	42.60	Nemrut and surrounding	5,0	
38	1914	38.46	42.15	Bitlis	5,8	
39	1915	38.80	42,50	Ahlat	5,6	
40	1930	38.22	44.660	Salmas	7,2	
41	1941	39.45	43.32	Erciş	5,9	
42	1945	38.63	43.33	Van	5,2	
43	1964	39.13	43.19	Van	5,3	
44	19.5.1905	39.20	41.60	Varto - Muş	6,9	
45	1976	39.0506	44.0368	Muradiye- Çaldıran	7,5	
46	1977	39.2703	43.7006	Van	5,1	
47	1988	38,5034	43.0727	Van	5,0	
48	2000	38.5100	43.0100	Lake Van	5,7	
49	23.10.2011	38.7300	43.4300	Van	7,2	
50	09.11.2011	38.4472	43.2638	Edremit- Van	5,6	

3. Methodology

In order to evaluate the performance of the existing buildings in Bitlis territory, a detailed computer structural analysis of each building based on the information obtained from the regional seismology, geotechnical investigations, as-built condition surveys is required. Data collection from the existing building structures for this evaluation was conducted during the period from 2009 to 2011 by the authors of this article. Site survey consisted of the measurement of structural member dimensions, the examination of reinforcing steel amounts, evidence for corrosion and verification of location, it also involved taking concrete cores from buildings and taking the steel samples for testing purposes.

The assessment procedure aims to estimate the earthquake force demand at which the building would sustain the performance objectives. Demand spectrum, which is used in determining the performance of the building's system, shows the maximum response that a building gives against seismic activities during an earthquake (Ilki and Celep 2011). The assessment calculations were done based on a simple technique called the 'equivalent displacement rule'. The equivalent displacement approximation is based on the assumption that inelastic spectral displacement is the same as that which would occur if the structure remained perfectly elastic (ATC-40 1996). For the flexible structures, where the natural vibrational periods are greater than the corner periods, this rule yields acceptable results. In other cases, particularly in short period (rigid) structures, where the natural vibrational periods are shorter than the corner periods, the displacements obtained from this approximation method might be significantly different from the actual results. (Fig. 4, Fig. 5). In such cases, elastic spectral displacement is modified by multiplying it with a spectral displacement amplification factor (C_{R1}) to obtain inelastic spectral displacement.

