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REVIEW-CIVIL ENGINEERING

A Comparative Evaluation of Earthquake Code Change on Seismic Parameter and Structural Analysis; A case of Turkey

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Abstract

Turkey, which is one of the countries with high seismic risk, has made significant changes in both seismic risk maps and seismic design codes over time by adapting to these developments. Information about the important changes in the last two earthquake maps and provisions in Turkey was given and the effects of these changes on structural and seismic parameters were examined in this study. In order to make comparisons of seismic parameters, seven different settlements from seven different geographical regions in Turkey were taken into account which have the same seismic risk in the previous earthquake risk map. Seismic moments were also calculated separately for these locations to describe the intensity of future tectonic activity. With the current earthquake hazard map, geographical location-specific earthquake risk has been started to be used instead of regional risk. For the selected settlements with the same seismic risk in the previous map, the seismic risks were found high in some and low in some with the current hazard map. In addition, structural analyses were carried out for the sample reinforced-concrete building with the same structural characteristics in these seven different settlements in order to reveal the effect of the code and map change on the structural analysis. While the target displacements expected from the structures for the settlements with the same seismic risk take the same values, the target displacements are obtained differently for each, since the specific design spectrum is used for each location with the current map.

Keywords Seismic hazard · Site-specific spectra · Turkey · Seismic moment

Abbreviations

A_o	Effective ground acceleration coefficient
BKS	Building usage class
BYS	Building height class
DTS	Earthquake design class
D	Over strength coefficient
F_S	Local ground effect coefficient for 0.2 s
F_1	Local ground effect coefficient for 1.0 s
I	Building importance coefficient
PGA	Peak ground acceleration
PGV	Peak ground velocity
$S_{ae}(T)$	Horizontal elastic spectral acceleration
$S_{ar}(T)$	The reduced design spectral acceleration
$S(T)$	Spectrum coefficient
S_{DS}	Spectral acceleration coefficient for 0.2 s
S_{D1}	Spectral acceleration coefficient for 1.0 s
S_S	Map spectral acceleration coefficient for 0.2 s
S_1	Map spectral acceleration coefficient for 01.0 s
R	Structural system behaviour coefficient
$R_a(T)$	Earthquake load reduction coefficient
T	Natural vibration period
T_A and T_B	Corner periods of the horizontal elastic design spectrum
T_{AD} and T_{BD}	Corner periods of the vertical elastic design spectrum

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Table 1 Earthquake hazard maps used in Turkey

Year	Map	Based on	Type	Number of zones
1945	Earthquake Zones	Damage	Regional	3
1947	Earthquake Zones	Damage	Regional	3
1963	Earthquake Zones of Turkey	Deterministic	Regional	4
1972	Earthquake Zones of Turkey	Deterministic	Regional	5
1996	Earthquake Zones of Turkey	Probabilistic	Regional	5
2018	Turkish Earthquake Hazard	Probabilistic	Site-specific	Site-specific

1 Introduction

Determining the location and magnitude of earthquakes does not seem possible using today's technologies. The constant repetition of earthquakes and the fact that they caused significant losses reveals the fact that human beings live with earthquakes. Representing the earthquake hazard in a realistic way is one of the pre-disaster measures to reduce earthquake damage [1–4]. In this context, earthquake hazard maps are used in different ways in different geographies and it is inevitable to update these maps over time [5, 6]. These maps show earthquake risk regions with different seismic characteristics in general. These maps were first started in the 1940s with the 1939 Erzincan earthquake, is known as the most destructive earthquake recorded in Turkey, where earthquakes that caused large-scale losses. The first map was made in 1945, taking into account the damage data, and was renewed on 5 different dates after this date [7–11]. All maps used in Turkey and their general features are given in Table 1. In general, each map is created with a significant change from the previous map.

There are different studies on the historical background of the development of earthquake hazard and zone maps of Turkey. Except for the current earthquake hazard map, the studies in which all official earthquake zone maps are handled chronologically and in detail were carried out by [5, 8, 10]. Eyidoğan and Güçlü [12] conducted the earthquake zone maps used until that time were compiled and the expected maximum intensity map in the country was created. The whole Turkey was divided into five seismic regions, and the effective ground acceleration coefficient was obtained for each region, taking into account the PGA values of 475 years and the recommended acceleration intervals by Gulkan et al. [13]. Kayabalı and Akın [14] produced a map containing four different earthquake zones using the deterministic method by evaluating all active faults of Turkey. According to Akkar et al. [15], compared the seismic hazard maps used in Turkey with the updated map in detail. They also examined the effects of the current map on seismic design codes. The 2018 earthquake hazard map has been prepared in a very detailed and detailed manner, taking into account both earthquake source parameters and the most up-to-date version of earthquake catalogues. However, Turkish Earthquake Hazard Map Interactive Web Earthquake Application (TEHMIWA) has been put into use at the point of obtaining seismic parameters with the map in a more practical way [16–18].

After the earthquake hazard is determined, the structures to be built in these regions and the rules are determined at the point of reducing earthquake damage. Structural damage data after earthquake, experiences gained from earthquake-exposed structures and developing engineering technologies significantly improve earthquake-resistant building design principles. Based on the updated earthquake hazard map, the Turkish Building Earthquake Code (TBEC-2018) [19] has been put into use. There are many different studies on the comparison of earthquake maps and seismic design codes in Turkey. Alyamac and Erdogan [20] gave information about 8 different earthquake codes between 1940–1998. Keskin and Bozdoğan [21], comparatively analysed between the TBEC-2018 [19] and Turkish Seismic Design Code (TSDC-2007) [22] for Kırklareli province. Işık et al., [23] made comparisons within the scope of the last two seismic design codes for 17 different settlements located on the North Anatolian Fault Zone. Ulutaş [24] compared the section damage limits in reinforced-concrete structures according to the last two regulations such as TBEC-2018 [19] and TSDC-2007 [22], in existing structures. Nemutlu et al. [25] examined the change of acceleration spectra according to 2007 and 2018 seismic design codes in Turkey for Bingöl and Elazig Provinces. Dalyan and Şahin [26] performed performance analyses of a 5-storey reinforced-concrete (RC) structure within the scope of the last two codes and compared the results. Çaycı and Eldemir [27] compared the building performance levels for 5 different RC structures according to the last two earthquake codes. Işık (2022) obtained seismic and structural parameters for 62 earthquake epicentres that occurred after 1900 in Turkey [28]. Cetin et al. [29], comparatively examined torsional irregularity for five different building models, taking into account different local soil classes, according to the last two codes. Peker and Işık [30] examined the effects of local soil classes in TBEC-2018 on steel building's performance. Aksoylu et al. [31] examined the comparisons between the last two earthquake codes used in Turkey specifically for RC structures, and also compared the results obtained with ASCE 7–16. Adar et al. [32] compared the results obtained by performing the structural analyses for the 15-storey RC building selected as an example, according to the last two codes. Akyıldız et al. [33] investigated the effect of local soil conditions in TBEC-2018 on RC structure performance. Albayrak and Morshid [34] obtained the seismic performance of steel lattice transmission towers by using the seismic parameters predicted in the current earthquake hazard map for the location in Eskişehir and the current earthquake code. Ergüneş and Özkül [35] examined the high-rise buildings section, which was added for the first time with the current seismic design code, on a sample reinforced concrete building. Seven different structural models were created for the planned building in Istanbul, and the concrete class and shear wall thickness were chosen as variables.

In this study, earthquake hazard maps that used in 1996 and 2018 and the last two earthquake provisions in 2007 and 2018, which are the last two earthquake codes, were taken into consideration. Within the scope of this study, one settlement was selected from seven different geographical regions of Turkey. All selected settlements are located in the 2nd degree seismic zone in the previous earthquake zone map. In this study, firstly, information about the important changes in last two earthquake maps and codes is given. Current seismic parameters were obtained for a randomly selected location in these settlements and compared with the previous map. All seismic parameters to be used in structural analysis and seismic moment values for the selected locations were obtained separately. Structural analyses for the sample RC building were carried out separately for each settlement. Target displacements have been obtained for building performance levels according to both the current seismic design code in Turkey and Eurocode-8, which is widely used in the world. In addition, target displacements according to different probabilities of exceedance are obtained for all settlements for different ground motion levels.

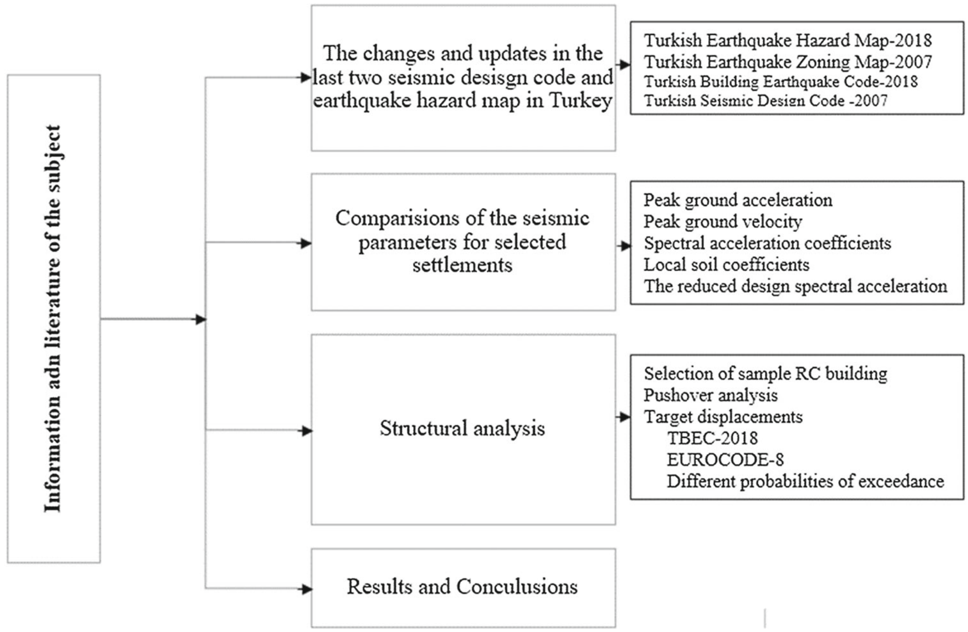
In this study, unlike other studies, important changes in the last two earthquake hazard maps and seismic design codes in Turkey were tried to be examined in detail. The effects of the innovations on both seismic and structural parameters have been demonstrated. It has been tried to determine to what extent the settlements with the same seismic risk in the previous map have different seismic risks with the current map and to what extent the analysis results are affected. Instead of earthquake hazard on a regional basis, the effect of seismic risk change specific to geographical location on both seismic parameters and structural analysis has been tried to be revealed. It has been tried to determine whether these changes are a mandatory requirement or not. In the studies about updates on the codes and maps, analyses were carried out either on a regional basis or specific to any province. For this purpose, the target displacement values expected from the building were obtained separately according to the last two earthquake codes as well as Eurocode-8. One of the innovations in this study is that the target displacements were obtained separately according to both earthquake codes in Turkey and Eurocode-8. In most of these studies, either only seismic parameter changes or structural analysis results were compared. In this study, one settlement from each geographical regions of Turkey are selected that has same seismic risk and its impact on both seismic and structural analysis. Another aspect that distinguishes the study from other studies is that the partial comparisons are handled as a whole.

