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RESEARCH ARTICLE

Evaluation of the seismicity of Sivas city according to the 2007 and 2018 Turkish earthquake codes

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Abstract

The Turkish Earthquake Code 2018 (TEC-2018) has been in use in Türkiye since January 1, 2019. Before this date, the Turkish Earthquake Code 2007 (TEC-2007) was in use. The earthquake zone map, which represents the country's seismic risk zones, was also updated as of January 1, 2019. In this study, the seismicity of Sivas city was investigated in consideration of the requirements of two codes. A four-story reinforced concrete building was used as a sample building. Structural analyses were performed using the ETABS software. Seismic calculations of the sample building were performed for all districts of Sivas using the response spectrum analysis, a linear calculation method. As a result of the analyses, modal analysis results, design spectra, base shear forces, and roof displacements were obtained for the strongest and weakest local soil classes of the earthquake codes. The results were compared to evaluate the differences between the two codes, specifically for Sivas province. The fact that Sivas districts have different seismic risks made the comparison of the codes more detailed. Thus, results were obtained and compared for different seismic risk zones. The numerical results showed that the values obtained according to TEC-2018 were greater than those obtained according to TEC-2007, especially in weak soils. The comparisons revealed that TEC-2018 was more detailed.

1. Introduction

Türkiye has numerous fault zones. This clearly demonstrates that Türkiye is an earthquake-prone country. The country has experienced several major earthquakes in recent years. These devastating earthquakes have highlighted the importance of earthquake-resistant structural design. The first earthquake-resistant structural design studies and earthquake codes were developed in the 1940s. Earthquake codes have been published in the country in 1940, 1944, 1949, 1953, 1962, 1968, 1975, 1998, 2007, and 2018. Earthquake codes have been updated in response to advances in structural and earthquake engineering. Comparing earthquake codes is crucial for taking precautions against future earthquakes. It's important to check whether the new codes are more detailed and realistic than previous ones. The two most recent earthquake codes used in Türkiye are the Turkish Earthquake Code 2018 (TEC-2018) and the Turkish Earthquake Code 2007 (TEC-2007) [1, 2]. In this context, studies comparing TEC-2018 and TEC-2007 are necessary. Furthermore, seismic zone maps have been published numerous times in 1945, 1947, 1963, 1972, 1996, and 2018 to be used in conjunction with these codes and to identify the country's seismic risk zones.

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Numerous studies exist in the literature regarding the historical development of Turkish earthquake codes and seismic zone maps. These studies also attempt to reveal differences in the codes and maps. Seyrek [3] investigated the differences between the design spectra of the 2007 and 2018 earthquake codes for the Aegean Region. The study determined how soil conditions affected the calculations. The differences in the seismic zone maps used by the two codes were revealed, and their impact on the calculations was examined. Another study [4] noted that seismic zone maps in Türkiye were created in the 1940s. It was noted that they were updated numerous times depending on developments. The study aimed to provide detailed information about the officially used seismic zone maps throughout Türkiye's history. There are many studies in the literature comparing seismic zone maps and discussing their historical development [5, 6]. In another study [7], the story drift calculations and boundary conditions were compared for the 2007 Earthquake Code and the draft 2016 Turkish Building Earthquake Code. Calculations were made considering the jointed and non-jointed cases of infill wall-frame connections. Karaca et al. [8] tried to reveal the differences between the 2007 and 2019 earthquake codes. Five buildings designed according to the 2019 earthquake code were evaluated according to the 2007 earthquake code. In this way, the conditions of the two codes were compared through examples. The design of the buildings was made for the city center of Niğde. As a result of the study, it was stated that one of the most important innovations introduced with the 2019 earthquake code is that the soil class effect is included in the design equations more than in the 2007 earthquake code. Another study [9] has indicated that one of the major differences between the 2007 and 2018 earthquake codes is the damage limits of the structural system elements used in deformation-based nonlinear methods. The performance evaluation of a reinforced concrete residential building was carried out using the incremental pushover analysis method according to the two codes. The comparisons determined that less seismic force was acting on the structure in the 2018 earthquake code. Furthermore, due to the stricter damage limits in the 2018 earthquake code, the study stated that similar results were obtained in terms of target performance compared to the 2007 earthquake code, despite the lower seismic force. Çetin et al. [10] performed 270 different analyses for 5 different building types. In the study, they tried to determine how soil classes affect torsional irregularity. They made the calculations according to the 2007 and 2018 Turkish earthquake codes and compared the results. As a result of the study, it was revealed that the torsional irregularity coefficients of irregular structures determined according to the 2018 earthquake code were much larger. Başaran [11] calculated equivalent earthquake loads for the five- and ten-story models for the center of Afyonkarahisar according to the Turkish Building Earthquake Code 2019 and the Regulation on Buildings to be Constructed in Earthquake Zones 2007. Different soil classes were also considered in the study. Seismic loads were compared according to both soil classes and the two codes. It was observed in the calculations that the equivalent earthquake loads obtained according to the new code were smaller. In another study [12], the differences between the 2007 and 2018 Turkish earthquake codes were revealed. The four- and nine-story models were created and analyzed. The seismic forces obtained as a result of the calculations were compared for the two codes. In the comparisons, it was observed that the base shear force values obtained for the new code were greater. Demir and Kayhan [13] compared the 2007 and 2018 Turkish earthquake codes in terms of time history analysis results. Single-degree-of-freedom systems with different dynamic characteristics were created. Nonlinear analyses were performed with these systems. Maximum drift demands were compared. Another study [14] focused on the design spectra recommended by earthquake codes for static earthquake calculations. Design spectra for the 2007 and 2018 earthquake codes were obtained and compared. Four cities were selected for the study, taking into account the seismicity of the regions. The comparison was also expanded to include different soil classes. The comparisons revealed that the 2018 earthquake code remained on the safer side for weak soil classes. Keskin and Bozdoğan [15] conducted various comparisons using the 2007 and 2018 Turkish earthquake codes for the city of Kırklareli. Design spectra for different soil classes were obtained and compared, considering the conditions of the two codes for the selected region. Furthermore, structural analyses were performed for a four-story building, again considering different soil classes. The results of the analyses revealed how they differed according to the two codes. The study concluded that the 2018 earthquake code made earthquake analyses more realistic. Nemutlu et al. [16] calculated the acceleration spectra used in the earthquake calculations of Bingöl and Elazığ city centers. Both the 2007 earthquake code and the 2018 earthquake code were used in the calculations. The differences between the two codes were compared according to the calculations. Two different ground motion levels were used in the study. Acceleration spectra, corner periods, and spectrum coefficients were examined. It was determined that the acceleration spectra differed between the two codes due to the Turkish earthquake hazard maps used by the 2018 Turkish earthquake code. It was mentioned that the 2018 earthquake code allows for the calculation of acceleration spectra in more detail. The study stated that the 2018 earthquake code is safer. Bayrakcı et al. [17] calculated spectral acceleration values and ground corner periods for the city center of Eskişehir, considering different soil classes. Both the Regulation on Buildings to be Constructed in Earthquake Zones 2007 and the Turkish Building Earthquake Code 2018 were used in the calculations. The results of the two codes were compared. There are many studies comparing earthquake codes considering different cities [18-24]. In a separate study conducted on a city basis [25], it was reported that the two major earthquakes that occurred in the Kahramanmaraş districts in 2023 were felt in many cities, including Niğde. The acceleration values recorded by the instruments in the city center of Niğde for these two earthquakes were compared with the design accelerations in the study. As a result of the evaluations, it was determined that the acceleration values for the Elbistan earthquake exceeded the design accelerations when the building period was around 1.00 seconds. It was also stated in the study that the Kahramanmaraş earthquakes were felt in a very wide area. Earthquakes were reported to have caused loss of life and economic damage in the provinces of Maraş, Hatay, Adıyaman, Gaziantep, Kilis, Diyarbakır, Şanlıurfa, Elazığ, Adana, and Malatya. The study also indicates that earthquakes were felt and caused damage in the provinces of Kayseri, Sivas, Tunceli, and Niğde.