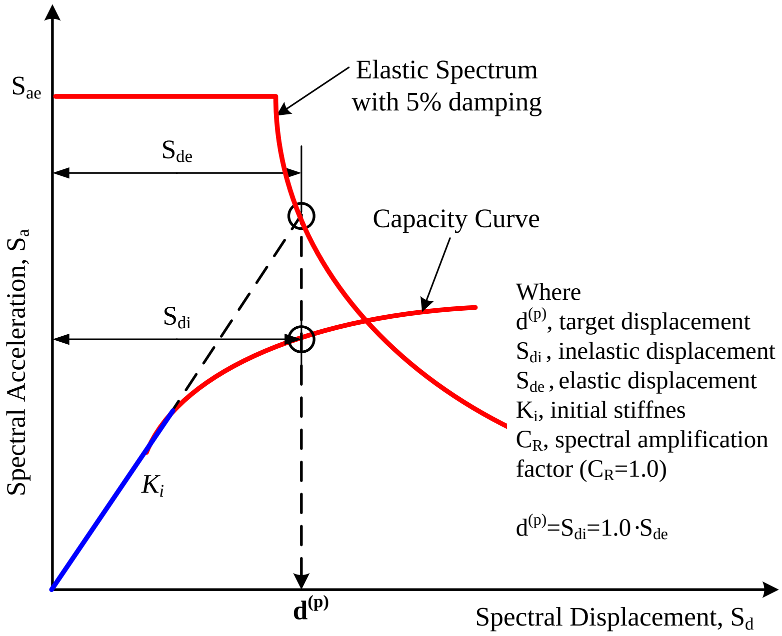

Fig. 4 Equivalent displacement rule: Flexible structures

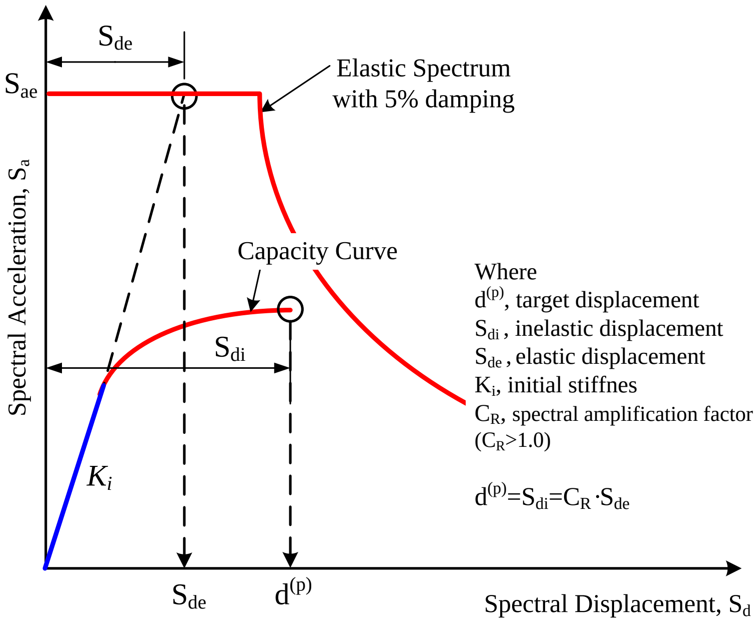

Fig. 5 Equivalent Displacement Rule: Rigid structures

The seismic hazard level during seismic safety assessment of the existing buildings in Bitlis and the required minimum seismic performance levels for a number of representative models are shown in Table 2 (modified from TEC-2007 Table 7.7). The building owners (a client), who has desired to have higher performance objectives than the objectives proposed by seismic codes, are also provided by the project engineer (Fig. 6). The procedure is summarized as follows: First of all, the seismic hazard level (demand) is determined, then, the performance objective (a target) under this hazard level is determined. For example, a target may be set by the client such as 'my building should show the performance of 'Life Safety (LS)' for major earthquakes, which has 2% of probability of exceedance in 50 years. If the result of LS performance is obtained through structural analysis, there won't be any strengthening work done on building's structure. But if the performance is assessed with the result of 'about to collapse (CP)', the structure of a building needs to be strengthened to a LS level (TEC- 2007, Kutanis 2006, Gökalp *et al*. 2009).

Earthquake performance of the buildings, which are evaluated in this work, will be determined by nonlinear methods. The purpose of nonlinear assessment methods is to calculate plastic deformation or force demands at each structural member. These demands are then compared with the internal force capacities and strain limit states of the member. As opposed to many other assessment codes, the TEC-2007 assumes a certain level of damage to be reached only if some

Table 2 Minimum seismic performance levels for design earthquakes (Table 7.7, TEC -2007)

Purpose of Occupancy and Type of building	**Probability of exceedance in 50 years**		
	50%	**10%**	**2%**
Buildings required to be utilized immediately after the earthquake	-	IO	LS
Intensively and long-term occupied buildings and buildings preserving valuable goods	-	IO	LS
Intensively but short-term occupied buildings	IO	LS	-
Buildings containing or storing toxic, explosive and flammable materials.	-	IO	CP
Other buildings	-	LS	-

(IO: immediate occupancy; LS: life safety CP: collapse prevention)

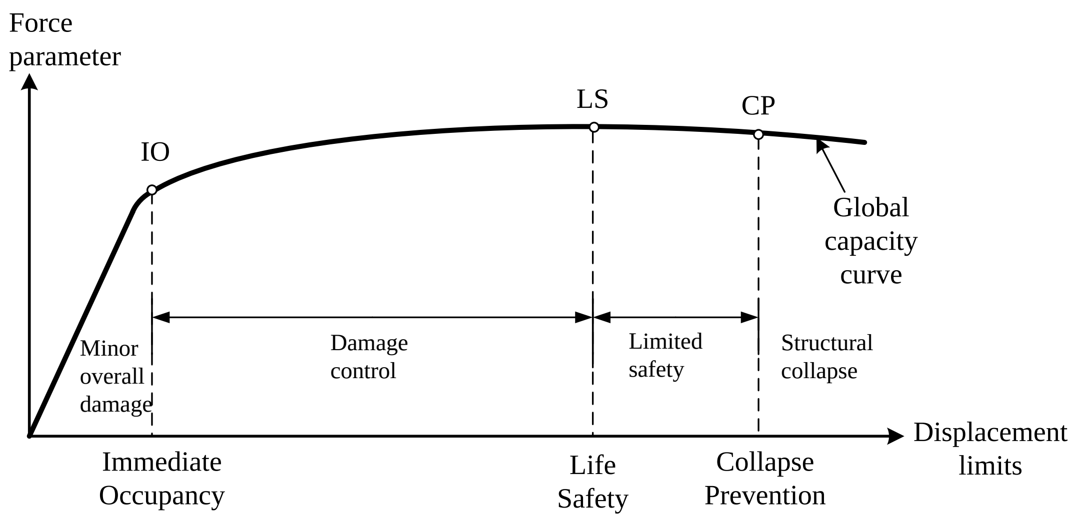

Fig. 6 Damage Limits at TEC-2007

percentages of the beams or columns have reached the sectional limit state defined a priori.

Two fundamental parameters of performance based design and assessment are earthquake demand and capacity (Ozer 2007, Fajfar 1999). Earthquake demand represents the earthquake ground movement, whereas capacity represents building's reaction under the effect of an earthquake. Structural capacity is represented by static pushover and capacity curve. This curve is derived by drawing the function between base shear force and building's roof displacement. Capacity curve is derived by calculating building system with gravitational loads and proportionately increasing lateral forces up to the target point where structural capacity ends. The actual purpose of the nonlinear static method is to determine the target displacement of a building, then by performing a final pushover analysis by increasing the lateral loads up to the target displacement. As a result, the demand values such as internal forces, rotations, strains and displacements are computed and the performance of the analyzed section is then evaluated by comparing the strains obtained from the total curvature of the section with the upper boundary strains designated for different cross-sectional performance levels. After deciding the performance levels of the sections and structural elements, building performance is measured by considering the conditions existing in different building performance levels as given in Table 2.