This study, which aims to analyse the last two earthquake hazard map and seismic design code changes in Turkey in a comprehensive way, consists of five different main parts. In the introduction part, similar studies on the subject are given and information about the procedures done in the article is given. In the second part, the changes in the last two codes and the map, which are the subject of this study, are indicated with their main titles. In the third part, the seismic parameters for the selected settlements were obtained and compared by considering the last two maps and codes. In the other part, structural analyses were carried out for the sample RC building, by using static pushover analysis in order to reveal the effects of the changes on the structural analysis results. In the last part, the obtained seismic and structural parameters and the values obtained as a result of these are interpreted. The flowchart of the article is given in Fig. 1.

2 The Last Two Earthquake Hazard Maps and the Seismic Design Codes in Turkey

The previous map was prepared in 1996 using probabilistic seismic hazard analysis, depending on the scientific and technologic innovations in earthquake engineering which called as Earthquake Zones Maps of Turkey. This map is based on ground acceleration values with a 90% probability of exceedance in 50 years [8]. Only an earthquake ground motion level was considered in this map. It differs from all previous maps in that it is the first map in which the probabilistic method is used (Table 1). However, like all previous maps, this map has been prepared on a regional basis also. Five different earthquake zones were taken into account in this map, which was prepared with a scale of 1/1.800.000. On the map, the regions where the ground acceleration will be 0.40 g and greater will be the 1° earthquake region, the regions where the ground acceleration will be between 0.30 and 0.40 g, the 2° earthquake region, the regions where the ground acceleration will be between 0.20 and 0.30 g, the 3° earthquake region, the ground acceleration will be 0.10–Regions expected to be between 0.20 g indicate the 4° earthquake region and regions expected to be less than 0.10 g

Fig. 1 Flowchart of this study



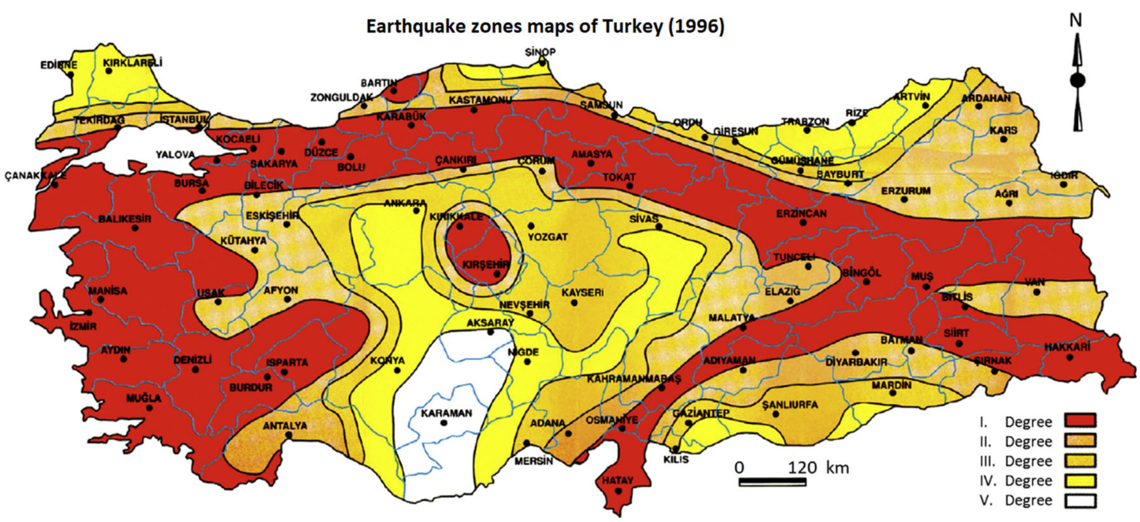


Fig. 2 Earthquake zones maps of Turkey [37]

indicate the 5° earthquake region [8, 10]. In addition, in order to use the map more practically, it has been prepared together with the map as an index in which earthquake zone the settlements are located [36]. This map used until 2019 is shown in Fig. 2.

The current earthquake hazard map in Turkey is a mandatory map since 2019. This map, which changed after a long period of 23 years, was prepared with the probabilistic method like the previous map. However, the most important difference from all other maps is that the concept of earthquake hazard on a regional basis has left its place to site-specific [23]. New approaches developed in seismic hazard analysis and new generation mathematical equations, updating the national active fault database and instrumental earthquake catalogue made it inevitable to update the earthquake map. This map, which is the output of the project "Updating the Seismic Hazard Map of Turkey", also forms the basis for the seismic design codes for buildings [15, 17, 38]. This map was prepared for four different earthquake ground motion levels and is shown in Fig. 3 for standard earthquake ground motion level.

The Code on Buildings to be Built in Earthquake Zones-2007 (TSDC-2007), which was in effect until 31.12.2018, consists of 7 main sections, and the current seismic design code, Turkey Building Earthquake Code-2018 (TBEC-2018), consists of 17 different sections. The current code is much more detailed and comprehensively. In this part of

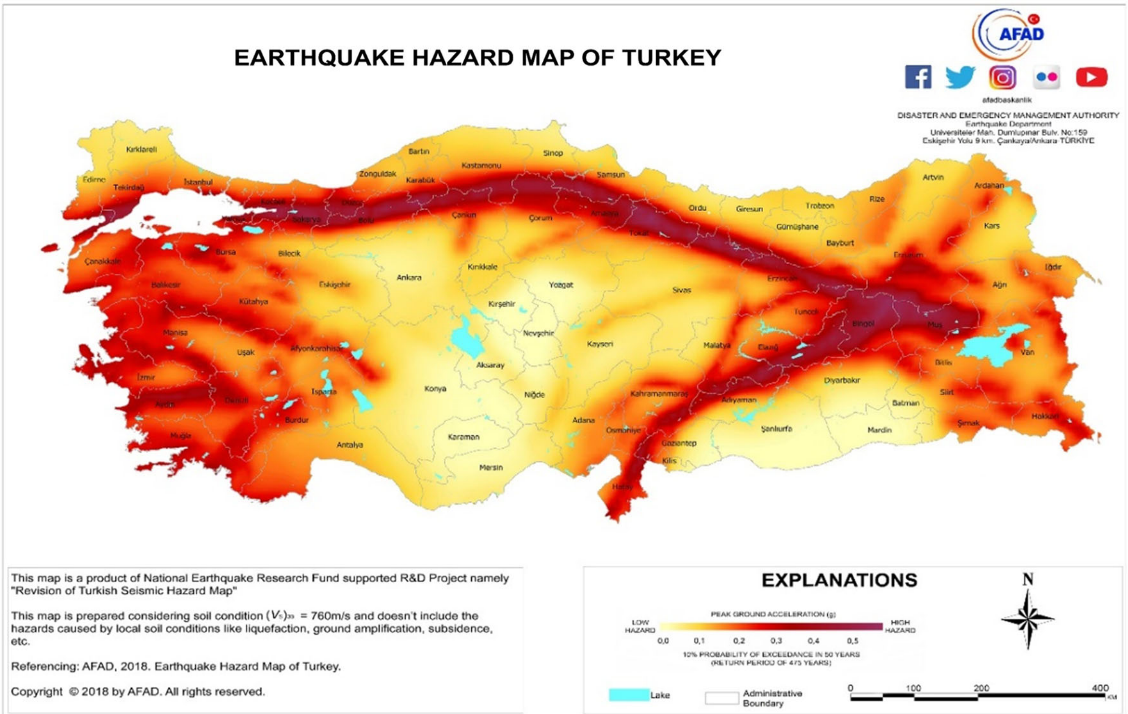


Fig. 3 Earthquake Hazard Map of Turkey (2018) [39]

the study, the differences between the last two earthquake codes used in Turkey will be given under the main headings.

- With the TBEC-2018, the term building was used for the first time instead of the term structure.
- While TSDC-2007 includes earthquake resistant structure design rules for RC, steel and masonry buildings; TBEC-2018 includes rules for buildings to be made of pre-engineered RC, light steel and wood materials as well as these structures.
- The seismic parameters predicted on the map can be obtained directly from TEHMIWA without any analysis and calculation, depending on any geographical location with TBEC-2018.
- While four different building usage classes (BKS) were expressed in TSDC-2007, there are only three different building usage classes in TBEC-2018.
- Earthquake design class (DTS) has been used for the first time with the current seismic design code.
- There are four different earthquake ground motion levels (recurrence period 2475, 475, 72 and 43 years) in the current seismic design code, while there was only the standard design earthquake ground motion level (recurrence period 475 years) in the previous seismic design code as earthquake ground motion level.
- While there were four different local soil groups and four different local soil classes in the previous code, six different local soil classes have been handled in a broader framework by combining local soil groups and classes with the current code.
- The vertical design acceleration spectrum was first used with TBEC-2018. Accordingly, the vertical load effect is stated for the first time among earthquake load combinations.
- Eight different building height classes (BYS) were taken into account for the first time in TBEC-2018. There is no information about BYS in the previous code.
- While there were three different damage levels in the previous code, four different damage levels were specified in the current code.
- While C20-C60 concrete grades can be used for RC structures in TSDC-2007, the concrete grade range is specified in the range of C25-C80 with TBEC-2018.
- While the reinforcement class to be used in RC structural elements was determined as S220 and S420 in TSDC-2007, the current code requires the usage of B420C and B500C ribbed reinforcement steel. S420 concrete steel, which provides the specified tensile/yield strength and strain limits, continues to be used together with the current code.
- One of the parameters used for the first time with the current code is the Over Strength Coefficient (D), which differs according to the building structural system and the building height.
- It is a new parameter created depending on the building performance target and application design, earthquake ground

motion level, design class and building height, together with the current code.