Although there are many studies on the comparison of TEC-2007 and TEC-2018 codes from different regions and cities, no study comparing the two codes specifically for Sivas was found in the literature. This study aimed to investigate the differences between the TEC-2018 and TEC-2007 codes, specifically for the city of Sivas. Seismic risk maps reveal that the districts of Sivas have different seismic risks. These differences are more suitable for comparing the codes. A four-story reinforced concrete building was used as a sample in the study. Structural analyses were conducted using the response spectrum analysis method for seismic calculation. Structural analyses were performed for all districts of Sivas, considering different soil classes. Design spectra, base shear forces, and roof displacements were obtained, and the changes of these values according to two earthquake codes were investigated. The analysis results were compared to reveal the differences between the codes.

2. Seismicity of Sivas

Sivas is located in the Central Anatolia Region of Türkiye. It is Türkiye's second-largest city in terms of surface area. It has a total of 17 districts. Sivas is seen to be in a seismically risky area, especially when its northern districts are considered (Fig. 1(a-b)) [26-28]. The North Anatolian Fault Zone (NAFZ), which is highly seismically hazardous, passes through the northern districts of Sivas, such as Gölova, Akıncılar, Suşehri, and Koyulhisar. These four districts were significantly affected by major earthquakes that occurred in the northern regions of Sivas and on the NAFZ, especially the 1939 Erzincan earthquake. Another important fault in Sivas is the Deliler Fault. This fault passes through the Gemerek, Şarkışla, and Ulaş districts of Sivas. The Divriği Fault, which passes through the Zara and Divriği districts, is a continuation of the Deliler Fault. Sarız, Ayvalı, and Gürün faults are located in the Gürün district in the south of Sivas. Faults that may pose a risk for the central district are the Deliler fault, due to its proximity, and the NAFZ, due to its potential for large earthquakes. These two faults are also active faults that pose an earthquake risk for Sivas. The active fault map of Sivas and earthquakes with magnitudes greater than 4.00 that occurred between 1900 and 2020 are shown in Fig. 1(c). A total of 48 earthquakes of these dates and magnitudes were recorded. The most significant examples of these earthquake records include the 1909 Koyulhisar earthquake, which had a magnitude of 6.40, and the 1929 Suşehri earthquake, which had a magnitude of 6.10. The largest earthquake close to Sivas city center during this period appears to have a magnitude of 5.10. It is observed that the majority of earthquakes have magnitude values between 4.00 and 5.00, and larger earthquakes are concentrated in seismically more active regions [26]. Considering the locations of Sivas' districts, Koyulhisar, Suşehri, Akıncılar, and Gölova are closer to the NAFZ. Therefore, the acceleration coefficients used in earthquake calculations for these districts are much higher than for other districts. Districts south of Sivas, such as Gürün and Kangal, have lower seismic risks due to fault lines. Therefore, the acceleration coefficients used in earthquake calculations are lower than for other districts.

The previous earthquake zone map, the Türkiye Earthquake Zones Map 1996 (TEZM-1996) [27], represents seismicity in five-degree scales, with the 1st degree being the most risky and the 5th degree being the least risky (Fig. 2(a)). The ground acceleration parameters used in earthquake calculations vary depending on these risk zones. The effective ground acceleration coefficients used in earthquake calculations conducted according to TEC-2007 are determined according to these earthquake zones. This coefficient is 0.4 for 1st-degree earthquake zones, 0.3 for 2nd-degree earthquake zones, 0.2 for 3rd-degree earthquake zones, and 0.1 for 4th-degree earthquake zones. This coefficient also changes the seismic forces applied to buildings. According to this map, the territory of Sivas province includes almost all seismic risk zones. The Akıncılar, Doğanşar, Gölova, İmranlı, Koyulhisar, Suşehri, and Zara districts of Sivas are in the 1st degree earthquake zone; the Hafik district is in the 2nd degree earthquake zone; Merkez, Altınyayla, Divriği, Gemerek, Şarkışla, and Yıldızeli are in the 3rd degree earthquake zone; Gürün, Kangal, and Ulaş are in the 4th degree earthquake zone [26, 27].

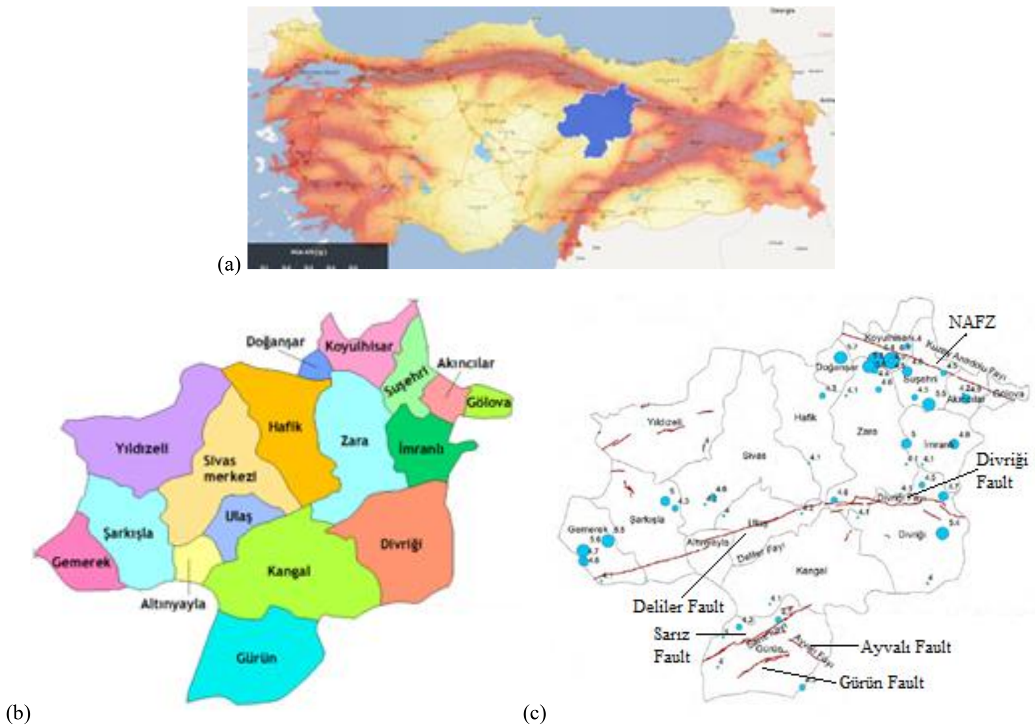
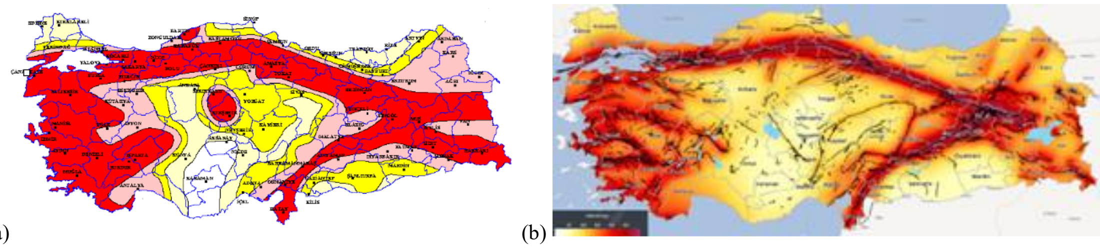


