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THE EFFECT OF LOCAL SITE CHARACTERISTICS ON DYNAMIC SITE RESPONSE ANALYSES OF A MAJOR URBAN AREA: WARNINGS OF MODERATE SCALE EARTHQUAKES

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Abstract. The Western Anatolia is one of the major seismically active regions in Turkey. The city of Izmir, which is the third greatest city of the country, has been subjected to moderate scale earthquakes in long distances since April 2003. The 10.04.2003 Urla Earthquake ($M = 5.6$), the 17.10.2005 Sığacık Bay (Seferihisar) Earthquakes ($M = 5.7$ and $M = 5.9$), and the 21.10.2005 Uzunkuyu-Urla Earthquake ($M = 5.9$) are the most serious earthquakes causing some damage to medium-height buildings on alluvial soil deposits. However, the most recently occurred moderate scale earthquake in the city center was the 16.12.1977 Izmir Earthquake ($M = 5.3$).). In this study, the effect of local soil conditions on dynamic site response analyses in the northern coast of Izmir Bay Area has been investigated. The design spectrum for the northern coast of Izmir Bay area was developed by using strong motion records of the abovementioned close and long distance earthquakes and following the equivalent-linear method principles. While dynamic site-response analyses have been performed, it has been determined that the limits of spectrum defined in the Turkish Seismic Code has been accessed / exceeded for some alluvial regions of the city. Results of dynamic site-response and structural performance analyses on selected damaged building have been interpreted according to the national and international seismic codes.

Keywords: seismic risk, site response analysis, design spectrum, pushover analysis, seismic code.
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1 Introduction

Growing population of metropolitan areas increasingly forces local and national authorities to take risks in their decisions of new urbanization area designations in seismically active regions. The city of Izmir demonstrates major examples of urbanization on marginal soils such as thick saturated alluvial soil deposits on or nearby active faults.

Izmir Bay and surrounding area are widely deformed by N-S and NE-SW oriented strike slip, reverse and the E-W directional normal faults. Assessment of critical faults and seismicity of the study area can be followed in detail in published literature (McKenzie, 1972; Dewey & Şengör, 1979; Ambraseys & Finkel, 1995; Emre & Barka, 2000; Sozbilir, 2002; Ocakoglu et al., 2005; Emre et al., 2005; Utku et al., 2001; Ansal, 1995; RADIUS, 1999; Akinci et al., 2000).

The city of Izmir was subject to major destructive earthquakes from historical ages to recent times. The 1688, 1739 and 1778 earthquakes caused significant damage in Izmir during historical period (Ambraseys & Finkel, 1995). Magnitudes of major instrumental seismic period earthquakes varied between 5.3 and 6.5, the latest taking place in 2005 (Sozbilir, 2002; Ocakoglu et al., 2005). Major seismic sources producing destructive earthquakes in the vicinity of Izmir were determined as the Izmir Fault, and faults located in the Karaburun and Urla Peninsulas (Fig. 1). The seismic risk area, which is shown as a circle with a diameter of 100 km, bounds critical seismic sources affecting Izmir (Emre et al., 2005; Utku et al., 2001).

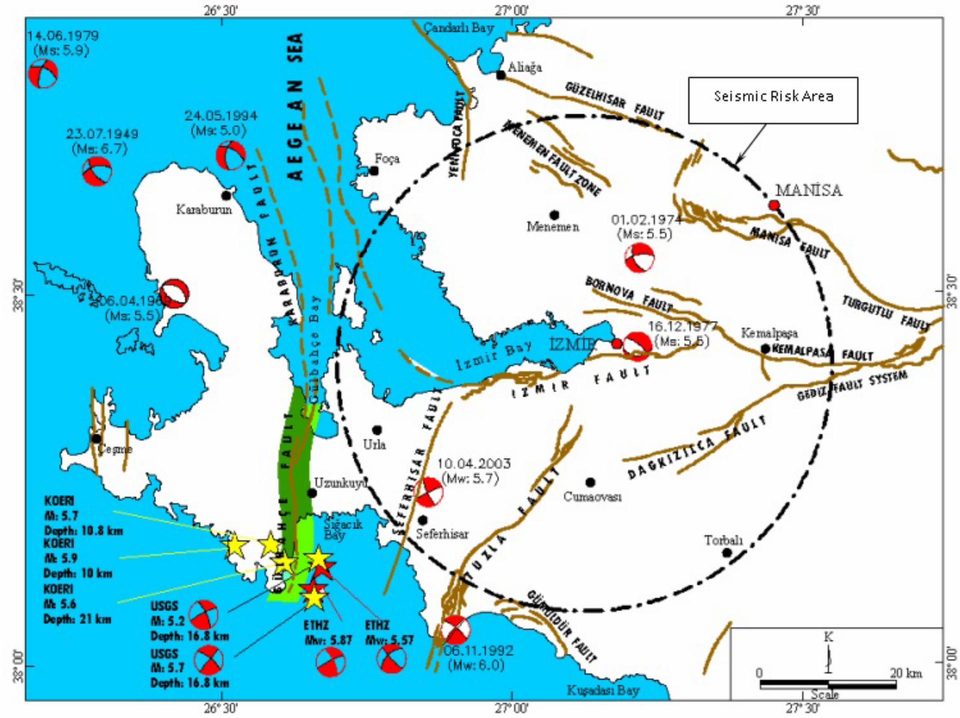

Figure 1: Major active faults and seismic risk area for seismic risk analyses of Izmir (Utku et al., 2001; Emre et al., 2005)

2 Seismicity and Geotechnical Properties

The seismic risk of the city of Izmir has been studied in the past. A scenario based deterministic risk analysis study sponsored by United Nations for the city of Izmir assumed the magnitude of the governing scenario motion on the Izmir Fault as M=6.5 (RADIUS, 1999).