The pushover curve does not have a direct significance on its own except globally showing analyzed structural system's nonlinear strength and system's location deformation capacity. To give a meaning to the pushover curve, curve's coordinates need to be converted to a modal capacity diagram. (Chopra 2002, Freeman *et al*. 1975, Arısoy 2010, Aydınoğlu 2003) As explained in TEC-2007 Section 7.6.5.4, when pushover curve to modal capacity diagram transformation arises, modal capacity diagram is obtained in the ADRS (Acceleration - Displacement - Response Spectrum) format. For low-rise first mode dominant structures, incremental equivalent seismic load method provides reasonable accuracy in calculations. According to TEC-2007, modal displacement is equal to inelastic spectral displacement (S_{di1}) as

$$d_1^{(p)} = S_{di1} \tag{1}$$

where $d_1^{(p)}$ is the modal displacement request belonging to the first mode and S_{di1} is the first mode non-linear spectral displacement value.

The modal displacement is converted to the top displacement of a building with following equation

$$u_{xN1}^{(p)} = \Phi_{xN1} \cdot \Gamma_{x1} \cdot d_1^{(p)} \tag{2}$$

where, $u_{xN1}^{(p)}$ is the first mode, Nth story target displacement in the *x*- direction; Φ_{xN1} is the amplitude of the first mode at the Nth story in the *x*- direction and Γ_{x1} is the modal participation factor in *x*- direction for the first mode.

The inelastic spectral displacement, (S_{dil}) is computed by multiplying elastic spectral displacement (S_{de1}) by spectral displacement amplification factor, (C_{R1})

$$S_{di1} = C_{R1} \cdot S_{de1} \tag{3}$$

where S_{de1} is obtained by the equation

$$S_{de1} = \frac{S_{ae1}}{\left(\omega_1^{(1)}\right)^2} \tag{4}$$

where S_{ae1} is the spectral acceleration and $\omega_1^{(1)}$ is the first mode frequency on the structure.

C_{R1} is calculated as being dependent on the corner period (T_B). If the first mode free vibration period is greater than the corner period, then C_{R1}=1. Otherwise, C_{R1}=1 needs to be calculated according to Section 7C.2.2 of the Codes.

4. Performance based assessment for residential buildings in bitlis province

The investigated buildings, analyzed in this study, have been provided with architectural and structural drawings and the documents were verified through observations and measurements made in building site. The distribution of buildings, according to the districts of the Bitlis province is listed in Table 3.

General information on sixteen buildings analyzed according to nonlinear performance calculations in the Bitlis city center is given in Table 4.

The limitations of the Incremental Equivalent Seismic Load method: (1) The number of the stories of the buildings excluding the basement must not be greater than 8 or the total height of a building must be less than 25 m high, and (2) torsional irregularity factor, η_{bi}, which is defined for any of the two orthogonal earthquake directions as the ratio of the maximum story drift at any story to the average story drift at the same story in the same direction, must be less than 1,4. In addition, the sum of effective participating masses calculated for the first mode in each of the given *x* and *y* perpendicular lateral earthquake directions cannot be less than 70% of the total building mass. The calculated effective mass ratios are given in Table 5. For example for building number 1, this ratio is 57% on *X* direction and 52% on Y direction. The ratio is under 70% both for *X* and *Y* directions. Therefore, Incremental Equivalent Seismic Load method cannot give reasonable results for building number 1 and therefore, it is not passed to the next stage in evaluation of this building. In this type of buildings, the nonlinear time history analysis methods can be used. This method; however, is not employed in this study.

Table 3 Distribution of buildings evaluated by performance

District Name	Number of Buildings
H.PAŞA	4
ATATÜ RK	1
İNÖNÜ	1
MÜŞTAKBABA	1
8 AGUSTOS	1
ŞEMSİ BİTLİS	1
SARAY	1
HERSAN	1
YÜKSELİŞ	1
TAŞ	2
GAZİBEY	1
ZEYDAN	1
TOTAL	16

Table 4 General information of buildings evaluated

Building Number	Total number of Floors	Ground Floor Height (m)	Normal Floor Height (m)	Total Height of Building (m)	Dimension of Building		The Average Concrete Strength (MPa)	Steel Grade
					Lx(m)	Ly(m)		
1	6	3,00	3,00	18,00	30,00	17,00	14,00	S220-S420
2	6	2,90	2,90	17,40	15,80	13,00	11,00	S220-S420
3	8	2,90	2,90	23,20	16,20	22,00	14,00	S420
4	8	2,90	2,90	16,20	23,20	22,00	14,00	S420
5	8	2,90	2,90	23,20	12,90	24,00	14,00	S420
6	7	2,90	2,90	17,40	15,30	21,00	14,00	S420
7	6	3,20	3,00	23,20	30,90	24,00	16,00	S420
8	8	2,90	2,90	23,20	14,10	23,40	14,00	S420
9	8	2,90	2,90	23,20	22,20	10,70	16,00	S420
10	6	2,90	2,90	17,40	22,00	12,60	8,00	S220
11	4	2,80	2,80	11,20	14,10	11,00	10,00	S220
12	4	4,30	2,90	13,00	18,10	18,30	11,00	S220
13	8	3,60	3,00	24,60	30,80	25,60	10,00	S220
14	8	3,50	2,90	23,80	21,20	17,60	12,00	S420
15	5	3,50	3,00	15,50	12,40	20,00	9,00	S220
16	8	2,90	2,90	23,20	24,20	14,20	16,00	S220-S420