Fig. 1. Districts and active fault map of Sivas city [26, 28]



(a) (b)

Fig. 2. Türkiye earthquake risk maps [27, 28]

The currently valid Türkiye Earthquake Hazard Map 2018 (TEHM-2018) [28], given by Fig. 2(b), shows that the highest ground acceleration values for Sivas city are concentrated around the NAFZ and Deliler faults [26, 28]. Seismic parameters such as acceleration coefficients can be accessed specifically for the location of the building using the TEHM-2018. By entering the building location information and the soil class information for that location into the interactive web application of the map, earthquake parameters for the desired earthquake ground motion level can be obtained. The TEC-2018 and TEHM-2018 allow for the calculation of acceleration spectra in more detail. The map spectral acceleration coefficients used in earthquake calculations conducted according to TEC-2018 are determined according to TEHM-2018. As the seismic risk of the building's location increases, these coefficients also increase. As these coefficients increase, the seismic forces applied to buildings also increase. The most important difference between TEHM-2018 and TEZM-1996 is the spectral acceleration values. Different values are obtained from the two maps for the same region. This difference causes the design spectra obtained according to TEC-2018 and TEC-2007 to be different.

3. Sample building

In this study, earthquake calculations were carried out on a 4-storey reinforced concrete building according to TEC-2018 and TEC-2007 codes. Structural analyses were carried out with the help of the ETABS software [29]. Sample views of the models were given in Fig. 3. The eccentricity ratio was neglected in all analyses. Analyses were performed for the earthquake level with a 10% probability of being exceeded in 50 years, which was defined as the design earthquake in TEC-2007 and as the DD-2 earthquake ground motion level (standard design earthquake ground motion) in TEC-2018. Since the cracked section is not taken into account in the linear calculation methods of TEC-2007, the effective flexural stiffnesses of the cracked section were not taken into account in the analyses performed according to TEC-2007. Since TEC-2018 states that effective section stiffnesses should be taken into account in reinforced concrete load-bearing system elements, effective section stiffnesses were included in the analysis performed according to TEC-2018 (Table 1).

The response spectrum analysis method, a linear calculation method, was used for the earthquake calculation. Twelve modes were included in the calculation. The sum of effective mass participating ratios for the 12 modes was obtained as 100% according to both earthquake codes. TEC-2007 stipulates that the sum of the effective masses calculated for each mode in each earthquake direction must exceed 90% of the total building mass. This requirement was increased to 95% in TEC-2018. Furthermore, the new code stipulates that all modes contributing more than 3% must be considered. Analyses were conducted in accordance with the two earthquake codes. A 5% damping ratio was used in the analyses. Calculations were made for the strongest and weakest local soil classes of the two codes. The strongest local soil class of TEC-2018 is ZA, and the weakest is ZE. The strongest local soil class of TEC-2007 is Z1, and the weakest is Z4. Sivas has a total of 17 districts. Structural analyses were performed for all districts using the mentioned soil classes. The coordinates where the building was thought to be located were randomly determined from the district centers (Table 2). Modal analysis results, elastic design spectra, base shear forces, and roof displacement values obtained from the analyses were compared. The comparisons evaluated how the results changed according to the codes. Since the sample building is symmetrical in the X and Y directions, the results for one direction were presented. Because the results in both directions were the same due to the symmetry condition.

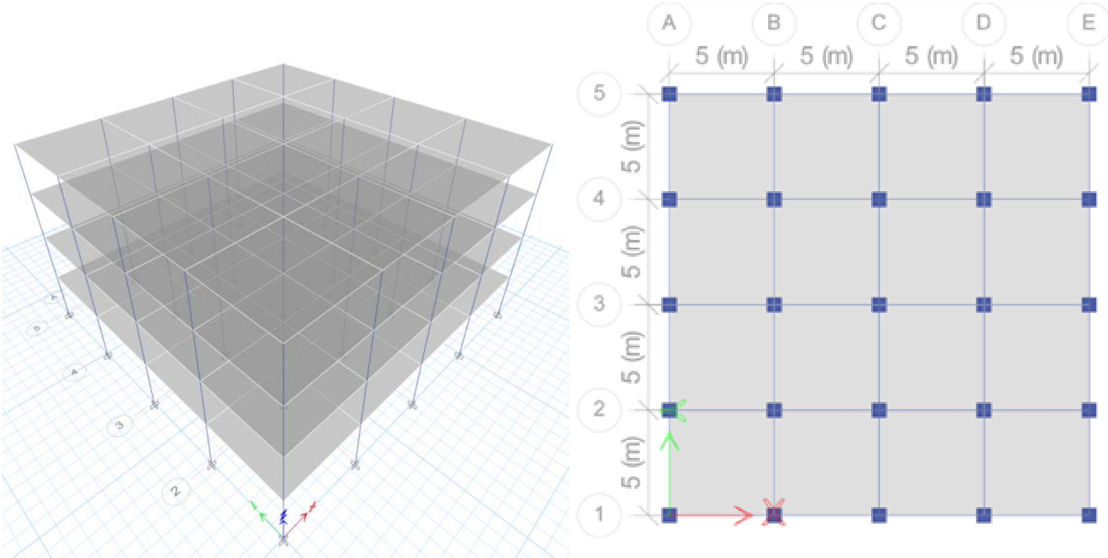


Fig. 3. Sample ETABS model

Table 1. TEC-2018 effective section stiffnesses

Structural element	Effective section stiffness factor		
	Bending	Shear	Axial
Slabs (in-plane)	-	0.25	0.25
Slabs (out-of-plane)	0.25	1.00	-
Beams	0.35	1.00	-
Columns	0.70	1.00	-