- Local ground coefficients, together with the map spectral acceleration coefficients, have been utilized for the first time together in the current map and the code.
- With the current code, it has become mandatory to use new calculation approaches on special issues such as high-rise buildings, insulated buildings and situations where the ground is very weak.
- While corner periods take fixed values in TSDC-2007, they vary according to geographical location in TBEC-2018 depending on the S_{DS} and S_{D1} parameters.
- With the current code, different effective section stiffness factors have been started to be used for different structural elements, taking into account the cracks that may occur under the effect of bending.
- The Building Importance Factor (I) takes four different values as 1.0, 1.2, 1.4 and 1.5 in the previous code. Although the Building Importance Factor (I) continues to be used in TBEC-2018, it takes three different values such as 1.0, 1.2 and 1.5. While using 1.4 in TSDC-2007 for buildings where people are present for a long time and where valuables are stored, this value is started to be considered as 1.5 by combining the previous value of 1.5 in the new seismic design code.
- While there were three different performance levels in TSDC-2007, four different performance levels were expressed in TBEC-2018.

All these changes have once again revealed Turkey's sensitivity towards earthquakes. The large-scale loss of life and property after the earthquake in the country reveals the importance of this issue.

3 Comparison of Seismic Parameters

Seismic parameters are obtained not on a regional basis, but according to any geographical location with the current map. In this context, in order to reveal the difference between regional values and location-specific values, seven different locations in the 2nd degree earthquake zone were taken into account in the previous earthquake zone map. While selecting these locations, one settlement from each geographical region in Turkey was taken into account. The geographic locations considered are shown in Fig. 4 on the previous map.

The frequency of occurrence of an earthquake ground motion in a particular region is expressed as the repetition period and is calculated statistically. This is defined as the probability of exceedance of the ground motion. In the previous seismic design code, only one earthquake ground motion level with a repetition period of 475 years and a probability of exceedance in 50% in 50 years was taken into account as the standard design earthquake ground motion. However, four different earthquake ground motion levels have been suggested with the current seismic design code. This situation is also valid for the earthquake hazard map. The current earthquake hazard map has also been created for these four different probabilities of exceedance. The standard earthquake ground motion level (DD-2) in both codes is taken into consideration for making comparisons. The earthquake ground motion levels in TBEC-2018 are given in Table 2. Here, in the previous seismic design code, the standard design earthquake ground motion level corresponds to DD-2.

Peak ground acceleration (PGA) and peak ground velocity (PGV) are one of important parameters for earthquake hazard assessments and is widely used for intensity measures [40, 41]. The comparison of PGA and PGV for the selected settlements, by taking into account the different earthquake ground motion levels, is shown in Table 3.

As the repetition period increased, PGA and PGV values increased indirectly. The comparison of PGV and PGA values obtained for different repetition periods is shown in Fig. 5. The values obtained for Adana (Ceyhan) were taken into account as an example province. Since the selected settlements are placed in the same seismic risky region in the previous map, PGA takes the same values for this settlements. However, since the current map is site-specific, different PGA's are obtained for each settlement. Comparison of the obtained PGA's is made in Fig. 6.

The highest PGA was obtained for Erzurum (Center), while the lowest PGA was obtained for Diyarbakir (Center) for the probability of exceedance 10% (DD-2). The predicted PGA value for Erzurum (Centre), Bursa (Orhaneli) and Kütahya (Centre) in TSDC-2007 is lower than the value in the current code. For other settlements, a lower PGA was obtained than the value predicted in the previous code. In the current code, since each settlement has its own seismicity characteristics, PGA values are obtained differently than the previous code. However, the previous map was regional based and all settlements within that earthquake zone had the same seismic risk. Since this difference will directly affect the structural analysis, it can be said that this arrangement is an important gain. The highest PGV was obtained for Bursa (Orhaneli), while the lowest PGV was obtained for Diyarbakir (Center) for the probability of exceedance 2% (DD-1). The PGA/PGV ratio was also obtained, since the settlements with the highest and lowest values obtained for different exceedance probabilities differ slightly. The ratio of PGA and PGV values obtained for different exceedance of probabilities over the TEHMIWA for selected settlements to each other is given in Table 4. The highest PGA/PGV ratio was obtained for Adana (Ceyhan), while the lowest ratio was obtained for Diyarbakır (Centre).

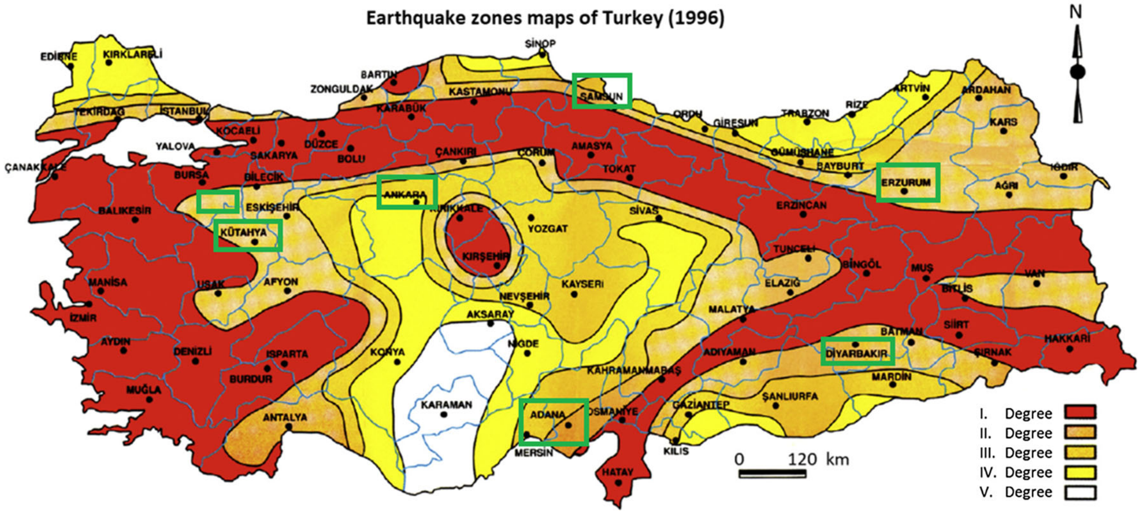


Fig. 4 The locations of settlements considered

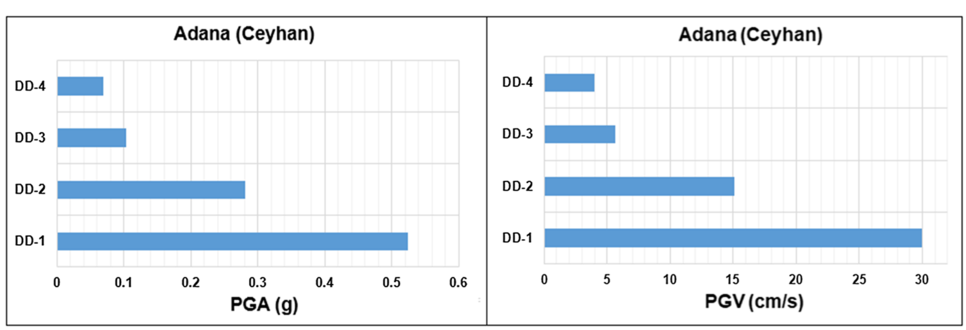
Table 2 Earthquake ground motion levels (TBEC-2018) [19]

Earthquake ground motion level	Repetition period (year)	Probability of exceedance (in 50 years)	Description
DD-1	2475	0.02	Largest earthquake ground motion
DD-2	475	0.10	Standard design earthquake ground motion
DD-3	72	0.50	Frequent earthquake ground motion
DD-4	43	0.68	Service earthquake movement

Table 3 Comparison of PGA and PGV values for different settlements

Location	PGA (g)				PGV (cm/s)			
	DD-1	DD-2	DD-3	DD-4	DD-1	DD-2	DD-3	DD-4
Adana (Ceyhan)	0.525	0.281	0.104	0.070	29.964	15.107	5.611	3.972
Erzurum (Centre)	0.781	0.433	0.145	0.095	48.128	26.173	9.101	5.905
Ankara (Elmadağ)	0.369	0.188	0.068	0.048	20.232	11.208	4.696	3.447
Bursa (Orhaneli)	0.853	0.430	0.135	0.093	51.681	25.611	8.340	5.897
Kütahya (Centre)	0.770	0.367	0.106	0.074	47.823	22.473	6.832	4.843
Diyarbakır (Centre)	0.254	0.142	0.061	0.044	17.972	10.502	4.575	3.299
Samsun (Centre)	0.409	0.221	0.089	0.062	26.980	15.375	6.387	4.485