Table 5 The ratio of the effective mass of first mode to the total mass of buildings that evaluated

Building Number	The Ratio of Effective Mass to Total Mass	
	X (%)	*Y* (%)
1	57	52
2	81	80
3	79	77
4	80	77
5	78	77
6	50	76
7	87	83
8	59	74
9	70	68
10	81	78
11	50	38
12	57	51
13	83	41
14	57	67
15	64	85
16	78	77

In this analysis, it is assumed that equivalent earthquake load distribution remain constant for each building. On the basis of this calculation, pushover curves were obtained from the pushover analyses that were made under the loads coming towards the floor in proportion to the first natural vibrations mode. Building pushover curve for *X* and *Y* directions for 2nd building are shown as example (Fig. 7, Fig. 8).

Static pushover curves obtained as a result of Incremental Equivalent Seismic Load method TEC 2007 Eq. (7.1) and (7.2) coordinates of 'Modal Displacement - Modal acceleration' were changed to capacity diagrams of *X* and *Y* as shown in Fig. 9 and Fig. 10.

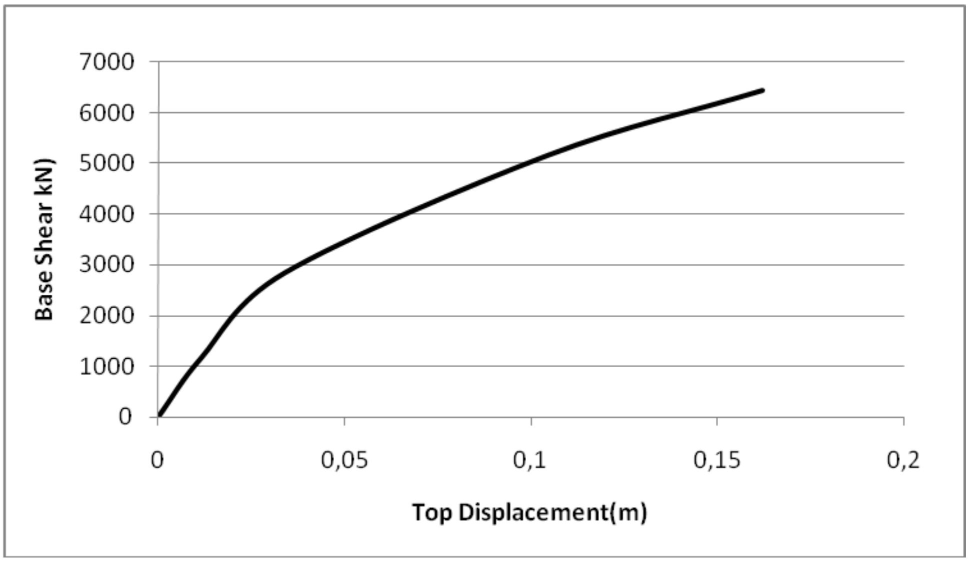

Fig. 7 Pushover curve of 2nd building for *X* direction

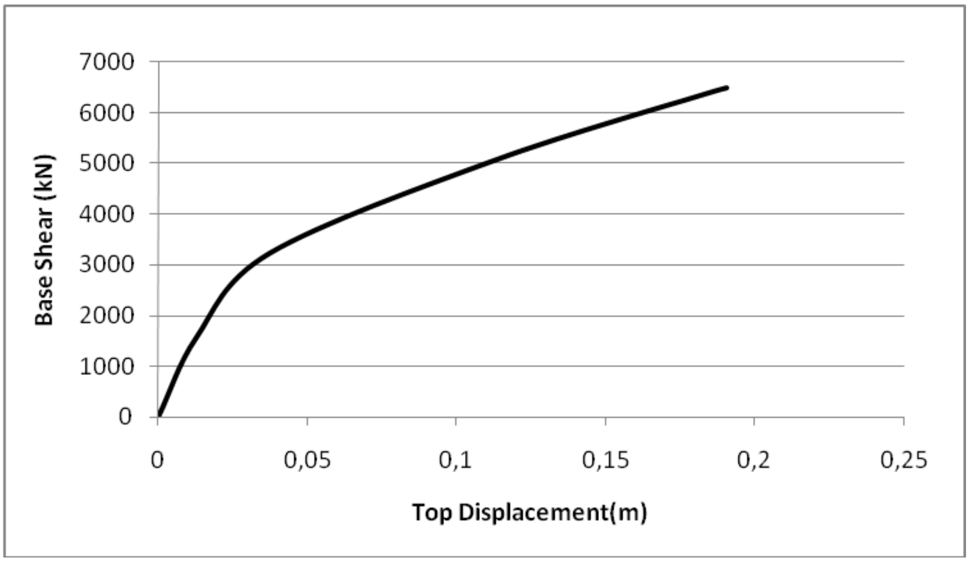

Fig. 8 Pushover curve of 2nd building for *Y* direction

In order to calculate building top displacement demand, it is necessary to obtain the first mode displacement demand. Mode displacement demand is calculated depending on building's capacity and earthquake's demand. For this purpose, modal capacity diagram with coordinates 'acceleration -displacement' and response spectrum diagram with coordinates 'S_a - S_d' are drawn together for each building analyzed. Modal capacity diagrams for *X* and *Y* directions for the 2nd building are shown as in Fig. 9 and 10.