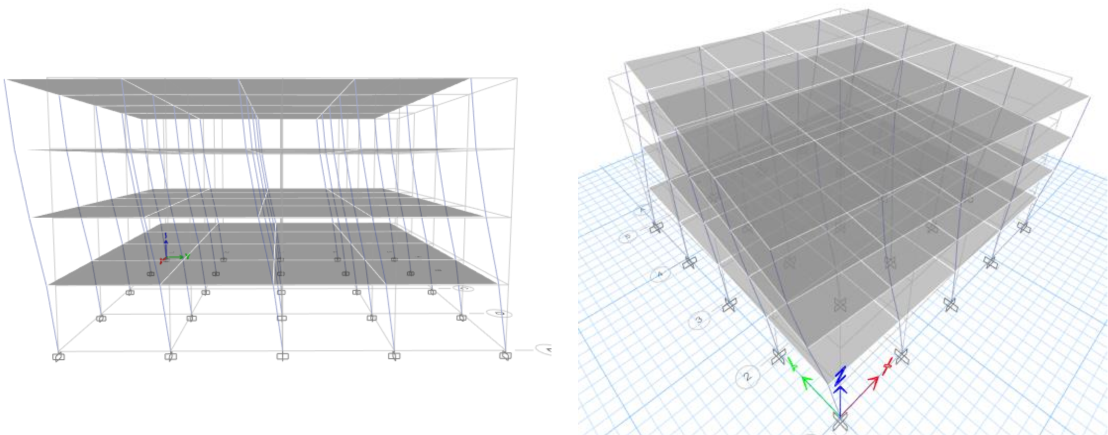
Table 2. Sample building coordinates

District	Latitude	Longitude	District	Latitude	Longitude
Akıncılar	40.078796	38.346721	Kangal	39.233885	37.390599
Altınyayla	39.272987	36.746777	Koyulhisar	40.302171	37.829649
Divriği	39.371753	38.120128	Merkez	39.751253	37.016752
Doğanşar	40.213455	37.539598	Şarkışla	39.351323	36.426407
Gemerek	39.184457	36.073224	Suşehri	40.163366	38.08887
Gölova	40.061147	38.611059	Ulaş	39.447147	37.038414
Gürün	38.720786	37.277892	Yıldızeli	39.869779	36.598861
Hafik	39.854876	37.388857	Zara	39.889527	37.744487
İmranlı	39.869428	38.117429	Kangal	39.233885	37.390599

Since the main purpose of the study was to compare the two codes, a plain, simple, regular, and symmetrical building was preferred. The sample building had four floors. The total height of the building was 12.00 m. The building's floor height was 3.00 m. It was modeled as four spans in both directions. All span lengths were determined as 5.00 m. C25/30 (f_{ck} = 25 MPa) was used as the concrete class. B420C (f_{yk} = 420 MPa) reinforcement class was considered. The modulus of elasticity of the concrete was included in the calculations as E_c = 30,250 MPa, and the modulus of elasticity of the reinforcing steel was included in the calculations as E_s = 200,000 MPa. The sample building was determined as a residential type. The building was designed with a high ductility level structural system. The total weight of the building was calculated as 20235.66 kN. The slab thickness was determined as 15.00 cm. The cross-sections of the beams were 35×70 cm. The cross-sections of the columns were 70×70 cm. The design of the building was carried out in accordance with both TEC-2018 and TEC-2007 conditions. As a result of the modal analysis of the building, the 1st mode vibration period values were obtained as 0.447 s in the model according to TEC-2018 and 0.307 s in the model according to TEC-2007. The effective mass participation ratio (modal participating mass ratio) values for the 1st mode were 0.7952 for the model according to TEC-2018 and 0.8169 for the model according to TEC-2007. Modal analysis results of the first three modes were given in Table 3, and mode shapes of the first three modes were given in Fig. 4. The main reason for the differences in the periods according to the codes is that TEC-2007 does not take into account the cracked section stiffness, while TEC-2018 takes into account the cracked section stiffness. When cracked section stiffness is used, the stiffness of the structural system elements decreases. In this case, the period of the building is extended. The difference in the building's stiffness and period between the two codes also results in different effective mass participation ratios. The effective mass participation ratio is a term that expresses the contribution of the modes to the building's total dynamic response. This ratio was obtained for the first mode as 79.52% according to TEC-2018 and 81.69% according to TEC-2007.

Table 3. Modal analysis results

Mode	Mode shape	Period, T (s)	
		TEC-2007	TEC-2018
1st mode	Translation	0.307	0.447
2nd mode	Translation	0.307	0.447
3rd mode	Torsion	0.275	0.392



(a) (b)

Fig. 4. First three mode shapes; a) 1st and 2nd modes b) 3rd mode

4. Results and discussion

As a result of the analyses, design spectra, base shear forces, and roof displacements were obtained. The results were compared using tables and graphs. When comparing the TEC-2018 and TEC-2007 codes, the results of districts located in the same seismic zone were also compared. During the comparisons, districts were grouped according to TEZM-1996. According to TEC-2007, districts located in the same seismic zone are exposed to the same seismic forces. The changes in the seismic forces of these districts compared to TEHM-2018 and TEC-2018 were also demonstrated through the tables and graphs.

4.1. Design spectrums

Design spectra (Elastic design spectral acceleration, Sae - Period, T graphs) for the coordinates determined for all districts of Sivas were obtained [1, 2, 27, 28]. Spectra were determined for both codes. The strongest (Z1 and ZA) and weakest (Z4 and ZE) local soil classes of the codes were considered. The graphs were given in Figs. 5-8. The maximum spectral acceleration values obtained according to the TEC-2007 and TEZM-1996 were given in Table 4. The maximum spectral acceleration values obtained according to the TEC-2018 and TEHM-2018 were given in Tables 5-8. It should be noted that the comparisons of the elastic design spectra obtained for the two codes were made for a specific period range. It is understood from the graphs that the differences between the values of the two codes are more pronounced in the regions with the largest spectral acceleration values, and that the differences between the codes decrease significantly as the period increases. Comparisons were made for the regions with the largest spectral acceleration values, where the differences were greatest.

When the districts in the 1st degree earthquake zone were examined, the peak spectral acceleration values obtained according to TEC-2018 in the Koyulhisar and Gölova districts were approximately 1.40 times larger than those obtained according to TEC-2007. This difference was 1.30 times larger for the Suşehri and Akıncılar districts. It was understood from the graphs that the elastic design spectra obtained from the two codes for the Doğanşar district were similar to each other. For the Zara and İmranlı districts, although the design spectra generated according to the two codes for weak soil were similar, the spectral acceleration values obtained according to TEC-2007 for strong soils were approximately 2.00 times larger than those obtained from TEC-2018. The reason why the spectral acceleration values obtained for Zara and İmranlı districts according to TEC-2007 are higher than those obtained by TEC-2018 is that the earthquake hazard maps used by the codes (TEZM-1996 and TEHM-2018) are different. Zara and İmranlı districts are considered to be in the 1st degree earthquake zone, the most risky area, in calculations made according to TEC-2007. However, in calculations made according to TEC-2018, earthquake risk is determined according to the coordinates of the building. Zara and İmranlı districts are located further south than Akıncılar, Doğanşar, Gölova, Koyulhisar, and Suşehri districts, which are also in the 1st degree earthquake zone. Therefore, they are further from the NAFZ than these districts. This was taken into account in TEC-2018, which uses a more detailed map, but not in TEC-2007.