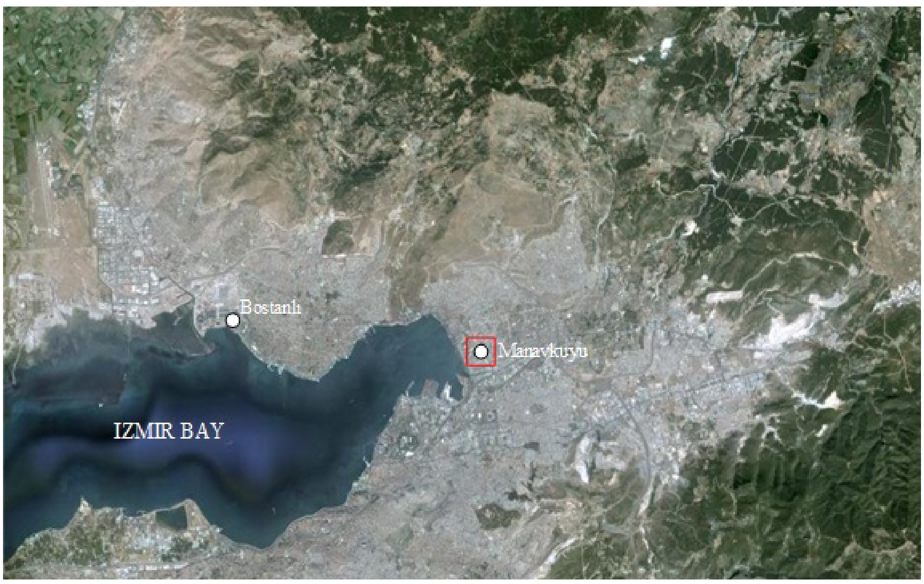

Figure 2: Location of Manavkuyu region in Izmir

The 2003 Urla Earthquake, the epicenter of which is about 42 km away from the investigated area, caused widespread slight to moderate damage on several medium rise apartment buildings situated in thick alluvial soils of Manavkuyu region of the city (Fig. 2).

It was observed during past moderate size earthquakes that local soil conditions played an important role on ground motions. Especially, earthquake intensity was considerably larger (VI to VII according to Modified Mercalli Intensity Scale) in regions of the city on thick alluvial soils when compared with sites on stiffer soils or rocks.

Geotechnical soil characteristics of Manavkuyu show variations because of horizontal and vertical discontinuities in alluvium soil layers. The idealized soil profile of the Manavkuyu is given in Fig. 3.

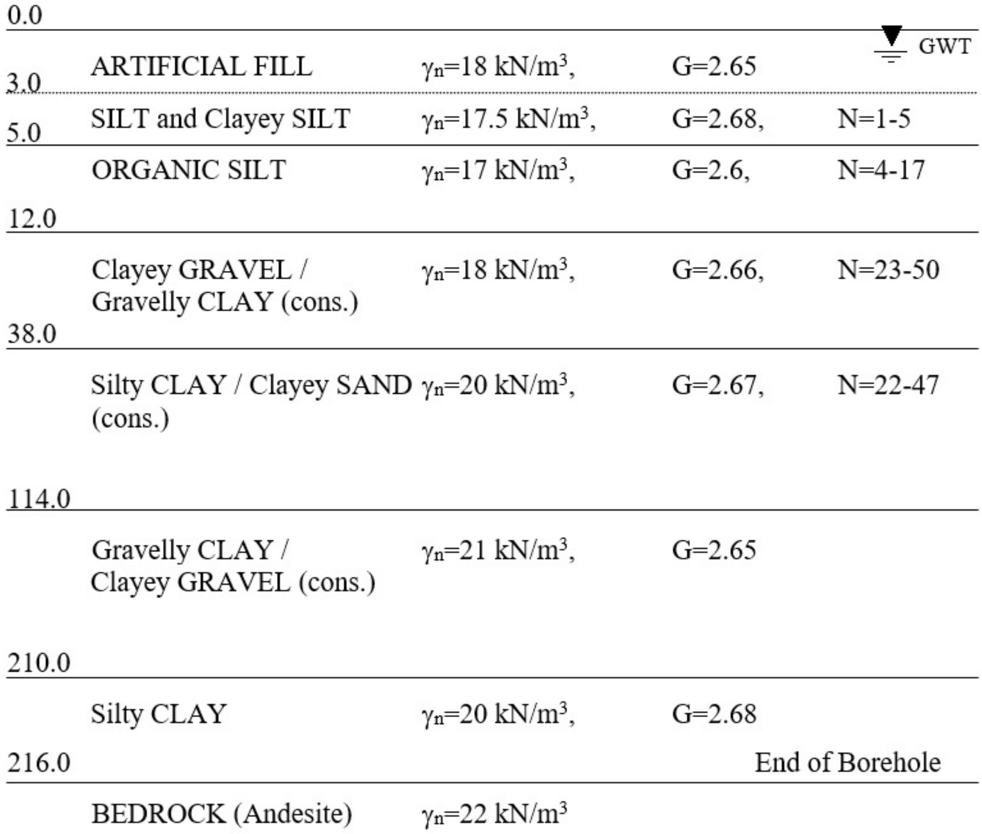

Figure 3: Idealized Soil Profile in Manavkuyu

Local soil conditions play an important role on seismic ground motion parameters that would directly govern structural design (Seed et al., 1990, 1987; Ansal, 1995; Marcellini et al., 2001; Hashash et al., 2010; Loris-Caballero, 2012; Eskisar et al., 2014; Tsai & Chen, 2014; Kaklamanos et al., 2015; Edincliler & Tuncay, 2018). Observations following past earthquakes in Izmir reminded that local soil conditions played a major role on damage distribution. Therefore, special attention was paid on developing site specific response spectra by means of equivalent linear one-dimensional site response method (Bardet et al., 2000). Variation of the maximum shear modulus and shear wave velocity values utilized in site response analysis is shown in Fig.4.