Fig. 5 PGA and PGV variation for different earthquake ground motion level



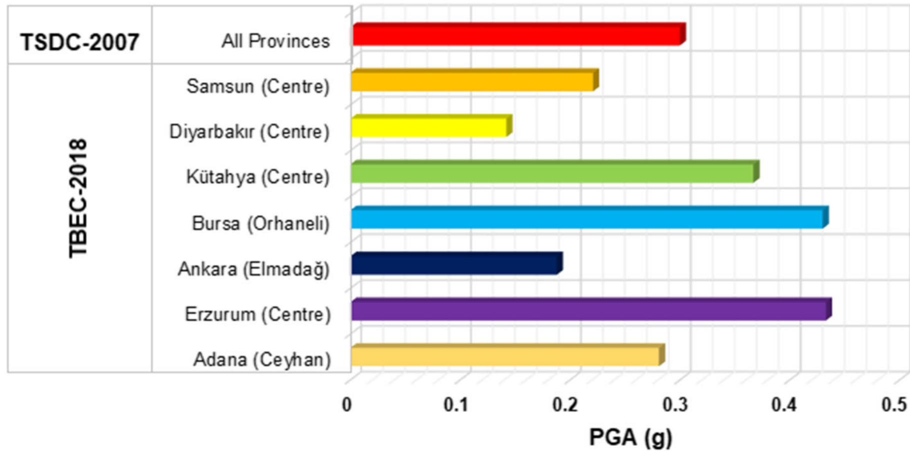


Fig. 6 Comparison of PGA for selected settlements for DD-2

Table 4 PGA/PGV ratios for settlements

Location	PGA/PGV			
	DD-1	*DD-2*	*DD-3*	*DD-4*
Adana (Ceyhan)	0.0175	0.0186	0.0185	0.0176
Erzurum (Centre)	0.0162	0.0165	0.0159	0.0161
Ankara (Elmadağ)	0.0182	0.0168	0.0145	0.0139
Bursa (Orhaneli)	0.0165	0.0168	0.0162	0.0158
Kütahya (Centre)	0.0161	0.0163	0.0155	0.0153
Diyarbakır (Centre)	0.0141	0.0135	0.0133	0.0133
Samsun (Centre)	0.0152	0.0144	0.0139	0.0138

Table 5 Comparison of map spectral acceleration coefficients obtained for short and long period

Location	S_S				S_1			
	DD-1	DD-2	DD-3	DD-4	DD-1	DD-2	DD-3	DD-4
Adana (Ceyhan)	1.264	0.645	0.232	0.159	0.319	0.163	0.061	0.043
Erzurum (Centre)	1.950	1.031	0.333	0.218	0.509	0.273	0.099	0.065
Ankara (Elmadağ)	0.886	0.438	0.155	0.109	0.229	0.129	0.054	0.039
Bursa (Orhaneli)	2.080	1.010	0.312	0.216	0.518	0.250	0.089	0.063
Kütahya (Centre)	1.914	0.873	0.246	0.168	0.483	0.221	0.076	0.054
Diyarbakır (Centre)	0.588	0.319	0.137	0.101	0.225	0.132	0.057	0.041
Samsun (Centre)	0.981	0.519	0.204	0.141	0.325	0.183	0.075	0.053

One of the parameters that have been used for the first time within the scope of current map and code is the map spectral acceleration coefficients. The map spectral acceleration coefficients correspond to the geometric mean of the earthquake effects in two perpendicular horizontal directions. These coefficients are defined as dimensionless and obtained by dividing the map spectral accelerations by the gravitational acceleration for a 5% damping ratio based on the reference ground condition [$(V_{S30}) = 760$ m/s] for a given earthquake ground motion level (TBEC-2018) [19]. Map spectral acceleration coefficients can be obtained separately for ground motion levels with 2%, 10%, 50% and 68% probability of exceedance in 50 years. The comparison of the map spectral acceleration coefficients (S_s) for the short period (0.2 s) and the map spectral acceleration coefficients (S_1) to be used for the 1.0 s period are given in Table 5.

For DD-1, the highest map spectral coefficients (S_S and S_1) were obtained for Bursa (Orhaneli), while the lowest values were obtained for Diyarbakir (Centre). For other earthquake ground motion levels (DD-2, DD-3 and DD-4), the highest map spectral coefficients (S_S and S_1) were obtained for Erzurum (Centre), while the lowest values were obtained for Diyarbakir (Centre).

Table 6 Comparison of local ground effect coefficients for 0.2 s and 1.0 s

Location	F_S				F_1			
	DD-1	DD-2	DD-3	DD-4	DD-1	DD-2	DD-3	DD-4
Adana (Ceyhan)	1.200	1.242	1.300	1.300	1.500	1.500	1.500	1.500
Erzurum (Centre)	1.200	1.200	1.300	1.300	1.491	1.500	1.500	1.500
Ankara (Elmadağ)	1.200	1.300	1.300	1.300	1.500	1.500	1.500	1.500
Bursa (Orhaneli)	1.200	1.200	1.300	1.300	1.500	1.500	1.500	1.500
Kütahya (Centre)	1.200	1.200	1.300	1.300	1.500	1.500	1.500	1.500
Diyarbakır (Centre)	1.265	1.300	1.300	1.300	1.500	1.500	1.500	1.500
Samsun (Centre)	1.200	1.292	1.300	1.300	1.500	1.500	1.500	1.500

Physical and mechanical properties of local soil type directly affect the behaviour of structures under different loads [40, 42]. With the current seismic design code in Turkey, local soil conditions have started to be taken into account in much more detail. Local ground effect coefficients have started to be used with the current code to take into account the influence of local soil conditions. For this, two different local ground effect coefficients have been used for the short and long periods such as F_s and F_1. The comparisons of the local ground effect coefficients (F_S) for the short period and the local ground effect coefficients (F_1) for the 1.0 s are shown in Table 6.

The local ground coefficients obtained for the short period are smaller than the values obtained for the long period. The local ground effect coefficients obtained in the settlements for the short and long periods were close to each other. When the same soil class was chosen, no large differences were obtained. These values differ for different soil types. With the current seismic design code, local soil classes have started to be taken into consideration more. By using local ground effect coefficients and map spectral acceleration coefficients can be converted into design spectral acceleration coefficients. The design spectral acceleration coefficients can be obtained with the following equations.

$$S_{\mathrm{DS}} = S_S \times F_S \quad (1)$$

$$S_{D1} = S_1 \times F_1 \quad (2)$$

The comparison of the spectral design acceleration coefficients (S_{DS}) for the short period and the spectral acceleration coefficients (S_{D1}) for the long period is given in Table 7 for different probabilities of exceedance. The same soil class was taken into account in order to make comparisons.

The obtained design spectral acceleration coefficients were obtained differently for all selected settlements through TEHMIWA. However, these values were the same in the previous seismic design code due to the fact that these settlements were located in the same seismic zone. The highest design spectral coefficients were obtained for Erzurum (Centre), while the lowest values were obtained for Diyarbakir (Centre) for DD-1, DD-2 and DD-3. Only for DD-1 the highest values were obtained for Bursa (Orhaneli). The design spectral acceleration coefficients take different values for all settlements as with other seismic parameters according to site-specific analysis. The comparisons of suggested PGA and S_{DS} values for selected locations for the last two seismic design codes are given in Table 8. The PGA values suggested by Gülkan et al. [13] and the values predicted in the last two codes were also compared in this table for the selected settlements. In order to make comparisons, the recommended values for the 10% probability of exceedance in 50 years in all three sources have been taken into account.

The highest PGA was suggested for Bursa (Orhaneli), and the lowest PGA for Ankara (Elmadag) according to Gulkan et al., [13]. The highest PGA was obtained for Erzurum (Centre), and the lowest PGA for Diyarbakır (Centre) according to TBEC-2018. Both have different PGA values for all settlements. However, PGA has the same value in TSDC-2007, since all settlements are located in the same earthquake zone. The change of seismic parameters depending on the earthquake characteristics of the region and the change from location to location has been clearly demonstrated. Therefore, the fact that the earthquake hazard is based on site-specific rather than on a regional basis is an important innovation with the current code. While suggested PGA increased for Erzurum (Centre), Kütahya (Centre) and Bursa (Orhaneli), they decreased for other settlements. This situation for PGA values remained valid for S_{DS} as well. The highest increase for S_{DS} was obtained for Erzurum (Centre) and the lowest decrease was obtained for Diyarbakır (Centre).

The elastic design spectra were used to determine the seismic loads that will affect the structures can be determined separately for horizontal and vertical with the current code. While only the horizontal component of the earthquake was taken into account in the previous code, both horizontal and vertical effects are taken into account in the current code.

Table 7 Comparison of design spectral acceleration coefficients (S_{DS} and S_{D1})

Location	S_{DS}				S_{D1}			
	DD-1	DD-2	DD-3	DD-4	DD-1	DD-2	DD-3	DD-4
Adana (Ceyhan)	1.517	0.801	0.302	0.207	0.479	0.245	0.091	0.065
Erzurum (Centre)	2.340	1.237	0.433	0.283	0.759	0.410	0.148	0.097
Ankara (Elmadağ)	1.063	0.569	0.201	0.142	0.344	0.193	0.081	0.058
Bursa (Orhaneli)	2.496	1.212	0.406	0.281	0.768	0.375	0.134	0.095
Kütahya (Centre)	2.297	1.048	0.320	0.218	0.725	0.331	0.114	0.081
Diyarbakır (Centre)	0.744	0.415	0.178	0.131	0.337	0.198	0.086	0.062
Samsun (Centre)	1.177	0.671	0.265	0.183	0.487	0.275	0.113	0.079

Table 8 Comparison of PGA and design spectrum coefficients

Location	Gülkan et al. [13] PGA (g)	TSDC-2007 PGA (g)	TBEC-2018 PGA (g)	PGA_{2007}/PGA_{2018}	SDS_{2007}	SDS_{2018}	SDS_{2007}/SDS_{2018}
Adana (Ceyhan)	0.310	0.300	0.281	1.068	0.750	0.801	0.936
Erzurum (Centre)	0.341	0.300	0.433	0.693	0.750	1.237	0.606
Ankara (Elmadağ)	0.291	0.300	0.188	1.596	0.750	0.569	1.318
Bursa (Orhaneli)	0.400	0.300	0.430	0.698	0.750	1.212	0.619
Kütahya (Centre)	0.367	0.300	0.367	0.817	0.750	1.048	0.716
Diyarbakır (Centre)	0.360	0.300	0.142	2.113	0.750	0.415	1.807
Samsun (Centre)	0.363	0.300	0.221	1.357	0.750	0.671	1.117

Horizontal and vertical design spectra can also be obtained by using the seismic parameters for a location. T_A and T_B, which are the corner periods of the horizontal elastic design spectrum, and the corner periods of the vertical elastic design spectrum are T_{AD} and T_{BD}, which have been used for the first time with the current code, are shown in Fig. 7 as an example.