When the elastic design spectra obtained from the two codes for the Hafik district, which is in the 2nd degree earthquake zone, were compared, it was determined that the design spectra for the Z4 and ZE weak local soil classes were close to each other. For the Z1 and ZA strong local soil classes, it was determined that the spectral acceleration values obtained according to TEC-2007 were approximately 2.00 times larger than those of TEC-2018.

When the elastic design spectra obtained from the two codes for districts located in the 3rd degree earthquake zone were compared, it was seen that the spectral acceleration values obtained from TEC-2007 for strong soil classes Z1 and ZA were approximately 1.40 times larger than those obtained from TEC-2018. For weak soil classes Z4 and ZE, the values obtained from TEC-2018 were approximately 1.65 times larger than those obtained from TEC-2007.

In the design spectra obtained for districts in the 4th degree earthquake zone, it was seen that the spectral acceleration values obtained from TEC-2018, especially for weak soils, were approximately 3.00 times larger than those obtained from TEC-2007. While the values were closer to each other in strong soils, it was understood from the graphs that the TEC-2018 values were larger.

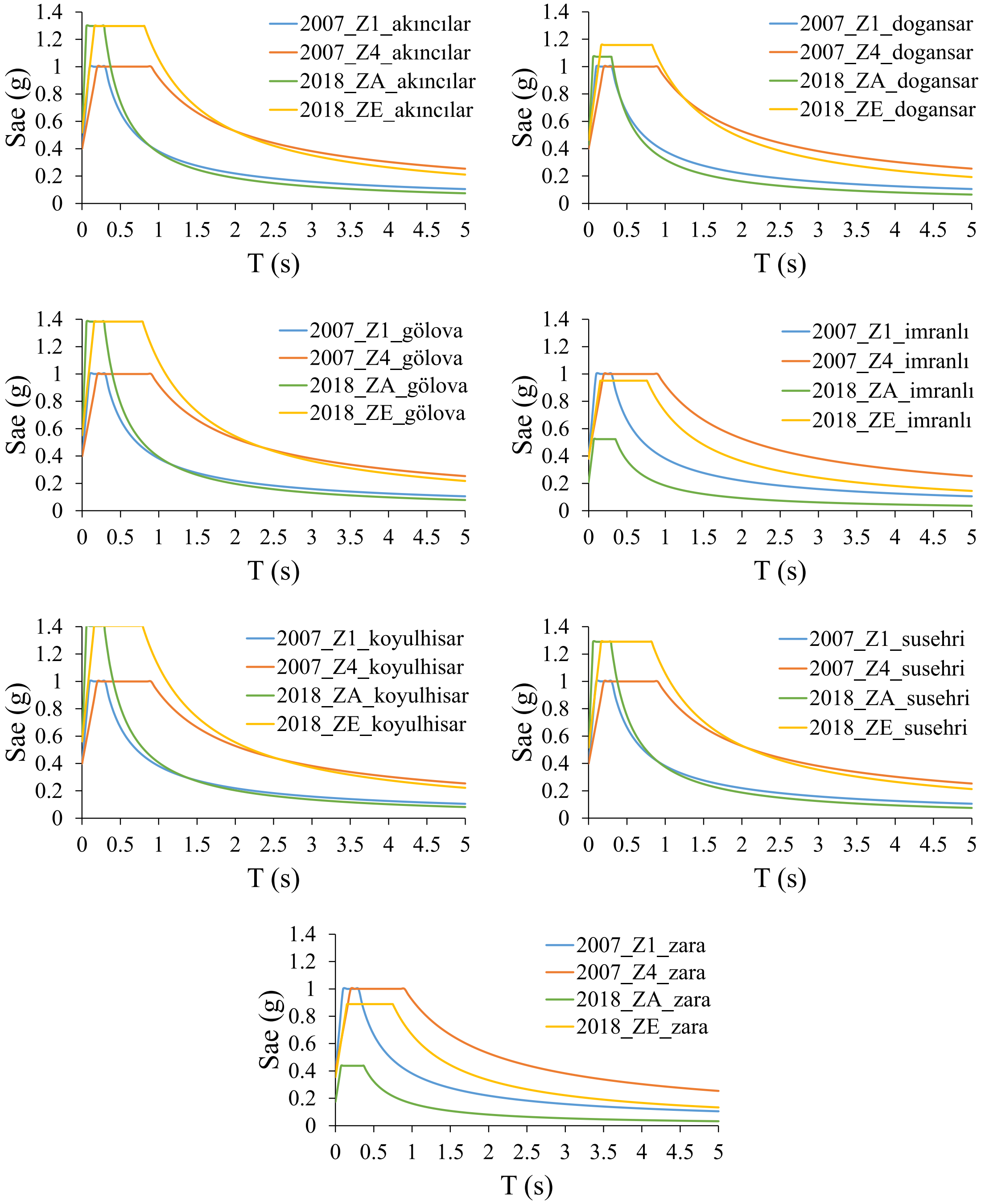


Fig. 5. Elastic design spectra for districts in the 1st degree earthquake zone

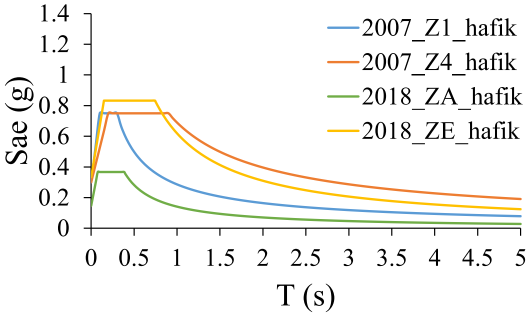


Fig. 6. Elastic design spectra for Hafik district in the 2nd degree earthquake zone