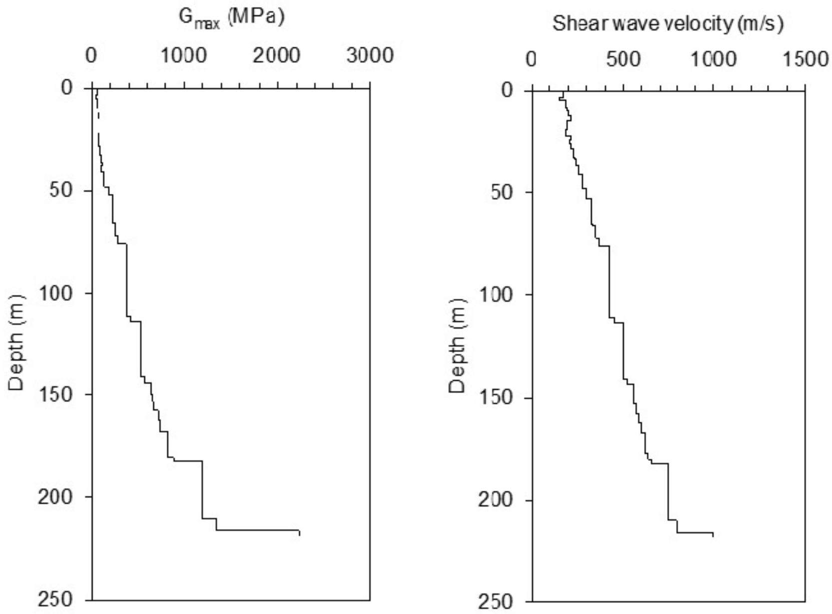

Figure 4: Variation of Dynamic Soil Parameters in Manavkuyu Region

3 Dynamic Site Response Analyses

The Izmir Fault and the south branch of the Karaburun Fault are considered as critical seismic sources in the vicinity of Izmir. The Izmir Fault, having normal fault characteristics, produced the 1977 Izmir Earthquake ($M = 5.3$) and is expected to impose larger level of hazard in close distance. The filtered record (Ambraseys et al., 2002) of this earthquake was selected as the representative close distance moderate scale earthquake record. In a similar manner, the April 2003 Urla ($M = 5.6$) and October 17-21 2005 Sığacık Bay ($M = 5.6$ and $M = 5.9$) earthquake records were considered as representative long distance ground motions. These earthquakes were strongly felt at alluvial soil sites in Izmir. The maximum bedrock acceleration that would occur in Manavkuyu was estimated using Campbell attenuation model (1997) (Campbell, 1997). Dynamic soil parameters were calculated from the equations in the literature (Seed & Idriss, 1970; Hardin, 1978; Hardin & Drnevich, 1972; Ohta & Goto, 1976; Imai & Tonouchi, 1982; Kramer, 1996). Dynamic site response analyses were performed based on the equivalent-linear model using EERA (Bardet et al., 2000) software. Results of dynamic analyses are summarized in Table 1. In this table, $PGA(g)$: Peak ground acceleration; Amp. Ratio: Amplification ratio ($PGA/a_{max,bedrock}$); $S_a(T)(g)$: Maximum spectral acceleration on ground surface; Spectral Amp. Ratio: Spectral amplification ratio ($S_a/S_{a,bedrock}$); and $T_{0,earthquake}(sec)$: Fundamental period of earthquake motion, $T_{0,site}(sec)$: Predominant period of soil profile in the site, are presented as symbols.

One may conclude from Table 1 that peak ground accelerations reach high values for close earthquakes, and spectral amplification ratios are more pronounced for long distance earthquakes. Dynamic site response analyses were repeated using Kalkan and Gülkan attenuation (Kalkan & Gülkan, 2004) based on Boore et al (1997) relationship. According to structural performance analyses mentioned in the following paragraphs, demands calculated from Campbell attenuation were in agreement with the observations of the general damage state. Therefore, results of dynamic analyses with Campbell attenuation relationship (Campbell, 1997) were given.

4 Construction of Design Spectra

A design spectrum was constructed with commonly used Newmark-Hall procedure (Chopra, 1995) using peak values of acceleration, velocity and displacement in site response analyses. The response spectra obtained from dynamic analyses using EERA (Bardet et al., 2000) are given in Figure 5. These spectra were obtained from close and long distance earthquakes and scenario earthquakes shown in Table 1. Fundamental period of computed earthquake motions for close distance earthquakes is approximately 0.11s whereas it is in the range of 0.55-1.7 s for long distance earthquakes.

Table 1: Results of Dynamic Site Response Analyses

Earthquake	PGA (g)	Amp. Ratio	$S_a(T)$ (g)	Spectral Amp. Ratio	$T_{0,earthquake}$ (sec)	$T_{0,site}$ (sec)
16.12.1977 Izmir (M=5.3)	0.20	1.67	0.82	2.00	0.10	1.87
10.04.2003 Urla (M=5.6)	0.08	3.42	0.28	4.00	0.82	1.87
17.10.2005 Sığacık Bay (I) (M=5.7)	0.07	4.50	0.23	4.07	0.86	1.87
17.10.2005 Sığacık Bay (II) (M=5.9)	0.08	4.88	0.25	4.10	0.74	1.87
21.10.2005 Uzunkuyu-Urla (M=5.9)	0.09	4.09	0.29	4.14	1.55	1.87
16.12.1977 Izmir (scaled up for M=6.5)	0.32	1.28	1.30	1.53	0.11	1.87
10.04.2003 Urla (scaled up for M=6.5)	0.16	2.90	0.56	3.50	0.82	1.87
17.10.2005 Sığacık Bay (I) (scaled up for M=6.5)	0.11	4.06	0.46	4.18	0.84	1.87
17.10.2005 Sığacık Bay (II) (scaled up for M=6.5)	0.12	4.07	0.61	4.07	0.74	1.87
21.10.2005 Uzunkuyu-Urla (scaled up for M=6.5)	0.15	3.75	0.48	3.69	1.55	1.87