Structural analyses were carried out using the same horizontal elastic design spectrum, since the selected settlements had the same seismic risk in the previous map. Since the seismic risks of these settlements change with the current map, different spectrum is used for each settlement. Therefore, the expected performance levels from the buildings will be more realistic. The comparison of the horizontal elastic design spectrum corner periods obtained for the different exceedance probabilities in the current seismic design code for seven different settlements within the same earthquake zone in this study is given in Table 9. The vertical elastic design spectrum corner periods are compared in Table 10.

The comparison of the design spectral acceleration coefficients and the corner periods of the design spectra within the scope of the last two codes are given in Table 11. In order to compare the results to be obtained, the ZC soil class was chosen as the local soil class as it is the average soil class for six different soil classes envisaged in TBEC-2018. Matching was made with Z3 class in TSDC-2007. The standard design ground motion level in both earthquake codes was taken into account at the point of making comparisons. Horizontal elastic design acceleration spectrum corner period (T_A), vertical elastic design acceleration spectrum corner period (T_{AD}), horizontal elastic design acceleration spectrum corner period (T_B), vertical elastic design acceleration spectrum corner period (T_{BD}) values also affect directly proportionally. With TBEC-2018, the fixed displacement plateau and the transition periods to the fixed displacement region are specified for T_L and T_{LD}, that is, horizontal and vertical design spectra that determine this plateau. For horizontal elastic design spectrum, this value is accepted as $T_L = 6.0$ s and for vertical $T_{LD} = 3.0$ s. This prevents the displacement demands from increasing uncontrollably.

Since TSDC-2007 was prepared on a regional basis, the same design spectral acceleration coefficients are used, but since the current code is site-specific, different values have

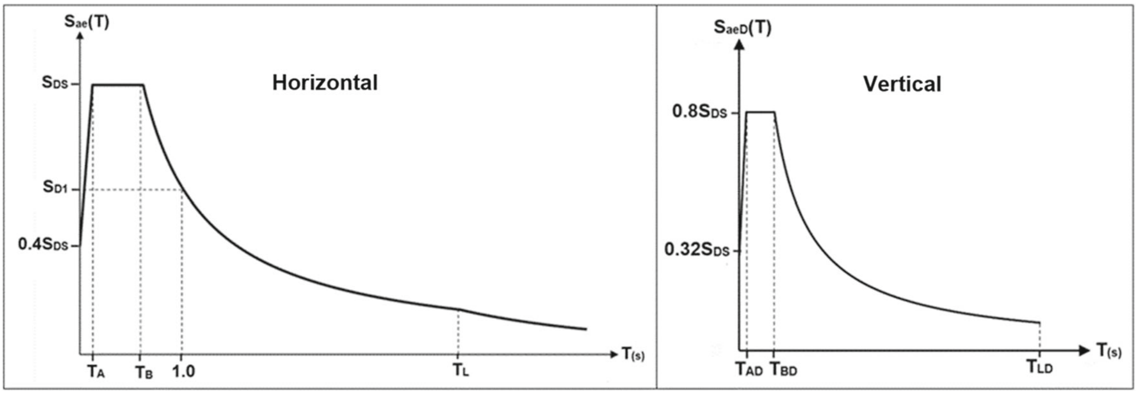


Fig. 7 Horizontal and vertical elastic design spectra and corner periods

Table 9 Comparison of horizontal elastic design spectrum corner periods

Location	T_A (s)				T_B (s)			
	DD-1	DD-2	DD-3	DD-4	DD-1	DD-2	DD-3	DD-4
Adana (Ceyhan)	0.063	0.061	0.061	0.062	0.315	0.305	0.303	0.312
Erzurum (Centre)	0.065	0.066	0.069	0.069	0.324	0.331	0.343	0.344
Ankara (Elmadağ)	0.065	0.068	0.080	0.083	0.323	0.340	0.402	0.413
Bursa (Orhaneli)	0.062	0.062	0.066	0.067	0.308	0.309	0.329	0.337
Kütahya (Centre)	0.063	0.063	0.071	0.074	0.315	0.316	0.356	0.371
Diyarbakır (Centre)	0.091	0.095	0.096	0.094	0.454	0.477	0.480	0.468
Samsun (Centre)	0.083	0.082	0.085	0.087	0.414	0.409	0.424	0.434

Table 10 Comparison of horizontal elastic design spectrum corner periods

Location	T_{AD} (s)				T_{BD} (s)			
	DD-1	DD-2	DD-3	DD-4	DD-1	DD-2	DD-3	DD-4
Adana (Ceyhan)	0.021	0.020	0.020	0.021	0.105	0.102	0.101	0.104
Erzurum (Centre)	0.022	0.022	0.023	0.023	0.108	0.110	0.114	0.115
Ankara (Elmadağ)	0.022	0.023	0.027	0.028	0.108	0.113	0.134	0.138
Bursa (Orhaneli)	0.021	0.021	0.022	0.022	0.103	0.103	0.110	0.112
Kütahya (Centre)	0.021	0.021	0.024	0.025	0.105	0.105	0.119	0.124
Diyarbakır (Centre)	0.030	0.032	0.032	0.031	0.151	0.159	0.160	0.156
Samsun (Centre)	0.028	0.027	0.028	0.029	0.138	0.136	0.141	0.145

been obtained for settlements. The highest S_{DS} was obtained for Erzurum (Centre), and the lowest S_{DS} for Diyarbakır (Centre) according to TBEC-2018. The predicted S_{DS} in TSDC-2007 for Ankara (Elmadağ), Diyarbakır (Centre) and Samsun (Centre) were obtained lower than the obtained S_{DS} in TBEC-2018. Higher values were obtained for other settlements.

The horizontal elastic design spectral accelerations $S_{ae}(T)$, which are the ordinates of the horizontal elastic design acceleration spectrum for any earthquake ground motion level, are obtained in TBEC-2018 in terms of gravitational acceleration (g) depending on the natural vibration period as follows.

$$
\begin{aligned}
S_{ae}(T) &= \left\{0.4 + 0.6\frac{T}{T_A}\right\}S_{DS} && (0 \le T \le T_A)\\
S_{ae}(T) &= S_{DS} && (T_A \le T \le T_B)\\
S_{ae}(T) &= \frac{S_{D1}}{T} && (T_B \le T \le T_L)\\
S_{ae}(T) &= \frac{S_{D1}T_L}{T^2} && (T_L \le T)
\end{aligned} \tag{3}
$$

In TSDC-2007, the spectrum coefficient, S(T), depending on the earthquake zone, is calculated with the following equation depending on the local ground conditions and the

Table 11 Comparison of spectral acceleration coefficients and corner periods

10% probability of exceedance in 50 years	Spectral Acceleration Coefficients				Horizontal				Vertical		
	All Type Soils		*ZC*								
Province	TSDC-2007		TBEC-2018		TSDC-2007		TBEC-2018		TSDC-2007	TBEC-2018	
	S_{DS}	$0.40S_{Ds}$	S_{DS}	$0.40S_{Ds}$	T_A	T_B	T_A	T_B	T_{AD} T_{BD}	T_{AD}	T_{BD}
Adana (Ceyhan)	0.75	0.30	0.801	0.320	0.15	0.60	0.061	0.305	There is no data	0.020	0.102
Erzurum (Centre)	0.75	0.30	1.237	0.495	0.15	0.60	0.066	0.331		0.022	0.110
Ankara (Elmadağ)	0.75	0.30	0.569	0.228	0.15	0.60	0.068	0.340		0.023	0.113
Bursa (Orhaneli)	0.75	0.30	1.212	0.485	0.15	0.60	0.062	0.309		0.021	0.103
Kütahya (Centre)	0.75	0.30	1.048	0.419	0.15	0.60	0.063	0.316		0.021	0.105
Diyarbakır (Centre)	0.75	0.30	0.415	0.166	0.15	0.60	0.095	0.477		0.032	0.159
Samsun (Centre)	0.75	0.30	0.671	0.268	0.15	0.60	0.082	0.409		0.027	0.136

building natural period.

$$S(T) = 1 + 1.5\frac{T}{T_A} \qquad (0 \le T \le T_A)$$
$$S(T) = 2.5 \qquad (T_A < T \le T_B) \tag{4}$$
$$S(T) = 2.5\left(\frac{T_B}{T}\right)^{0.8} \qquad (T_B < T)$$

The elastic spectral acceleration ($S_{ae}(T)$), which is the ordinate of the elastic acceleration spectrum that defined for the 5% damping ratio, is obtained with the help of the equation below. The effective ground acceleration coefficient (A_o) was taken as 0.30 for all selected settlements since these settlements have the same seismic risk in the previous earthquake map. This coefficient that used in the previous code, no longer used with the current seismic design code.

$$A(T) = A_o \mathrm{IS}(T)$$
$$S_{ae}(T) = A(T)g \tag{5}$$

Earthquake Load Reduction Coefficient $R_a(T)$, which will be taken as a basis in reducing linear elastic earthquake loads, is defined as follows. It is found in TBEC-2018 and TSDC-2007 with the help of the following equation:

$$R_a(T) = \frac{R}{I} \qquad T > T_B$$
$$R_a(T) = D + \left(\frac{R}{I} - D\right)\frac{T}{T_B} \quad T \le T_B \text{TBEC - 2018} \tag{6}$$
$$R_a(T) = 1.5 + (R - 1.5)\frac{T}{T_A} \quad (0 \le T \le T_A)$$
$$R_a(T) = R \qquad (T_A < T)\text{TSDC - 2017}$$

where R and D are the structural system behaviour coefficient and over strength coefficient, l is the building importance coefficient, T the natural vibration period of the system and T_A and T_B the defined spectrum corner period. As can be seen from the above equations, the coefficient of over strength has been used for the first time in Turkey with the current code. The reduced design spectral acceleration S_{ar}(T), which is the ordinate for a given natural vibration period T of the reduced design acceleration spectrum to be used for determining the reduced seismic loads in the horizontal direction, is defined in both codes by the following equation:

$$S_{aR}(T) = \frac{S_{ae}(T)}{R_a(T)} \tag{7}$$

where $S_{ae}(T)$ is the horizontal elastic design spectral acceleration determined for the DD-2 earthquake ground motion, and $R_a(T)$ is the earthquake load reduction coefficient. In this study, the 7-storey RC building selected as an example has a total height of 21 m, and since it is greater than BYS ≥ 3, the buildings where all the earthquake effects are covered by RC frames with high moment transmitting ductility level are considered as $R = 8$ and $D = 3$. The natural vibration period for the sample RC building was obtained from the software program as 0.699 s. It is assumed that the sample building will be used for residential purposes. The building importance coefficient is obtained as 1 in both codes. The comparison of these values obtained within the scope of both codes is given in Table 12.