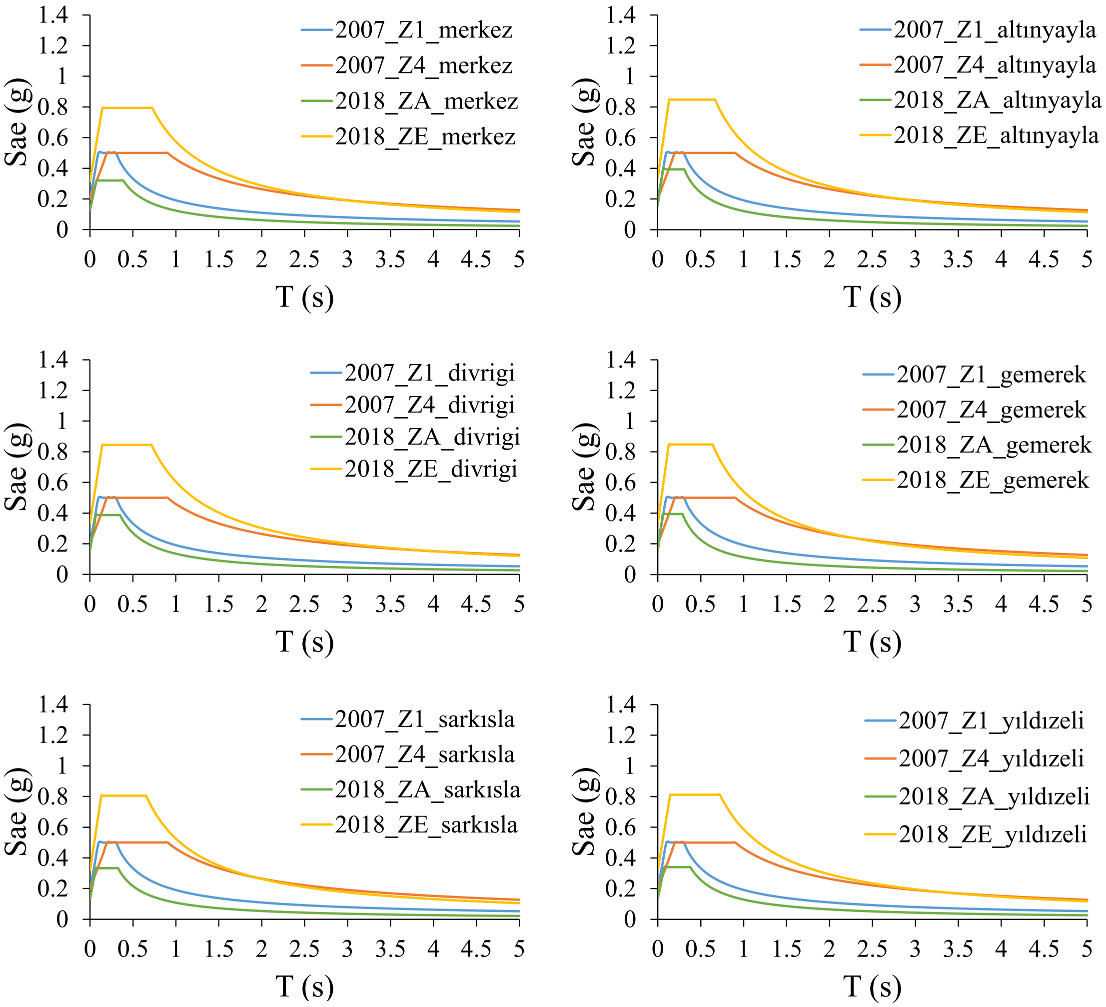


Fig. 7. Elastic design spectra for districts in the 3rd degree earthquake zone

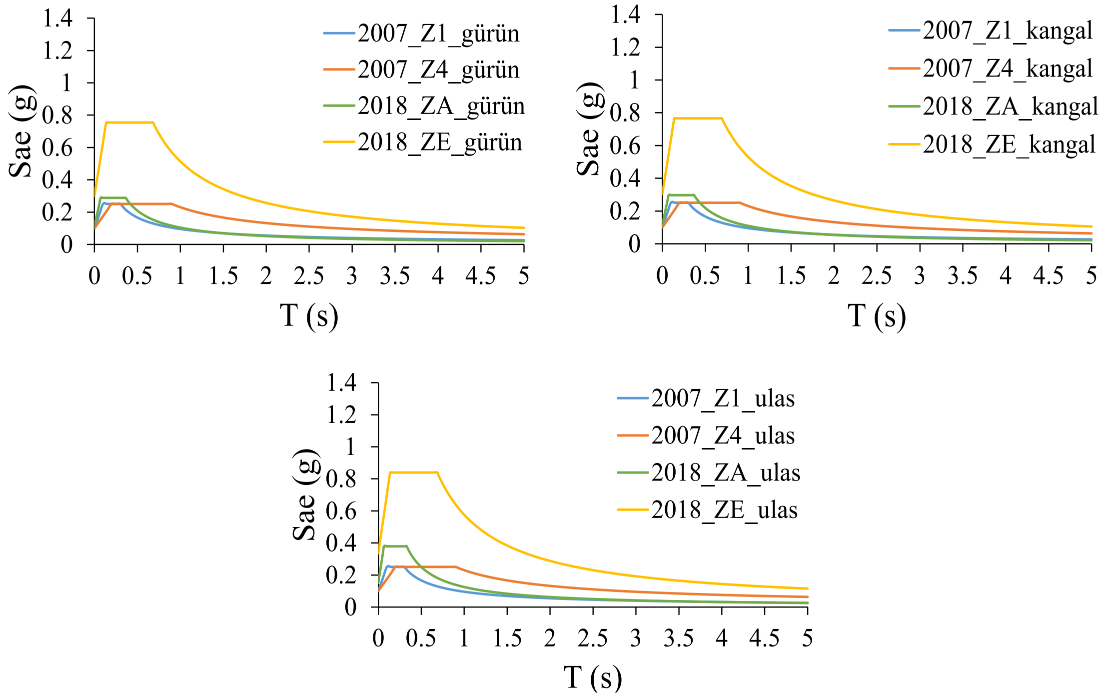


Fig. 8. Elastic design spectra for districts in the 4th degree earthquake zone

Table 4. TEC-2007 maximum spectral accelerations (for Z1 and Z4 soil classes)

Earthquake zone	Spectral acceleration (g)
1st degree	1.00
2nd degree	0.75
3rd degree	0.50
4th degree	0.25

Table 5. TEC-2018 maximum spectral accelerations (districts in the 1st degree earthquake zone)

District	Spectral acceleration (ZA) (g)	Spectral acceleration (ZE) (g)
Akıncılar	1.2976	1.2976
Doğanşar	1.0720	1.1578
Gölova	1.3832	1.3832
İmranlı	0.5240	0.9511
Koyulhisar	1.4056	1.4056
Suşehri	1.2904	1.2904
Zara	0.4376	0.8889

Table 6. TEC-2018 maximum spectral accelerations (district in the 2nd degree earthquake zone)

District	Spectral acceleration (ZA) (g)	Spectral acceleration (ZE) (g)
Hafik	0.3664	0.8326

Table 7. TEC-2018 maximum spectral accelerations (districts in the 3rd degree earthquake zone)

District	Spectral acceleration (ZA) (g)	Spectral acceleration (ZE) (g)
Merkez	0.3208	0.7928
Altınyayla	0.3936	0.8472
Divriği	0.3872	0.8446
Gemerek	0.3944	0.8480
Şarkışla	0.3328	0.8050
Yıldızeli	0.3400	0.8118

Table 8. TEC-2018 maximum spectral accelerations (districts in the 4th degree earthquake zone)

District	Spectral acceleration (ZA) (g)	Spectral acceleration (ZE) (g)
Gürün	0.2888	0.7541
Kangal	0.2976	0.7656
Ulaş	0.3784	0.8401

Considering all seismic zones, when the spectral acceleration values obtained from the two codes for weak soil classes (Z4 and ZE) were compared in all districts except Zara and İmranlı, it was revealed that the values obtained according to TEC-2018 were larger. It was also understood from the elastic design spectra that the values obtained from the two codes in Zara and İmranlı districts were close to each other. According to the spectral acceleration values obtained for the strong soil classes Z1 and ZA, the TEC-2018 values were larger in the districts in the 1st degree earthquake zone, except for Zara and İmranlı districts, the TEC-2018 values were smaller in the districts in the 2nd and 3rd degree earthquake zones, and the TEC-2018 values were larger in the districts in the 4th degree earthquake zone.