A statistical study was performed using set of motions in Table 1 recorded on soft soil conditions. Firstly, the average acceleration spectrum was obtained in terms of spectral amplification

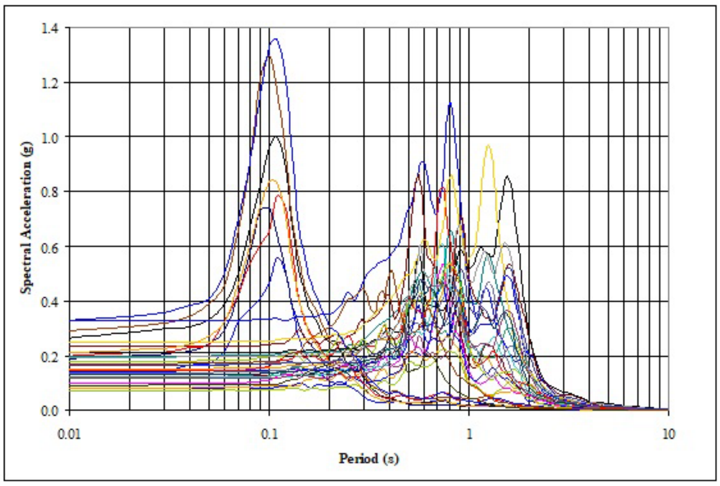

Figure 5: Spectral shapes obtained from close and long distance earthquakes

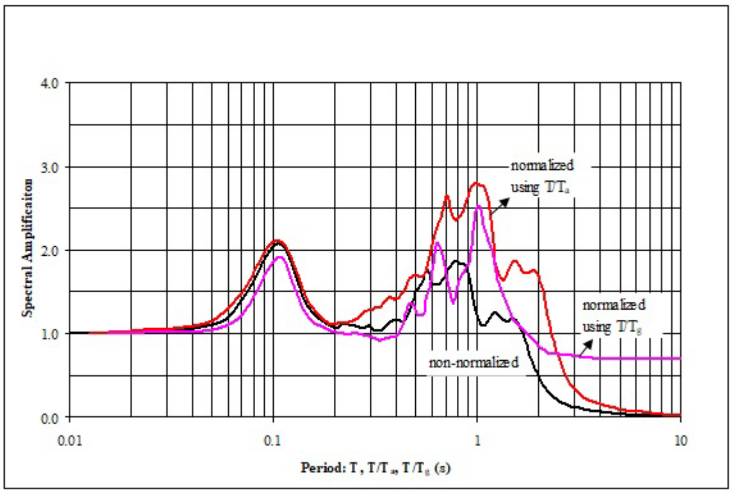

Figure 6: Average acceleration spectra based on set of motions recorded on soft soil

(Fig. 6). The structural period presented in this figure is expressed in three different ways (Gazetas, 2006): (*i*). The actual period, T used in construction of design response spectra is given; (*ii*). The normalized period T/T_g, where T_g is defined as the "effective" ground period that 5%-damped velocity response spectrum attains its maximum (Miranda & Bertero, 1994), is obtained; and (*iii*). The normalized period T/T_a, where T_a is a period that acceleration spectrum attains its maximum, is found.

When spectral amplification is plotted against the actual period, the average spectrum shows two peaks nearby fundamental periods of close and long distance earthquakes. The spectra of close and long distant earthquake motions recorded on soft soil give their peaks at different periods, clearly (Fig. 5). However, averaging the spectra provides a smoothing shape in which peak spectral amplifications are obtained at 0.11 and 0.8 s. When plotted against the normalized period T/T_a, the average spectrum gives a characteristic peak at value of T/T_a in the vicinity of 1. Spectral amplification value closes to 2.8 for long distant earthquake motions, and an increased period due to soil-structure interaction (SSI) occurs. Similarly, a characteristic peak is obtained at value of T/Tg nearby 1. Spectral amplification reaches to 2.5 for long distant earthquake motions. Determining the characteristic dominant period (in this study, $T_a = 0.8$ s and $T_g = 0.64$ s) for a given site and properly normalizing the structural period by a dominant period of motion before statistically processing response spectral values produces an increased period due to SSI causing higher response. An important role of soil-structure interaction on design of buildings was emphasized in previous studies (Gazetas, 2006; Miranda & Bertero, 1994; Miranda, 1993; Gazetas & Mylonakis, 1998) and is also proven with this work.

The elastic design spectra were constructed based on the spectral acceleration values using Campbell and Kalkan & Gülkan attenuation relationships (Campbell, 1997; Kalkan & Gülkan, 2004) in dynamic analyses. Two design spectra have been constructed in this study for close and long distance earthquake records and scenario motions (Fig. 7). The characteristic periods of design spectra cover the defined periods in the Turkish Seismic Code (Turkish Seismic Code, 2007) for $Z4$ type of soils. The characteristic periods were $TA = 0.2$ and $TB = 0.9$ seconds for deep saturated alluvial soils ($Z4$ type of soils) in the Seismic Code. The constructed design spectra have greater spectral plateau than the Seismic Code. The characteristic periods of design spectrum based on spectral accelerations using Campbell attenuation in Fig. 5 were determined as 0.08 and 1.5 seconds. Kalkan and Gülkan relationship give characteristic periods of 0.09 and 1.6 seconds. Characteristic periods of design spectrum from scenario motions with Campbell were calculated as 0.07 and 1.6 seconds. The periods were found as 0.08 and 1.75 seconds.