The highest horizontal elastic design spectral acceleration was obtained for Erzurum (Centre) and the lowest was obtained for Ankara (Elmadağ). This value, which was obtained differently in TBEC-2018 for all settlements, was obtained lower than TSDC-2007. In TSDC-2007, it took the

Table 12 Comparison of the results for the sample RC building

Location	T_A(s)	T_B(s)	T_L(s)	S_{ae}(T)(g)	R	D	R_a(T)	S_{aR}(T)(g)
Adana (Ceyhan)	0.061	0.305	6.0	0.351	8	3	8	0.044
Erzurum (Centre)	0.066	0.331	6.0	0.587	8	3	8	0.073
Ankara (Elmadağ)	0.068	0.340	6.0	0.276	8	3	8	0.035
Bursa (Orhaneli)	0.062	0.309	6.0	0.536	8	3	8	0.067
Kütahya (Centre)	0.063	0.316	6.0	0.474	8	3	8	0.059
Diyarbakır (Centre)	0.095	0.477	6.0	0.283	8	3	8	0.035
Samsun (Centre)	0.085	0.409	6.0	0.393	8	3	8	0.049
TSDC-2007	0.150	0.600	3.0	0.664	8	–	8	0.083

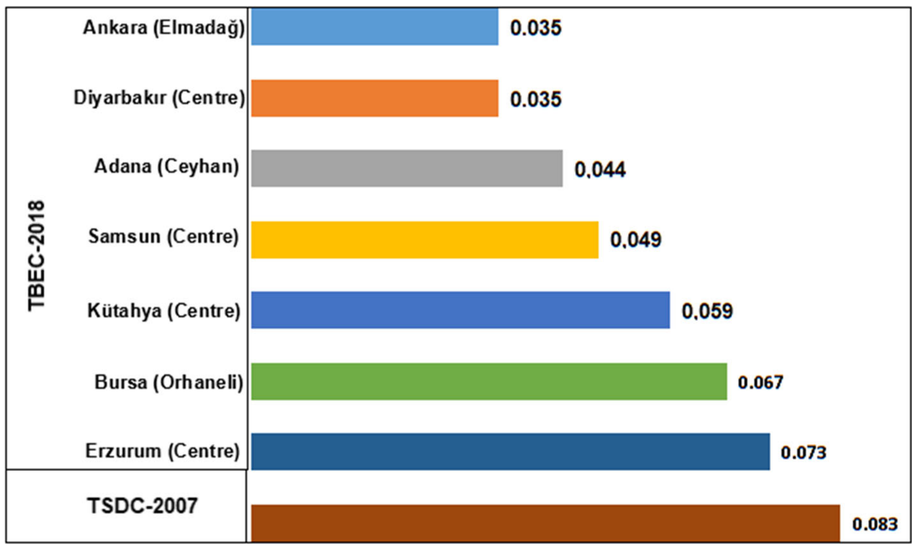


Fig. 8 The comparison of the reduced design spectral accelerations

same value for all settlements because of regional basis. This situation is valid also for the reduced design spectral acceleration $S_{ar}(T)$. This is because the structural system behaviour coefficient does not change. The comparison of the reduced design spectral accelerations obtained according to the current and previous code is shown in Fig. 8.

One of the concepts used for the first time with the TBEC-2018 has been the earthquake design class (DTS). The earthquake design class is determined based on the building usage class (BKS) and the S_{DS} obtained for the DD-2 earthquake ground motion level and is shown in Table 13. Building utilization class (BKS) is obtained as 3 for a sample RC building to be used for residential purposes in this study.

According to the S_{DS} values obtained according to TBEC-2018, DTS = 1 for Adana (Ceyhan), Erzurum (Centre), Bursa (Orhaneli) and Kütahya (Centre); DTS = 3 for Diyarbakir (Centre); DTS = 2 is obtained for Ankara (Elmadağ) and Samsun (Centre). Considering S_{DS} = 0.75, which is included in TSDC-2007 and is equal for all provinces, it is obtained as DTS = 1 for all settlements. All these results show that the earthquake effect of seismic hazard on a regional basis will not be realistic in structural analysis.

Table 13 Earthquake design classes (DTS)

S_{DS} for DD-2 earthquake ground motion level	Building usage class	
	BKS = 1	*BKS = 2,3*
S_{DS}<0.33	DTS = 4a	DTS = 4
0.33 ≤ S_{DS}<0.50	DTS = 3a	DTS = 3
0.50 ≤ S_{DS}<0.75	DTS = 2a	DTS = 2
0.75 ≤ S_{DS}	DTS = 1a	DTS = 1

In this study, besides seismic parameters, seismic moments were determined for the selected settlements. The areas where seismicity is observed intensely are the places where there is a cycle in the form of accumulation of energy

Table 14 Seismic moment and expected earthquake magnitude for settlements

Location	Expected earthquake magnitude (Mw)	Seismic moment (dyn.cm)
Adana (Ceyhan)	6.4	5.01^{25}
Erzurum (Centre)	6.9	2.81^{26}
Ankara (Elmadağ)	5.8	6.30^{24}
Bursa (Orhaneli)	7.0	3.98^{26}
Kütahya (Centre)	7.2	7.94^{26}
Diyarbakır (Centre)	6.6	1.0^{26}
Samsun (Centre)	5.0	3.98^{23}

in the stressed environment and its release with the defeat of the strength conditions. The energy released during an earthquake is directly proportional to the effect and size of the earthquake. Seismic moment (Mo) reflects regional tectonic conditions, source behaviour characteristics, and energy accumulation before earthquakes. Therefore, obtaining the seismic moment for a region is important in terms of defining the size of the energy that will emerge during the recurrence interval of earthquakes. Moment magnitude (Mw) calculation was found more appropriate to define the true size of the earthquake. For numerically recorded earthquakes, Mo can also be calculated from the amplitude spectra of the seismic waves [43–46]. The most widely used formula was developed by Kanamori (1977) [47] as follows;

$$Log M_o = 1.5M_w + 16.1 \quad (8)$$

The calculation made for the settlements selected using this Equation is given in Table 14. These values were obtained for a single earthquake in each region. This situation does not reflect the seismic moment distribution in that region. However, it varies in direct proportion to the selected earthquake magnitude. Işık et al. [23] showed that the regional seismic moment distribution reveals values that increase with the frequency of earthquake occurrence. The seismic moment acts as the average of a region's tectonic conditions, earthquake energy accumulation, and source properties. Accordingly, the areas with the highest accumulation potential of earthquake energy are seen as Kütahya, Bursa (Orhaneli), Erzurum and Diyarbakır.

4 Structural Analysis

Seismostruct software [48] was used for structural analysis. Pushover analyses performed for the sample 7-storey RC building for all settlements, respectively. The blueprint of the sample RC building is shown in Fig. 9.

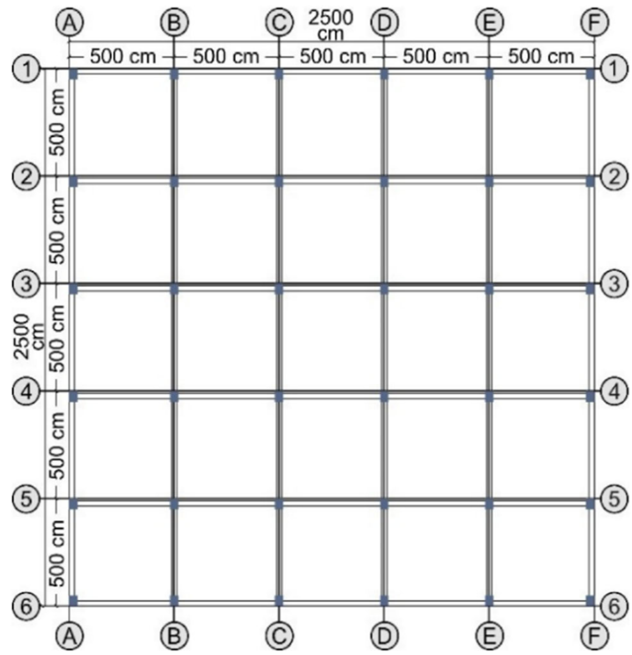


Fig. 9 The blueprint of RC building model

The loads applied to the sample RC building and the 2 and 3 dimensional structural models are shown in Fig. 10.

The structural features that taken into account in the sample RC building model are shown in Table 15. All these features are taken into account as constant for all settlements. No changes were made to enable comparisons.

Since the structural features are the same, the natural vibration period, seismic capacity, elastic and effective stiffness values of the building have taken the same for all settlements within the scope of both codes. Within the scope of this study, primarily target displacements were obtained for four different performance levels envisaged in TBEC-2018. The four different performance levels specified in TBEC-2018 are shown in Fig. 11 and their explanations are given in Table 16.

The target displacement values obtained according to TBEC-2018 by considering the standard design earthquake for the sample RC building for all settlements are shown in Fig. 12.