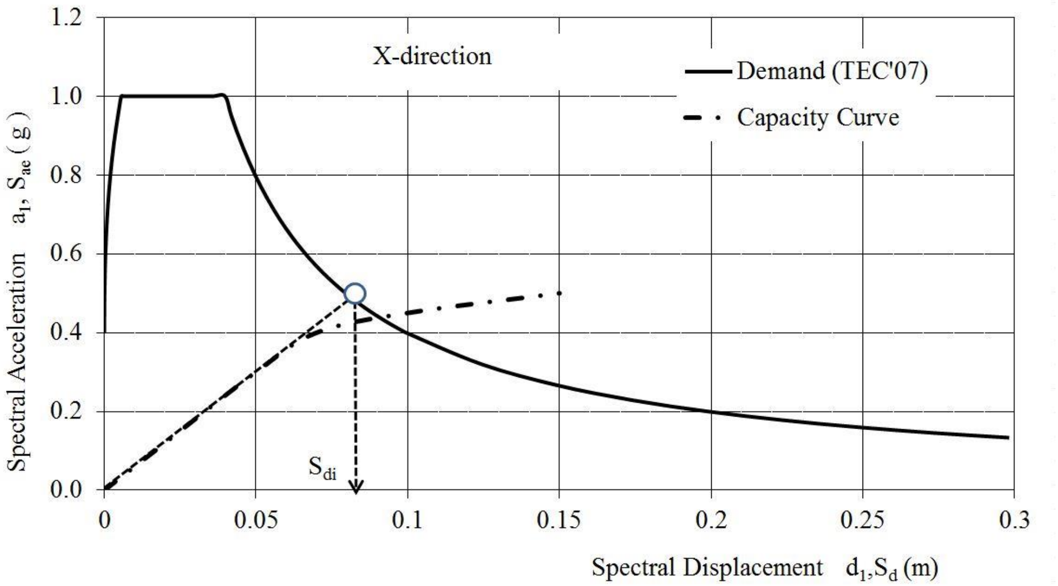

Fig. 9 Modal capacity and demand spectrum curves of the 2nd building for *X* direction

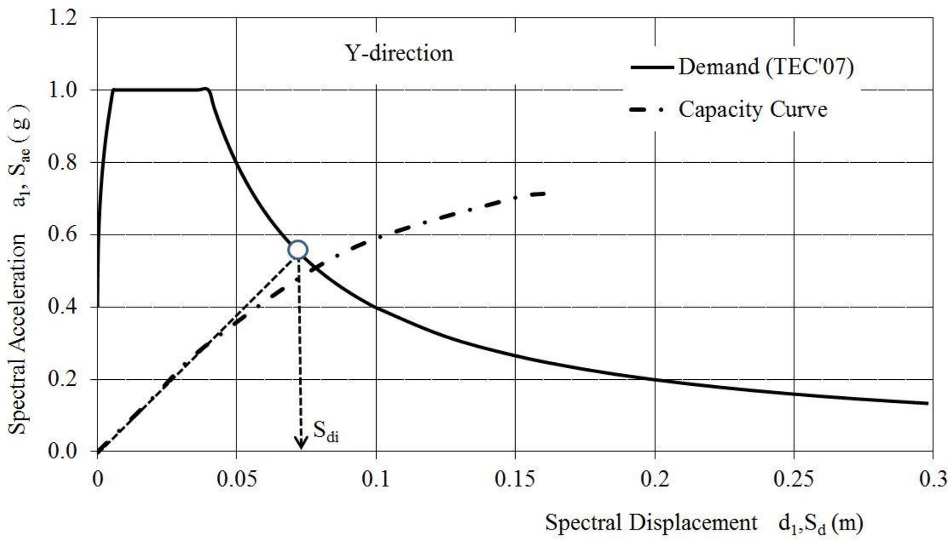

Fig. 9 Modal capacity and demand spectrum curves of the 2nd building for *Y* direction

The values calculated for buildings target displacement demands are shown in Table 5. For all the buildings that were analyzed, top displacement will have been calculated for both *X* and *Y* as in Table 6; pushover analysis has been repeated until the values in Table 6 are equalized and all corresponding levels will have been calculated.

The Evaluation of analyzed buildings based on the performance is as in Table 7.