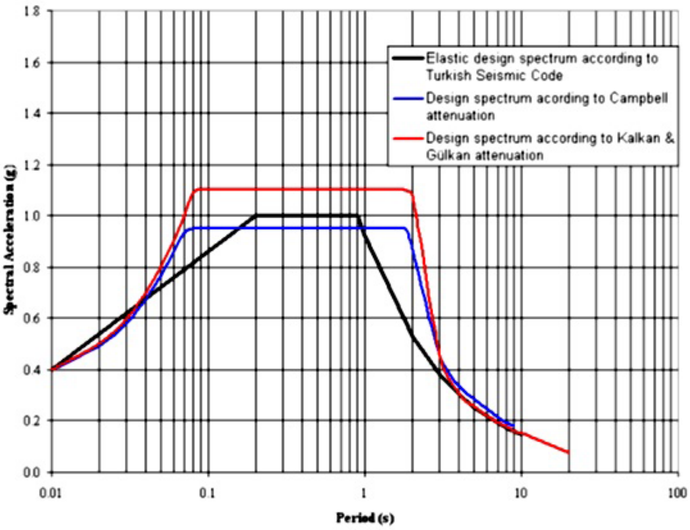

Figure 7: TSC elastic design spectrum and design spectra obtained from occurred and scenario earthquakes

5 Structural Performance Analyses

In order to investigate the effect of moderate scaled long distance earthquakes on mid-rise reinforced concrete (RC) buildings in Manavkuyu region, a 9-storey RC building with 25.1 m height, 23.4 m × 12.2 m plan dimensions was selected. Height of the ground floor is 3.5 m and the other floors are 2.7 m each. Fig. 8 shows the plan and 3D structural model of the building. The main lateral force-resisting system includes a number of columns connected with floor slabs and beams. The total weight of the building is calculated as $W = 2663$ tons. The foundation system of building takes place on thick saturated alluvium strata which is classified as $Z4$ according to Turkish Seismic Code (Turkish Seismic Code, 2007).

In order to determine the earthquake performance of the investigated building during scenario earthquake with $M = 6.5$, firstly it is attempted to define appropriate attenuation relationship for Manavkuyu region. For this purpose, the observed structural damage and earthquake performance of structure during the 2003 and 2005 Urla Earthquakes are compared with the theoretical earthquake performance evaluated according to Campbell and Kalkan & Gülkan attenuation relationships. Observations after the 2003 Urla Earthquake with $M = 5.6$ show that there was no structural damage occurred at the building but slight damages were observed at

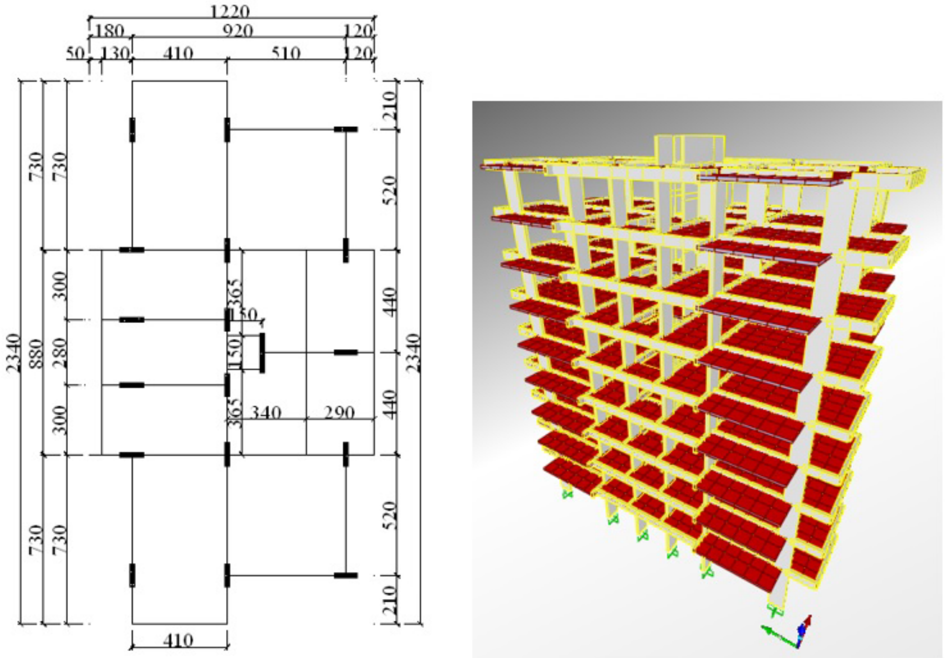

Figure 8: The plan and 3D structural model of the building

non-structural elements. Following this earthquake, another moderate scale earthquake $M = 5.9$ was occurred at Uzunkuyu-Urla region in 2005. Investigations after this earthquake show that some structural and non-structural elements reached to moderate damage state.

The detailed 3-D finite element idealizations were constructed for the building in order to perform pushover analysis. All structural 3-D analyses were carried out using structural analysis and design program ETABS®. Basic structural properties in that fundamental period, participating mass ratio and modal participation factor for X and Y directions of the building obtained from analyses are given in Table 2.

Table 2: The structural parameters of the selected building

Direction	T_1 **(sec)**	$a(\%)$	Γ
X	1.957	77.6	1.297
Y	1.384	78.1	1.350

Since modal mass participation ratios α in both directions are more than 70%, lateral load distribution throughout the height of the building is chosen as the fundamental mode shape of the investigated direction at the pushover analysis. The capacity curve and displacement demands of 2003 and 2005 Urla earthquakes for X and Y directions of the building calculated from strong motion records are shown in Figures 9 and 10, respectively.

Spectral accelerations were calculated using Campbell (1997) and Kalkan & Gülkan (2004) attenuation relationships in this study. In order to make comparison, earthquake displacement demand also obtained using design spectrum for Z4 soil class in Turkish Seismic Code (Turkish Seismic Code, 2007). It is seen from Figs. 9 and 10 that displacement demands calculated from both attenuation relationships are smaller than the Turkish Seismic Code one as expected. Nevertheless, displacement demands predicted for Campbell relationship is less than those calculated for Kalkan & Gülkan relationship in all cases.