4.2. Base shear forces

The base shear forces obtained as a result of the analyses were given in Tables 9-12. When the base shear forces obtained for the districts in the 1st-degree earthquake zone were compared, it was seen that the base shear forces obtained for the strongest and weakest soil classes of TEC-2007 had very close values to each other. When a similar comparison was made for TEC-2018, it was seen that the values obtained for ZE were approximately 2.00 times larger than the values obtained for ZA. It was seen that this difference was up to 3.00 times in Zara and İmranlı districts. When the results obtained for the strongest soil classes of the two codes (Z1 and ZA local soil classes) were compared, it was seen that the values of the two codes were close to each other, except for Zara and İmranlı districts. It was understood from the table that the values obtained according to TEC-2018 were much smaller in the Zara and İmranlı districts. When the results obtained for the weakest soil classes of the two codes (Z4 and ZE local soil classes) were compared, the values obtained from TEC-2018 were approximately 1.20 times larger for the districts of Zara and İmranlı. This difference increased to 1.60 times for the district of Doğanşar. For the districts of Akıncılar, Gölova, Koyulhisar, and Suşehri, it was approximately 1.80 times larger.

When comparing the base shear forces obtained for the Hafik district, located in a 2nd-degree earthquake zone, it was seen that the values obtained for the two local soil classes of TEC-2007 were very close to each other. When comparing the values obtained for the two soil classes of TEC-2018, the value obtained for the weak soil class ZE was approximately 3.40 times larger than the value obtained for ZA. When comparing the values obtained for soil classes Z1 and ZA, it was seen that the value obtained for Z1 was approximately 2.25 times larger than the value obtained for ZA. The value obtained for ZE was approximately 1.45 times larger than the value obtained for Z4.

Table 9. Base shear forces of districts in the 1st degree earthquake zone, V_t (kN)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Akıncılar	2075.9972	2122.7052	1849.3228	3752.4377
Doğanşar	2075.9972	2122.7052	1584.7197	3376.1257
Gölova	2075.9972	2122.7052	1958.3805	3946.1614
İmranlı	2075.9972	2122.7052	895.4439	2671.3662
Koyulhisar	2075.9972	2122.7052	2019.2738	4012.6809
Suşehri	2075.9972	2122.7052	1859.4605	3747.5561
Zara	2075.9972	2122.7052	782.8491	2476.0935

Table 10. Base shear forces of the district in the 2nd degree earthquake zone, V_t (kN)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Hafik	1557.7679	1592.8282	679.2799	2312.8420

Table 11. Base shear forces of districts in the 3rd degree earthquake zone, V_t (kN)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Merkez	1037.8761	1061.3525	597.4489	2176.7178
Altınyayla	1037.8761	1061.3525	597.1299	2239.3957
Divriği	1037.8761	1061.3525	659.0467	2307.2255
Gemerek	1037.8761	1061.3525	560.5522	2193.0133
Şarkışla	1037.8761	1061.3525	530.2547	2104.4018
Yıldızeli	1037.8761	1061.3525	619.4725	2225.6503

Table 12. Base shear forces of districts in the 4th degree earthquake zone, V_t (kN)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Gürün	518.2173	529.8406	508.3543	2012.6899
Kangal	518.2173	529.8406	530.3000	2059.4635
Ulaş	518.2173	529.8406	611.9826	2250.5277

When the base shear forces obtained for the districts in the 3rd degree earthquake zone were compared, it was seen that the values obtained for the strongest and weakest local soil classes of TEC-2007 were very close to each other. In TEC-2018, the values obtained for ZE were approximately 3.75 times larger than the values obtained for ZA. In comparisons made considering the two codes, it was seen that the values obtained for Z1 were approximately 1.70 times larger than those obtained for ZA. The values obtained for ZE were also found to be approximately 2.00 times larger than those obtained for Z4.

When the base shear forces of the districts in the 4th degree earthquake zone were examined, it was found that the values obtained for Z1 and Z4 soil classes in TEC-2007 were very close to each other. According to TEC-2018, the values obtained for ZE were approximately 3.75 times larger than those obtained for ZA. It was clear from the table that the base shear forces obtained for the weakest soil classes of the two codes, Z1 and ZA, were close to each other. The values obtained for ZE were approximately 3.90 times greater than those obtained for Z4.

When the base shear forces obtained for the Z1 and ZA local soil classes, which are the strongest soil classes of the two codes, were compared, it was seen that the values obtained according to TEC-2007 were greater in all districts except Ulaş and Kangal. For the Z4 and ZE soil classes, the values obtained according to TEC-2018 were much greater in all districts.

4.3. Roof displacements

The roof displacement values obtained for the sample building are given in Tables 13-16. A comparison of the roof displacement values obtained for the districts in the 1st-degree earthquake zone revealed that the roof displacement values obtained for the strongest and weakest soil classes of TEC-2007 were very similar. A similar comparison for TEC-2018 revealed that the values obtained for ZE were approximately 2.00 times greater than those obtained for ZA. This difference increased to 3.00 times in the Zara and İmranlı districts. Comparing the results for the strongest soil classes of the two codes (Z1 and ZA local soil classes), it was observed that the values were close to each other for Zara and İmranlı districts. For districts other than Zara and İmranlı, the values obtained according to TEC-2018 were approximately 1.85 times greater. Comparing the results obtained for the weakest soil classes of the two codes (Z4 and ZE local soil classes), the values obtained from TEC-2018 were approximately 2.50 times larger for the Zara and İmranlı districts. This difference increased to 3.50 times for the Doğanşar district. It also increased to approximately 3.90 times for the Akıncılar, Gölova, Koyulhisar, and Suşehri districts.

Table 13. Roof displacement values of districts in the 1st degree earthquake zone (mm)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Akıncılar	3.793	3.860	6.920	14.976
Doğanşar	3.793	3.860	5.955	13.484
Gölova	3.793	3.860	7.323	15.729
İmranlı	3.793	3.860	3.422	10.632
Koyulhisar	3.793	3.860	7.563	15.996
Suşehri	3.793	3.860	6.967	14.962
Zara	3.793	3.860	3.006	9.847

Table 14. Roof displacement values of the district in the 2nd degree earthquake zone (mm)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Hafik	2.846	2.897	2.617	9.195

Table 15. Roof displacement values of districts in the 3rd degree earthquake zone (mm)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Merkez	1.896	1.930	2.303	8.643
Altınyayla	1.896	1.930	2.251	8.852
Divriği	1.896	1.930	2.517	9.156
Gemerek	1.896	1.930	2.097	8.647
Şarkışla	1.896	1.930	2.009	8.307
Yıldızeli	1.896	1.930	2.383	8.836

Table 16. Roof displacement values of districts in the 4th degree earthquake zone (mm)

District	2007_Z1	2007_Z4	2018_ZA	2018_ZE
Gürün	0.947	0.964	1.949	7.966
Kangal	0.947	0.964	2.035	8.158
Ulaş	0.947	0.964	2.324	8.911

A comparison of the roof displacement values obtained for the Hafik district, located in a 2nd-degree earthquake zone, revealed that the values obtained for the two local soil classes of TEC-2007 were very close to each other. A comparison of the values obtained for the two soil classes of TEC-2018 revealed that the value obtained for ZE was approximately 3.50 times greater than the value obtained for ZA. The values obtained for soil classes Z1 and ZA were very close to each other. The value obtained for ZE was approximately 3.15 times greater than the value obtained for Z4.