The target displacement values of all settlements were obtained differently from each other for the four different performance levels specified in TBEC-2018. However, the same design spectrum would be used for the settlements considered in this study in the previous code and the same target displacements would be obtained. Different target displacements for each location are obtained by using the site-specific design spectrum together with the current code. Therefore, the predicted performance levels for the damage estimations in the structures are obtained more realistically. Otherwise, since the target displacement values will differ, the expected

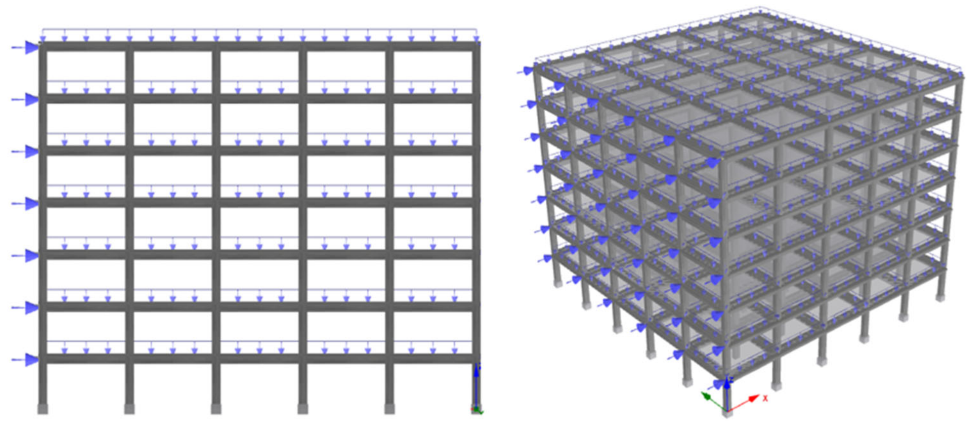


Fig. 10 2D and 3D models of sample RC building

Table 15 The structural features of sample RC building

Parameter		Value
Concrete grade		C25
Reinforcement grade		S420
Beams		250 × 600 mm
Height of floor		120 mm
Cover thickness		25 mm
Columns		400 × 500 mm
Longitudinal reinforcement	Corners	4Φ20
	Top bottom side	4Φ16
	Left right side	4Φ16
Transverse reinforcement		Φ10/100
Steel material model		Menegotto-Pinto [49]
Concrete material model		Mander et al. nonlinear [50]
Constraint type		Rigid diaphragm
Incremental load		2.38 kN
Permanent load		5 kN/m
Target displacement		0.42 m
Ground type		C
Importance class		II
Damping ratio		5%

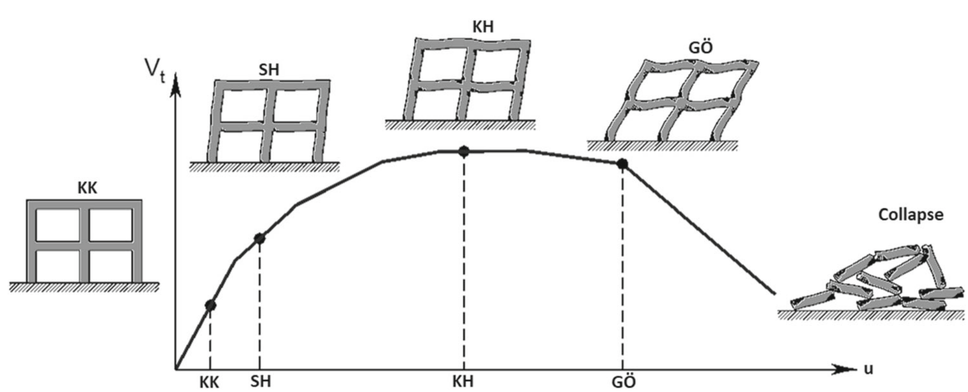


Fig. 11 The performance levels in TBEC-2018

Table 16 Performance Levels (TBEC-2018) [19]

Performance level	Description
Continuous use (KK)	Very light, negligible or no damage to the structural members
Immediate occupancy (HK)	Limited damage in the structural members. The nonlinear structural response remains limited
Life safety (CG)	Controlled damage levels, so that ensure life safety, Typically the sustained can be repaired
Collapse prevention (GÖ)	The state just before collapse. Heavy damage has been sustained by the structural members, but partially or completely collapse of the building has been prevented

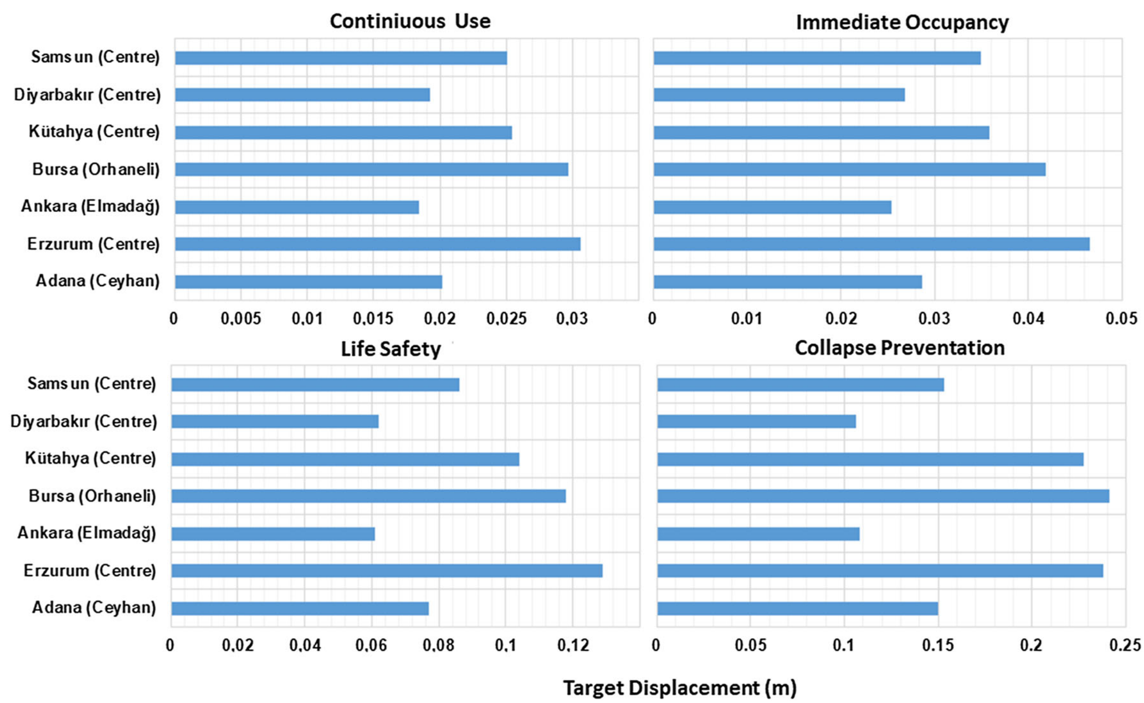


Fig. 12 Comparison of target displacements for different performance levels in TBEC-2018

Table 17 Limit states in Eurocode 8 (Part 3) [51, 52]

Limit state	Description	Return period	Probability of exceedance
Limit state of damage limitation (DL)	Only lightly damaged, damage to non-structural components economically repairable	225	0.20
Limit state of significant damage (SD)	Significantly damaged, some residual strength and stiffness, non-structural components damaged, uneconomic to repair	475	0.10
Limit state of near collapse (NC)	Heavily damaged, very low residual strength and stiffness, large permanent drift but still standing	2475	0.02

performance levels from the building will not be achieved (Table 17).

In order to show the effect of seismicity parameters that vary depending on the geographical location within the scope of this study, the results of the structural analyses using the PGA values obtained for different earthquake ground motion levels for all settlements are shown in Table 18. In this section, Eurocode 8 (Part 3), which is more widely used in the world, is taken into account. The target displacements for damage estimation must be determined for performance limits of structural elements in performance-based earthquake engineering. In this study, we used the limit states which are defined in Eurocode-8 (Part 3) [51, 52]. The limit states for damage estimation in this code are given in Table 17.

Table 18 Comparison of target displacement values for different earthquake ground motion levels

Location	DD-1			DD-2			DD-3			DD-4		
	DL	SD	NC	DL	SD	NC	DL	SD	NC	DL	SD	NC
Adana (Ceyhan)	0.191	0.245	0.424	0.102	0.131	0.227	0.038	0.049	0.084	0.025	0.033	0.057
Erzurum (Centre)	0.284	0.364	0.631	0.157	0.202	0.350	0.052	0.068	0.117	0.035	0.044	0.077
Ankara (Elmadağ)	0.134	0.172	0.298	0.068	0.088	0.152	0.025	0.032	0.055	0.017	0.022	0.039
Bursa (Orhaneli)	0.310	0.398	0.689	0.156	0.200	0.348	0.049	0.063	0.109	0.034	0.043	0.075
Kütahya (Centre)	0.280	0.359	0.622	0.133	0.171	0.297	0.039	0.049	0.086	0.027	0.035	0.060
Diyarbakır (Centre)	0.092	0.112	0.205	0.092	0.118	0.205	0.022	0.028	0.049	0.016	0.021	0.036
Samsun (Centre)	0.149	0.191	0.331	0.080	0.103	0.179	0.032	0.041	0.072	0.023	0.029	0.050
TSDC-2007	–			0.109	0.140	0.242	–			–		