Damage states of a building are described in several seismic codes with different structural criteria. In this study, the damage state of investigated building was evaluated according to ATC-13 (ATC 13, 1985) performance levels. Limit values of each damage state given in ATC-13 are given in Table 3. In this table, damage states change from “None” (Level I) to “Destroyed” (Level VII).

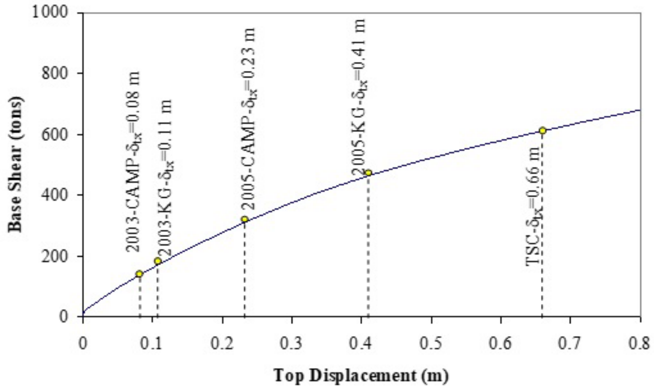

Figure 9: The capacity curve and displacement demands of 2003 and 2005 Urla Earthquakes for X direction of the structure

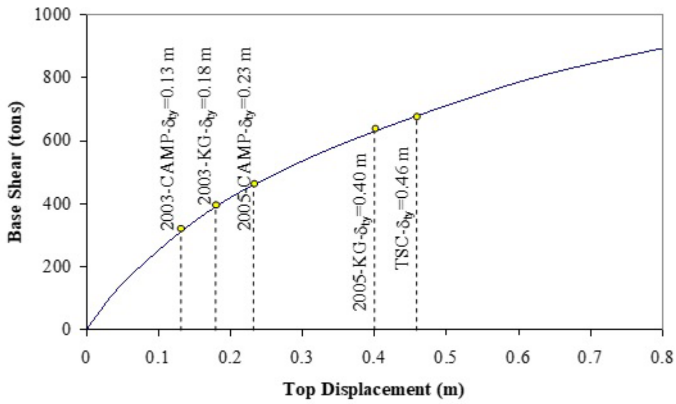

Figure 10: The capacity curve and displacement demands of 2003 and 2005 Urla Earthquakes for Y direction of the structure

Interstorey drifts calculated for X and Y directions of the building for the 2003 Urla Earthquake ($M = 5.6$) using both attenuation relationships were shown in Fig. 11. Maximum interstorey drift ratio of the investigated building was determined as 0.67% for Campbell attenuation and damage state was classified as “Light Damage” according to ATC-13 (ATC 13, 1985). On the other hand, maximum interstorey drift ratio obtained from Kalkan & Gülkan relationship is 0.92% and damage state of the building was estimated as “Moderate Damage”.

Similarly, interstorey drifts were calculated for X and Y directions of the building for the 2005 Uzunkuyu-Urla Earthquake ($M = 5.9$) and obtained values were shown in Fig. 12. Maximum interstorey drift ratios calculated using Campbell and Kalkan & Gulkan attenuations are 1.42% and 2.81%, respectively. According to Table 5, damage state was estimated as “Moderate Damage” and “Major Damage” for these attenuation relationships.

When observed damages compared to displacement demands calculated from Campbell and Kalkan & Gülkan attenuations, Campbell was in agreement with the observed damage state of the investigated building for 2003 and 2005 Urla Earthquakes. Therefore, it is concluded that Campbell attenuation relationship (Campbell, 1997) is better for predicting scenario earthquake motion effects of long distance seismic sources for Manavkuyu region.

In the second stage, displacement demands and damage levels that calculated using $Z4$ design spectrum in Turkish Seismic Code (Turkish Seismic Code, 2007), and a spectrum derived

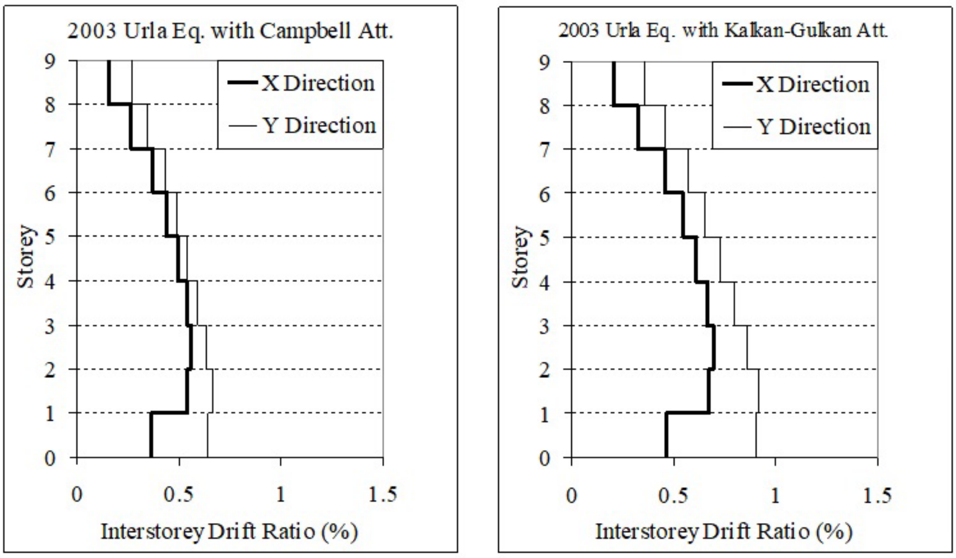

Figure 11: Interstorey Drift Ratios for the 2003 Urla Earthquake obtained from Campbell and Kalkan & Gülkan attenuations