When the roof displacement values obtained for the districts in the 3rd degree earthquake zone were compared, it was seen that the values obtained for the strongest and weakest local soil classes of TEC-2007 were very close to each other. In TEC-2018, the values obtained for ZE were approximately 4.00 times larger than the values obtained for ZA. When the two codes were considered, the values obtained for ZA were approximately 1.20 times larger than those obtained for Z1. The values obtained for ZE were also approximately 4.50 times larger than those obtained for Z4.

When the roof displacement values of the districts in the 4th degree earthquake zone were examined, it was determined that the values obtained for soil classes Z1 and Z4 in TEC-2007 were very close to each other. According to TEC-2018, the values obtained with ZE were approximately 4.00 times larger than those obtained for ZA. When the roof displacement values obtained for the weakest soil classes of the two codes (Z1 and ZA) were examined, it was understood that the values obtained for ZA were approximately 2.00 times larger. The values obtained for ZE were approximately 8.00 times larger than those obtained for Z4.

When comparing the roof displacement values obtained according to the TEC-2007 and TEC-2018 codes, it was observed that the values obtained according to TEC-2018 were greater for both the strongest soil classes (Z1 and ZA) and the weakest soil classes (Z4 and ZE). Only for the comparison of the strong soil classes of İmranlı, Zara, and Hafik districts, the values obtained from TEC-2007 were greater.

5. Conclusions

In this study, the TEC-2018 and TEC-2007 codes were compared, considering all districts of Sivas. A four-story reinforced concrete building was used as a sample. The strongest and weakest local soil classes of both codes were included in the calculations. The response spectrum analysis method was used for earthquake calculations. The analysis results were evaluated, and the differences between the two codes were revealed, specifically for Sivas. The results obtained can be summarized as follows.

1. When the modal analysis results obtained according to the TEC-2018 and TEC-2007 principles were examined, it was seen that the 1st mode period value obtained according to TEC-2018 is 1.456 times greater than the value obtained according to TEC-2007. This was explained by the fact that TEC-2018 includes cracked section stiffness in its linear calculations, while TEC-2007 does not.
2. According to TEC-2007, the elastic design spectra of regions within the same seismic zone and soil class are identical. Furthermore, in the elastic design spectra obtained according to TEC-2007, if the building is located in the same seismic zone, the peak spectral acceleration value remains unchanged regardless of the soil class. The period range affected by the peak ground acceleration changes with the change of soil class. In TEC-2018, both the peak ground acceleration values and the period range affected by the peak ground acceleration can change. In TEC-2007, the same design

spectra are used for buildings in the same seismic zone. In TEC-2018, design spectra vary across districts, even when buildings are in the same seismic zone. This demonstrates that TEC-2018 creates more realistic and detailed elastic design spectra than TEC-2007. The TEHM-2018 used in TEC-2018 is one of the most important factors contributing to the more realistic and detailed design spectra. The graphs demonstrate that the local soil class effect is reflected much more effectively in the design spectra obtained with TEC-2018 than in those obtained with TEC-2007. It should be noted that the acceleration spectra for the long-period values in the elastic design spectra obtained for the two codes are close to each other. It can be noted that the comparisons were made in the regions with the highest spectral acceleration values in the design spectra, which correspond to the shorter period range.

3. Elastic design spectra were compared for small period values with large spectral acceleration values in this study. The graphs indicate that the spectral acceleration values obtained for the two codes are very close to each other after a certain period value. The elastic design spectra indicate that the difference between the spectral acceleration values obtained for the two codes decreases significantly after 1 s for strong soils and after 2 s for weak soils. This will affect earthquake calculations depending on the period of the buildings.
4. When the base shear forces and roof displacement values obtained for the Z1 and Z4 local soil classes, the strongest and weakest local soil classes of TEC-2007, were compared, it was determined that the values obtained for the two local soil classes were very similar. When the base shear forces and roof displacement values obtained for the ZA and ZE local soil classes, the strongest and weakest local soil classes of TEC-2018, were compared, it is clear from the tables that the values obtained for the ZE soil class were much larger. It should be noted that these assessments are valid for the sample building used in the study, and that it would be inappropriate to generalize to the codes. These values can vary significantly, especially with changes in the building period.
5. Comparisons of base shear forces for the two codes indicated that TEC-2007 was safer on strong soils, while TEC-2018 was safer on weak soils. Comparisons of roof displacements also revealed that TEC-2018 was significantly safer, particularly on weak soils.
6. According to TEC-2007, the same results were obtained for districts in the same earthquake zone. However, according to TEC-2018, the results also differed for districts in the same earthquake zone. This difference was particularly evident in the Doğanşar, İmranlı, and Zara districts, which were in the first-degree earthquake zone, and in the Ulaş district, which was in the fourth-degree earthquake zone. This was primarily due to the different seismic zone maps used by the codes. The TEHM-2018 used by TEC-2018 is much more detailed.
7. Some of the results obtained for Zara, İmranlı, and Hafik districts showed that the values obtained with TEC-2007 were larger. It was thought that one of the main reasons for this situation was that TEZM-1996 considered these districts as more seismically risky than TEHM-2018.
8. The analyses indicated that the districts of Gölova and Koyulhisar in Sivas are most at risk in terms of seismicity. Furthermore, the analyses indicated that the central district is not at high risk, while the districts of Gürün and Kangal are the least at risk.
9. When the results (design spectrums, base shear forces, roof displacements) were examined, it was seen that the local soil class effect was better reflected in TEC-2018. However, the differences in the results were not solely related to the local soil class. There are differences in many parameters used in the earthquake calculations of the two codes, such as spectral acceleration coefficients, design spectrum formulas, and seismic maps. These parameters may cause the results to differ.
10. It should be noted that the code comparisons were made for a sample building and coordinates determined specifically for the city of Sivas. It would be inappropriate to generalize based on the

differences between the two codes based on the results obtained in the study, such as base shear forces and roof displacements. The codes contain numerous differences, including earthquake parameters, soil parameters, and seismic hazard maps. These differences also lead to differences in seismic calculations based on the dynamic properties of the buildings. It is believed that more sample buildings and different locations will be needed to generalize the calculation results obtained under the two codes.

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Data availability statement

All the data generated and used in the current study are available in the manuscript.

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