Table 6 The values for the target displacement demand of the buildings that were evaluated

Building number	Direction	S_{ae1}	$(\omega_1^{(1)})^2$	S_{de1}	T_1	C_{R1}	S_{di1}	$d_1^{(p)}$	Γ_1	Φ_{N1}	u_{N1}
1	X	Effective mass ratio is not enough									
	Y										
2	X	6,965	124,37	0,056	0,60482	1	0,056	0,056	29,57	0,044	0,073
	Y	6,082	103,08	0,059	0,53849	1	0,059	0,059	29,45	0,044	0,067
3	X	5,69	79,02	0,072	0,8417	1	0,072	0,07	38,84	0,033	0,0923
	Y	5,592	70,78	0,079	0.7975	1	0,079	0,08	37,84	0,035	0,1046
4	X	5,69	79,02	0,072	0,8417	1	0,072	0,07	38,84	0,033	0,0923
	Y	5,592	70,78	0,079	0.7975	1	0,079	0,08	37,84	0,035	0,1046
5	X	5,052	63,15	0,08	1,29225	1	0,08	0,08	34,4	0,039	0,1073
	Y	5,788	83,88	0,069	1,12475	1	0,069	0,069	33,83	0,039	0,091
6	X	Effective mass ratio is not enough									
	Y	6,671	113,07	0,059	0.7975	1	0,059	0,059	32,05	0,042	0,0794
7	X	5,003	63,33	0,079	0,8283	1	0,079	0,079	50,54	0,025	0,0998
	Y	7,456	70,78	0,051	0,5722	1	0,051	0,051	46,39	0,028	0,066
8	X	Effective mass ratio is not enough									
	Y	6,671	113,07	0,059	0.7975	1	0,059	0,059	32,05	0,042	0,0794
9	X	4,414	49,6	0,089	0,7313	1	0,089	0,089	35,24	0,037	0,116
	Y	Effective mass ratio is ot enough									
10	X	7,063	133,27	0,053	0,7005	1	0,053	0,053	28,94	0,044	0,0675
	Y	4,316	49,05	0,088	0,6002	1	0,088	0,088	31,43	0,041	0,113
11	X	Effective mass ratio is not enough									
	Y										
12	X	Effective mass ratio is not enough									
	Y										
13	X	5,396	71	0,072	0,7895	1	0,072	0,072	49,4	0,025	0,0889
	Y	Effective mass ratio is not enough									
14	X	Effective mass ratio is not enough									
	Y										
15	X	Effective mass ratio is not enough									
	Y	6,377	102,85	0,062	0,584	1	0,062	0,062	22,83	0,056	0,079
16	X	5,543	71,71	0,073	0,7005	1	0,073	0,073	37,28	0,036	0,098
	Y	5,15	66,03	0,078	0,6002	1	0,078	0,078	34,09	0,039	0,104

Table 7 Results of performance based assessment

Building Number	Direction	Result of performance evaluation
1	X	Effective mass ratio is not enough
	Y	
2	X	Immediate use
	Y	Immediate use
3	X	Immediate use
	Y	Immediate use
4	X	Immediate use
	Y	Immediate use
5	X	Immediate use
	Y	Immediate use
6	X	Effective mass ratio is not enough
	Y	Immediate use
7	X	Life safety
	Y	Immediate use
8	X	Effective mass ratio is not enough
	Y	Immediate use
9	X	Immediate use
	Y	Effective mass ratio is not enough
10	X	Immediate use
	Y	Life safety
11	X	Effective mass ratio is not enough
	Y	
12	X	Effective mass ratio is not enough
	Y	
13	X	Immediate use
	Y	Effective mass ratio is not enough
14	X	Effective mass ratio is not enough
	Y	
15	X	Effective mass ratio is not enough
	Y	Life safety
16	X	Immediate use
	Y	Immediate use

5. Conclusions

Performance based earthquake engineering filled a very important gap in civil engineering discipline. With the performance based planning and evaluation, it is possible to determine the

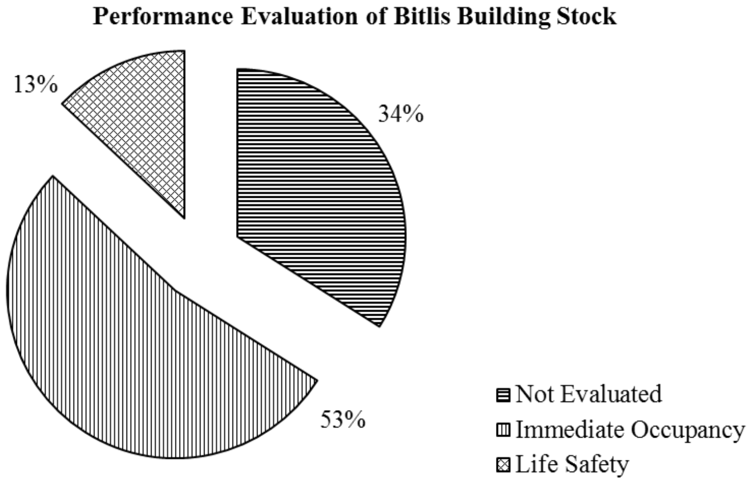

Fig. 11 Results of performance based assessments in Bitlis

material losses and possible life losses and to calculate quantitatively what level of performance a building or building stock can have. In order to prevent an earthquake, to turn into a disaster where lives are lost, performance based method is used to enable decision makers to receive information on numerical data and calculations considering building performance.