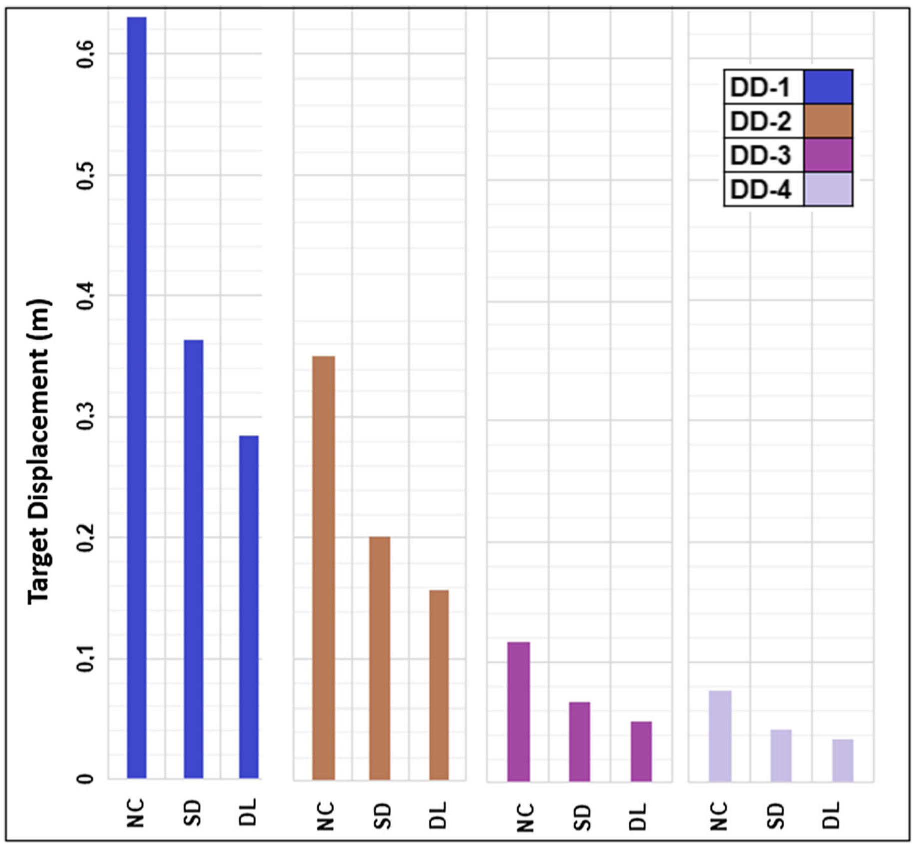


Fig. 13 Comparison of target displacements for different probabilities of exceedance

The comparison of the target displacements obtained for different earthquake ground motion levels is shown in Fig. 12. Erzurum (Centre) was chosen as an example and all the target displacements obtained for this location are shown in Fig. 13.

One of the new concepts used with TBEC-2018 has been four different earthquake ground motion levels. Four different earthquakes that are likely to be probabilities of exceedance in 50 years are taken into account and these earthquakes are given in Table 2. As the repetition period of the earthquake increases, the magnitude of the expected earthquake also increases. As a result of the increase in the expected earthquake magnitude, the expected target displacement values for the performance levels of the structures have also increased.

In order to compare the results obtained, the comparison of the results obtained for the standard design ground motion level in both codes with each other is shown in Table 19.

The comparison of all the target displacements and the ratios of the target displacements by last two codes to each other are shown in Fig. 14.

While target displacement values increased for Samsun (Centre), Erzurum (Centre), Adana (Ceyhan) and

Table 19 Comparison of target displacements for standard design ground motion (DD-2)

Location	TBEC-2018			TSDC-2007			TSDC-2007/TBEC-2018		
	DL	SD	NC	DL	SD	NC	DL	SD	NC
Adana (Ceyhan)	0.102	0.131	0.227	0.109	0.140	0.242	1.069	1.069	1.066
Erzurum (Centre)	0.157	0.202	0.350				0.694	0.693	0.691
Ankara (Elmadağ)	0.068	0.088	0.152				1.603	1.591	1.592
Bursa (Orhaneli)	0.156	0.200	0.348				0.699	0.700	0.695
Kütahya (Centre)	0.133	0.171	0.297				0.820	0.819	0.815
Diyarbakır (Centre)	0.092	0.118	0.205				1.185	1.186	1.180
Samsun (Centre)	0.080	0.103	0.179				1.363	1.359	1.352

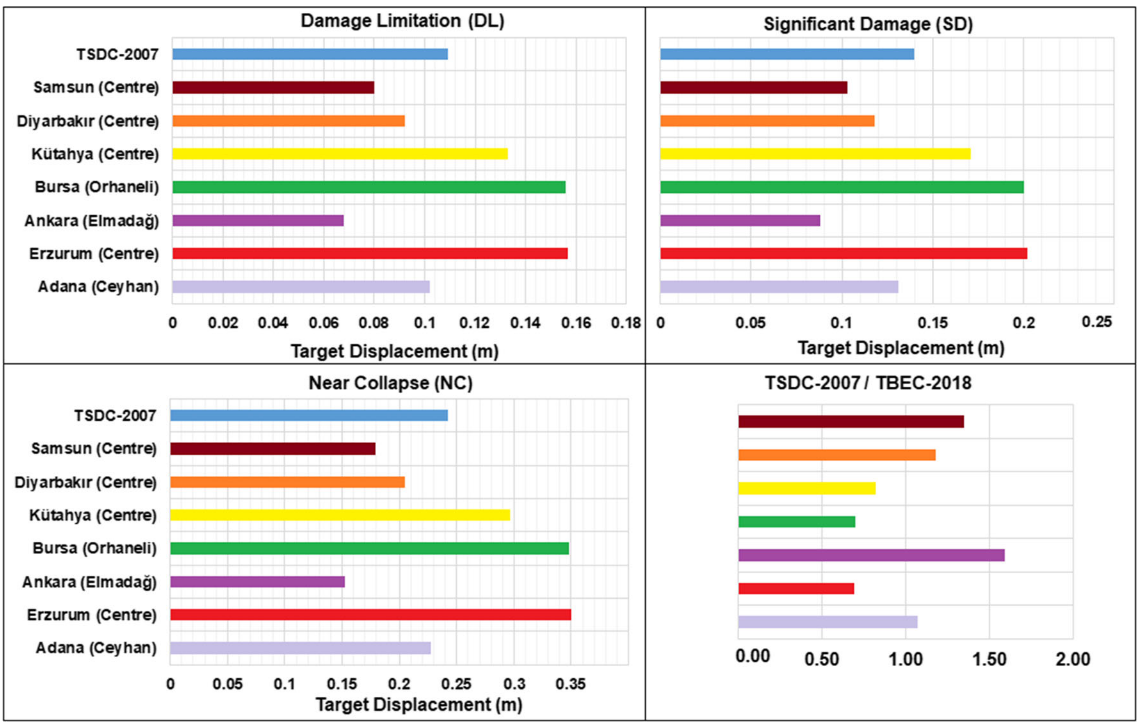


Fig. 14 Comparison of target displacements that predicted in Eurocode-8, Part-3

Bursa (Orhaneli) compared to the previous code, they decreased for other settlements. In the previous code, the same target displacements were obtained, since the same earthquake zone was taken into account. According to the values predicted for the current code, the target displacements differed for each settlement. The highest target displacements were obtained for Erzurum (Centre), while the lowest values were obtained for Ankara (Elmadag). The expected target displacements from the structure for damage estimation increased as the seismic risk increased.

5 Conclusions

Within the scope of this study, the last two seismic design codes and hazard maps used in Turkey were examined together with their details. All the results obtained show that both the regulation and the map have changed significantly. Earthquake damages, scientific developments, current seismic hazard analysis, seismic sources and new generation mathematical equations necessitate this change. These changes made after about 20 years include important gains in terms of civil and earthquake engineering. Within the scope of the study, the important differences between the last two maps and regulations are stated in detail. In order to reveal the effect of significant changes, seismic parameters were obtained for seven different settlements in the same earthquake zone in the previous map and compared with current parameters.

There are significant changes between in the last two seismic design codes in the analysis and evaluations of buildings under earthquake impact. Concepts such as earthquake design class (DTS), building height class (BYS), earthquake ground motion level (DD) and vertical elastic design spectrum curves were introduced for the first time with TBEC-2018. While the concept of performance and performance levels were valid only for existing buildings in previous code, these concepts and levels started to be used for new buildings with TBEC-2018.

Site-specific seismic parameters have been started to be obtained by making the necessary updates in the earthquake hazard map, depending on the structural analyses that should be made specific to the site in the current code. However, four different earthquake ground motion levels have been started to be used for different exceedance probabilities with the current code while only one earthquake ground motion level was used in the previous code. The PGA predicted in the previous map for all settlements is 0.300 g for standard design earthquake ground motion level. The PGA values were not the same due to the difference in location-specific seismicity parameters in the current map. The PGA values were obtained in the range of 0.142–0.433 g for the same ground motion level (DD-2) with the current map. While there was an increase in some provinces, there was a decrease in some provinces. All the results obtained vary depending on these values. In this context, there is a complete agreement between the results obtained from both seismic parameters and structural analysis. This shows that the determination of earthquake hazard should not be made on a regional basis due to site-specific seismicity elements. The seismicity elements of each geographical location vary, and as a result, the design spectrums to be used in structural analysis will also different. The change in the amplitude of the design spectrum will directly affect the predicted performance levels for the damage estimation in the structures. Otherwise, it will not be possible to achieve the predicted performance levels. The usage of site-specific design spectrums has been implemented for the first time with the current code in Turkey. As of 2019, earthquake hazard is no longer used on a regional basis. Briefly, with the current code, the macro earthquake hazard has left its place to the micro earthquake hazard. The results obtained reveal that the new seismic design code and earthquake hazard map reveal the earthquake hazard more realistically. As a result, earthquake effects are taken into account more realistically in earthquake resistant building design rules.

This study is limited to regular RC structures with the same structural characteristics and the same earthquake zone. This study will make important contributions to the structural analysis of irregular and different structural systems as well as other innovations in the current code. The results obtained for the analysis type used in this study will allow comparisons to be made in studies using different analysis types. This and similar studies will shed light on the studies to be carried out for different earthquake zones and different soil classes.

One of the important data in seismic hazard analysis is the tectonic elements of the studied region. With a good knowledge of tectonic elements, seismotectonic studies related to the region in terms of future earthquake hazard will allow more realistic results to be obtained. In addition, attenuation relationships to be used in seismic hazard analysis can also be developed site-specific.

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