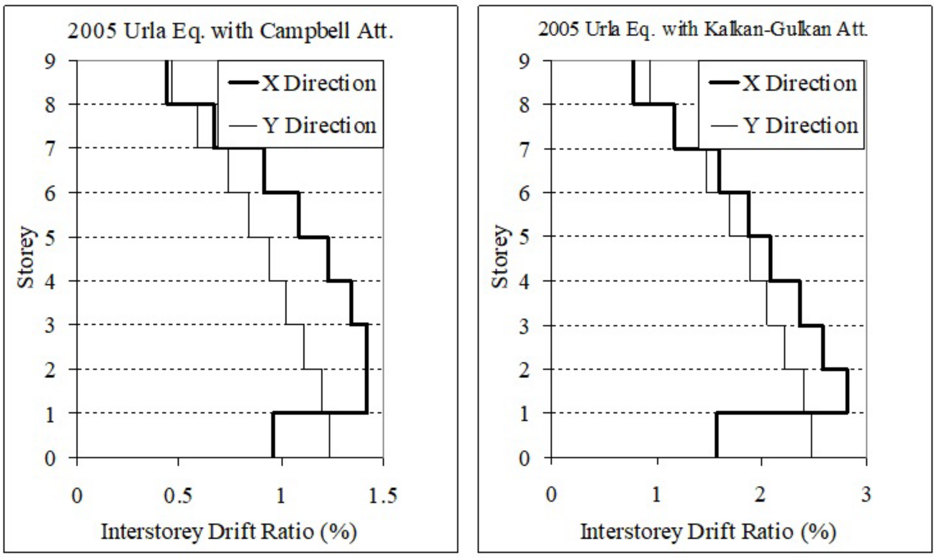

Figure 12: Interstorey Drift Ratios for the 2005 Urla Earthquake obtained from Campbell and Kalkan & Gülkan attenuations

from Campbell attenuation relationship for scenario earthquake ($M = 6.5$), are compared for investigating the local site effects on the earthquake performance of the building. Displacement demands estimated from scenario spectrum and Turkish Seismic Code spectrum for $Z4$ soil class are shown in Figs. 13 and 14.

Interstorey drifts calculated for X and Y directions of the building for both TSC-2007 [30] and Campbell scenario earthquake spectra were obtained, also. Maximum interstorey drift ratio calculated from Campbell scenario spectrum was found as 5.2% and which corresponds to "Destroyed Damage" according to ATC-13 (ATC 13, 1985). Moreover, maximum interstorey drift ratio obtained from TSC-2007 Z4 spectrum is 3.5% and damage state of the building was predicted as "Major Damage".

It can be seen from the results of analyses that when a scenario earthquake ($M = 6.5$)

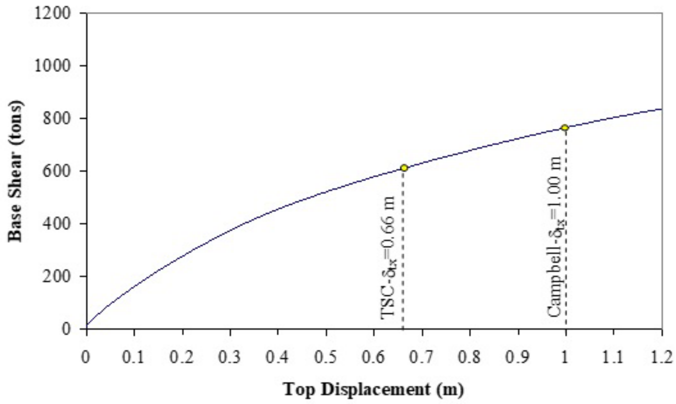

Figure 13: The capacity curve and displacement demands for TSC-2007 (Turkish Seismic Code (2007)) and scenario earthquakes for X direction of the structure

Table 3: Performance levels of a building in terms of interstorey drift ratio*

Performance level	Damage state	Interstorey drift ratio (%)
I	None	Δ<0.2
II	Slight	0.2<Δ<0.5
III	Light	0.5<Δ<0.7
IV	Moderate	0.7<Δ<1.5
V	Heavy	1.5<Δ<2.5
VI	Major	2.5<Δ<5
VII	Destroyed	Δ>5

* $ATC - 13$ (1985) (ATC 13 (1985))

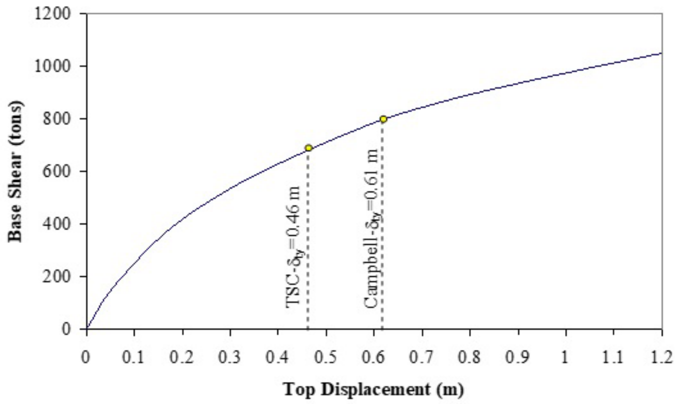

Figure 14: The capacity curve and displacement demands for TSC-2007 (Turkish Seismic Code, 2007) and scenario earthquakes for Y direction of the structure

occurs in long distance seismic sources, the displacement demand for the investigated building are greater than that calculated from the Turkish Seismic Code design spectrum (Figs. 13 and 14). Therefore, long distant scenario earthquake motions may cause heavy-major damage for buildings on deep saturated alluvial soils in Izmir. The use of locally constructed design spectra for different earthquakes occurred in the vicinity of Izmir can be recommended instead of the design spectrum defined in the Turkish Seismic Code for $Z4$ type of soils.