In this study, performance based assessment was carried out in Bitlis building stock by taking samples from different districts of the province. Sixteen reinforced concrete buildings have been investigated. 53% of the buildings were evaluated at Immediate Occupancy performance level, 13% of them at Life Safety performance level and 34% of them were not evaluated with incremental equivalent seismic load method due to the method's limitations. (Fig. 11).

This work has been done with limited resources and covers only a certain building stock. Therefore, this work needs to be widened to all the residential area of Bitlis city. Such a work will lead to system of earthquake prevention, which will be used to analyze an inventory of building stock against earthquake danger. While taking precautionary measures against reducing earthquake risk after producing a building inventory, the buildings, which are not safe and not economical to strengthen, need to be demolished. The buildings, which can be saved by strengthening, need to be strengthened after necessary engineering work is done. Performance approach of earthquake engineering will enable new research areas to be introduced compared with classical earthquake engineering. If 1995 Vision 2000 Report is accepted as it is, the developments achieved over the last ten years are promising. If substantial amount of databases are formed and necessary analyses are performed, lost lives and economic loss will be minimized and therefore, earthquakes will create less havoc in earthquake afflicted region.

As Bitlis is a historical and cultural city, historical buildings in Bitlis need to be a part of the basis of the performance-based evaluation methods. Considering historical buildings play an important role in protecting both historical and cultural heritage of Bitlis and Turkey.

Design spectrum given in TEC-2007 has been included in this work. Using the response spectrum obtained from probabilistic seismic hazard analysis will make obtained data for Bitlis and other regions which are under a threat of earthquakes.

Only reinforced concrete buildings are considered in the case study loss model presented herein and the structural characteristics of which are discussed. Furthermore, loss estimation analyses for the masonry structures which form a great deal of the building stocks of Bitlis will make results more valuable.

Bitlis and its vicinity are sensitive to earthquake ground motions, due to negative geologic and topographic factors. It is practically impossible to perform detailed experimental and analytical studies for each existing building to determine its collapse vulnerability because of time and money constraints. Therefore, this region's buildings must be constructed according to national earthquake codes especially in Lake Van Basin where a possibility of an earthquake occurrence has mostly been neglected.

References

Arısoy, B., (2010), "Yapısal özellikleri farklı BA binaların performansa dayalı analizi", *J. Fac. Eng. Architec. Gazi Univ.*, **25**(3), 431-439.

Applied Technology Council (ATC), (1996), Seismic evaluation and retrofit of concrete buildings, Report No. ATC-40, Seismic Safety Commission, State of California.

Armenian Soviet Encyclopedia (1976), *Armenian Academy of Sciences*, Yerevan, Armenia

Aydınoğlu, M.N. (2003), "Yapıların deprem performansının değerlendirilmesi için artımsal spektrum analizi (arsa) yöntemi", *5. Conference on Earthquake Engineering*, Istanbul, Turkey.

Aydınoğlu, M.N. (2007), "A response spectrum-based nonlinear assessment tool for practice: incremental response spectrum analysis (IRSA)", *ISET J. Earthq. Technol.*, **44**(1), 169-192.

Barka, A. and Kadinsky-Cade, K.(1988), "Strike-slip fault geometry in Turkey and its influence on earthquake activity", *Tectonic.*, **7**(3), 663-684.

Bonnin, J., Cara, M. and Cisternas, A. (1988), *Seismic Hazard in Mediterranean Regions*, Procedings of the Summer School Organized in Strasbourg, France.

Bozkurt, E. (2001), " Neotectonics of Turkey -a synthesis", *Geodinamica Acta*, **14**(1), 3-30.

Chopra, A.K. and Goel, R.K., (2002), "A modal pushover analysis procedure for estimating seismic demands for buildings", *Earthq. Eng. Struct. Dyn.*, **31**(3), 561-582.

Doran, B., Akbaş, B., Sayım, İ., Fahjan, Y. and Alacalı, S.N. (2011), "Uzun periyotlu bir yapıda yapısal sağlık izlemesi ve deprem performansının belirlenmesi", *Turkey Conference on Earthquake Engineering and Seismology*, Ankara, Turkey.

Fajfar, P. (1999), "Capacity spectrum method based on inelastic demand spectra", *Earthq. Eng. Struct. Dyn.*, **28**(9), 979-993.

Fema 356 (2000), *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, FEMA, Washington, DC.

Freeman, S.A., Nicoletti, J.P. and Tyrell, J.V. (1975), "Evaluations of existing buildings for seismic risk - a case study of Puget Sound Naval Shipyard Bremerton, Washington", In *Proceedings of the 1st US National Conference on Earthquake Engineering*, Oakland, CA: Earthquake Engineering Research Institute.

Gökalp, E. and Bağcı, M. (2009), "A2 Düzensizliği bulunan betonarme bir binanın, mod birleştirme yöntemi İle deprem performansının belirlenmesi", *Electron. J. Constr. Technol.*, **5**(1), 37-48.