6 Conclusion

In this study, influence of local soil conditions on dynamic site response analyses in Izmir Bay Area has been investigated. Izmir was selected to investigate seismic response of medium-height (7-10 storeys) buildings due to the seismic sources capable of moderate scale earthquakes around the city. Firstly, design spectrum for the northern coast of Izmir Bay area was developed according to the equivalent-linear method. In this way, the effect of local site conditions and earthquake characteristics were taken into consideration and the current study has become a deterministic seismic hazard analysis for the northern coast of Izmir Bay area. Results of dynamic site-response and structural performance analyses were interpreted according to the national and international seismic codes (Turkish Seismic Code, 2007; ATC 13, 1985; NEHRP, 2001).

The design spectrum was developed for occurred earthquake records and scenario earthquake motions in close and long distances to Izmir. The 1977 Izmir Earthquake ($M = 5.3$), the 2003 Urla Earthquake ($M = 5.6$) and the 2005 Uzunkuyu-Urla Earthquake ($M = 5.9$) data were used in dynamic site-response analysis. Campbell (1997), and Kalkan & Gülkan (2004) attenuation relationships were used for estimating bedrock accelerations of investigated sites. The elastic design spectra were constructed based on the spectral accelerations obtained from equivalent-linear site-response analyses with EERA (Bardet et al., 2000) computer program. The characteristic periods of developed design spectra cover the recommended periods in the Turkish Seismic Code (Turkish Seismic Code, 2007) for $Z4$ type of soils. The characteristic periods were defined as $T_A = 0.2$ and $T_B = 0.9$ seconds for deep saturated alluvial soils ($Z4$ type of soils) in the Turkish Seismic Code. The constructed design spectra have greater spectral plateau than the Seismic Code.

Location of the site and characteristics of the earthquake have significant effect on the strong motion parameters. Therefore, it would be appropriate to design medium-height buildings taking locally produced elastic design spectra such as the ones presented in this study into consideration as the Turkish Seismic Code (2007) recommends in a general manner. Besides, it would be more beneficial to add additional requirements to the code for alluvial sites.

Manavkuyu and Bostanlı regions take place on deep saturated alluvial soils in Izmir. Light-moderate levels of damages were observed at $7-10$ storey medium-height buildings in Manavkuyu following the long distance 2003 and 2005 Urla Earthquakes. Although amplification values were greater in Bostanlı than those in Manavkuyu, significant damage was not reported following the 2003 and 2005 earthquakes at buildings in Bostanlı. The reason for this observation can be explained by the fact that the fundamental periods of 18-22 storey high-rise buildings in Bostanlı are away from the period range ($0.5-0.9$ s) corresponding to maximum spectral acceleration values. This period range was close to fundamental periods of the $7-10$ storey medium-height structures in Manavkuyu region. $7-10$ storey medium-height buildings are scarce in Bostanlı area, and they were built on pile foundations probably enlarging their natural periods.

A 9-storey reinforced concrete building was selected in order to investigate the effect of moderate scale long distance earthquakes on medium-height buildings in Manavkuyu region. This building was subjected to light-moderate damage during the 2003 Urla Earthquake, and moderate damage was observed after the 2005 Uzunkuyu-Urla Earthquake. Pushover analysis was performed for this building in order to determine structural capacity. The capacity curve and displacement demands for X and Y directions of the building were obtained for occurred earthquakes and scenario motions. The observed damage was compared to the displacement demands calculated from occurred earthquakes using Campbell and Kalkan & Gülkan attenuation relationships (Campbell, 1997; Kalkan & Gülkan, 2004).

Damage state levels of buildings can be evaluated according to ATC-13 (ATC 13, 1985) performance levels in terms of interstorey drift ratios. Maximum interstorey drift ratio of the investigated building was calculated as 0.67% for Campbell relationship taken into account the

2003 Urla Earthquake and the damage state was classified as "Light Damage" according to ATC-13 (Gazetas, 2006). Maximum interstorey drift ratio of the building was determined as 0.92% for Kalkan & Gülkan attenuation and the damage state was predicted as "Moderate Damage" for the same earthquake. Similarly, interstorey drifts were calculated for X and Y directions of the building for the 2005 Uzunkuyu-Urla Earthquake ($M = 5.9$). Maximum interstorey drift ratios were calculated using Campbell and Kalkan & Gulkan attenuations as 1.42% and 2.81%, respectively. Damage state was determined as "Moderate Damage" for Campbell and "Major Damage" for Kalkan & Gülkan relationships.

Demands calculated from Campbell relationship were in agreement with the observed damage of the investigated building. Therefore, it is concluded that Campbell (Campbell, 1997) attenuation relationship is better for predicting scenario earthquake motion effects of long distance seismic sources for Manavkuyu region. Then, displacement demands and damage levels were calculated using Z4 design spectrum in Turkish Seismic Code (Turkish Seismic Code, 2007), and a spectrum derived from Campbell attenuation relationship for scenario earthquake ($M = 6.5$) in long distance. They were compared for investigating the local site effects on the earthquake performance of the building. Maximum interstorey drift ratio obtained from TSC-2007 Z4 spectrum is 3.5% and damage state of the building was estimated as "Major Damage". Moreover, maximum interstorey drift ratio calculated from Campbell scenario spectrum was obtained as 5.2% which corresponds to "Destroyed Damage" according to ATC-13. The displacement demand for the investigated building was greater than that calculated from the Turkish Seismic Code design spectrum for long distant scenario motion.

The response of the investigated building is expected as worried under possible long distant strong earthquake. This study shows the need for developing local design spectrum to obtain reliable damage levels for similar medium-height buildings. Such research studies and new regulations in seismic codes would be highly beneficial for earthquake resistance of medium-height structures on alluvial formations in Izmir and similar provinces having marginal soil conditions.

This paper is a complimentary part of the author's previous seismic evaluation studies on the city of Izmir. In order to keep the integrity of the evaluation, and to enable a comparison with the previous published works, the Turkish Seismic Code (2007) was used for seismic evaluations in this paper. The Turkish Seismic Code for Buildings was introduced at the beginning of 2019, while this study's final results were prepared. The author plans to work with Turkish Seismic Code for Buildings for the future seismic evaluation studies.

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