Homke, S. (2007), "Timing of shortening and uplift of the Pusht-e Kuh Arc in the zagros fold and thrust belt (Iran); A combined magnetostratigraphy and apatite thermochronolgy analysis", Universitat de Barcelona, Facultad de Geologia,Departamento de Geodinámica y Geofísica, Barcelona, Spain.

Horasan, G. and Boztepe-Güney, A. (2007), "Observation and analysis of low-frequency crustal earthquakes in Lake Van and its vicinity", *East. Turkey J. Seismol.*, **11**(1), 1-13.

Işık, E., Aydın, M.C., Bakış, A. and Özlük, M.H. (2012), "The faults near Bitlis and seismicity of the region", Bitlis Eren University, *BEU J. Sci*., **1**(2), 153-169.

Ilki, A. and Celep, Z. (2011), "Betonarme yapıların deprem güvenliği", *Türkiye Deprem Mühendisliği ve Sismoloji Konferansı*, Ankara, Turkey.

İnel, M. (2008), " 2007 Deprem yönetmeliğinde mevcut binaların performanslarının değerlendirilmesi", İMO Denizli Şubesi, Lectures notes.

Kutanis, M. and Boru, O.E. (2014), "The need for upgrading the seismic performance objectives", *Earthq. Struct.*, **7**(4), 401-414.

Kutanis, M. (2006), "Investigation of novel nonlinear static analysis procedures", *7th International Congress on Advances in Civil Engineering*, Istanbul, Turkey.

Lyberis, N., Yürür, T., Chrowicz, J., Kasapoğlu, E. and Gündoğdu, N. (1992) "The East Anatolian fault : an oblique collisional belt", *Tectonophys.*, **204**(1), 1-15.

McClusky, S., Balassanian, S., Barka, A., Demir, C., Ergintav, S., Georgiev, I., Gurkan, O., Hamburger, M., Hurst, K., Kahle, H., Kastens, K., Nadariya, M., Ouzouni, A., Paradissis, D., Peter, Y., Prilepin, M., Reilinger, R., Sanli, I., Seeger, H., Tealeb, A., Toksöz, M.N. and Veis, G. (2000), "GPS constraints on plate kinematics and dynamics in the Eastern Mediterranean and Caucasus", *J. Geophysic. Res.*: *Solid Earth*, **105**(B3), 5695-5719.

Ö zer, E. (2007), "Performansa Dayalı Tasarım ve Değerlendirme", ITU, Lectures Notes.

Piper, J., Tatar, O., Gürsoy, H., Mesci, L., Koçbulut, F. and Huang, B. (2008), "Post-collisional deformation of the Anatolides and motion of the Arabian indenter : a paleomagnetic analysis", *IOP Publishing, Donald D Harrington Symposium on the Geology of the Aegean, IOP Conference Series: Earth and Environmental Science* 2.

Reilinger, R., McClusky, S., Vernant P., Lawrence, S., Ergintav, S., Cakmak, R., Ozener, H., Kadirov, F., Guliev, I., Stepanyan, R., Nadariya, M., Hahubia, G., Mahmoud, S., Sakr, K., ArRajehi, A., Paradissis, D., Al-Aydrus, A., Prilepin, M., Guseva, T., Evren, E., Dmitrotsa, A., Filikov, S. V., Gomez, F., Al-Ghazzi, R. and Karam, G. (2006), "GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions", *J. Geophys. Res.*: *Solid Earth*, **111**(B5).

SEAOC (1995), *Vision 2000: Performance Based Seismic Engineering of Buildings*, San Francisco.

Sengör, A.M.C., Görür, N. and Saroglu, F. (1985), "Strike-slip deformation, basin formation and sedimentation: strike-slip faulting and related basin formation in zones of tectonic escape: Turkey as a case study", *Soc. Eco. Paleontol. Mineral*., **37**, 227-264.

Stern, R.J. and Johnson, P.R. (2008), "Do variations in Arabian Plate lithospheric structure control deformation in the Arabian-Eurasian Convergence Zone", *IOP Publishing, Donald D Harrington Symposium on the Geology of the Aegean, IOP Conference Series: Earth and Environmental Science* 2.

Sucuoğlu, H. (2006), *2007 Deprem Yönetmeliği Performans Esaslı Hesap Yöntemlerinin Karşılıklı Değerlendirmesi*, Türkiye Mühendislik Haberleri, 444-445.

Toker, M., Krastel, S., Demirel-Schueter, F., Demirbağ, E. and Imren, C. (2007), "Volcano-seismicity of Lake Van (Eastern Turkey), a comparative analysis of seismic reflection and three component velocity seismogram data and new insights into volcanic lake seismicity", *International Earthquake Symposium*, Kocaeli, Turkey.

Turkish Earthquake Code (2007), Turkish earthquake code-specification for structures to be built in disaster areas, Turkey.

Utkucu, M., Durmuş, H., Yalçın, H., Budakoğlu, E. and Işık, E. (2013), "Coulomb static stress changes before and after the 23 October 2011 Van, eastern Turkey, earthquake (MW=7.1): implications for the earthquake hazard mitigation", *Natl. Haz. Earth Syst. Sci.*, **13(7)**, 1889-1902.

CC