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Critical Evaluation of Strong Ground Motions in Izmir and Implications for Future Earthquake Simulation Results

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ABSTRACT

Izmir, a major city in western Turkey, is located in a highly seismic region, subject to frequent earthquakes due to its proximity to active fault systems. This paper critically evaluates the strong ground motions recorded in Izmir, with a focus on understanding the implications for urban infrastructure and future seismic hazard mitigation. Historically available data is collected and compared with the available ground motion prediction equations (GMPE). Later, the most appropriate prediction equation is selected and used to determine the target response spectrum. 2020 Sisam earthquake is a well-documented seismic event and the data from the stations are then used to further calibrate the 1D site response model. Lastly, possible future events are generated and results are compared with the current Turkish Earthquake Code (TEC). Amplification factors prescribed by code for İzmir Bay have been surpassed by projected future events, highlighting the necessity for reassessment. Therefore, region-specific seismic zoning should be established when standard code practices fall short in accounting for significant site effects. Concrete recommendations about local site modification factors and evaluations on this topic have been provided within the article.

Keywords: Ground motion prediction equations, Site response, Future events, Local site modification factors

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1. INTRODUCTION

1.1. Scope and Aim

Izmir, Turkey's third-largest city, is located on the Aegean coast, and its proximity to active fault lines makes it highly vulnerable to seismic activity. Izmir is located within the extensional tectonic regime of the Aegean region, where several active faults, including the Izmir Fault and the Seferihisar Fault, contribute to the area's high seismic risk (Emre et al., 2018). The proximity of Izmir to the Hellenic subduction zone also increases its seismic hazard, as this plate boundary is responsible for generating frequent and potentially large earthquakes (McKenzie, 1978). In particular, shallow crustal earthquakes have historically caused significant ground shaking and damage in the region (Emre et al., 2005). Some of the recent studies have detailed the active faults in the region from which, the activity of the seismic hazard can be evaluated easily (Figure 1).

The city has been impacted by numerous destructive earthquakes throughout history. The 1688 and 1778 earthquakes were particularly devastating, with reports of widespread destruction (Tepe et.al. 2021). In more recent times, the 2020 Samos earthquake have provided critical data on the ground motions experienced in the region. These events highlighted the varying response of different local soil conditions and the importance of considering site-specific factors in seismic hazard assessment (Cetin et.al, 2022).

Given the city's dense population and economic importance, a critical evaluation of the ground motion characteristics during earthquakes is essential for improving preparedness and urban resilience. Buildings with poor design or inadequate retrofitting were particularly vulnerable, as they were not able to withstand the amplified seismic waves. Understanding these interactions is key to developing more effective risk mitigation strategies and informing future urban planning.

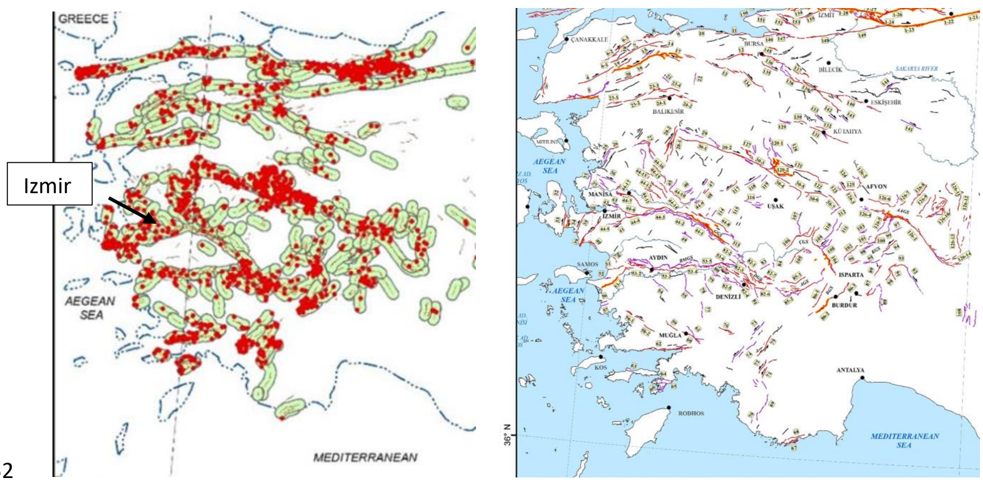

Figure 1. Active Seismic Faults and recent earthquakes in the region (Emre et.al, 2018)

The purpose of this study is divided into two main parts: First part is to evaluate the strong ground motions recorded in Izmir during past seismic events, particularly focusing on their effects on local geotechnical conditions and built

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environments. In the second part, a future earthquake scenario and potential engineering outcomes will be examined by using the findings obtained in the first part.

The steps involved in this study include:

a. Data Collection: Gathering historical earthquake data from the Izmir region, including earthquake magnitudes, source-to-site distances, and PGA measurements.
b. Selection of GMPEs: Choosing GMPE models that are applicable to the regional tectonic and geological conditions.
c. Comparison of GMPE Predictions and evaluation of GMPE Accuracy: Comparing the predicted PGA values from different GMPEs with the observed values from historical earthquakes. Differences were observed between the predicted and actual ground motions, emphasizing the importance of site-specific adjustments in GMPEs for accurate seismic hazard assessment. Using statistical methods, such as Root Mean Square Error (RMSE), to assess the accuracy of the GMPE predictions and identify the most reliable model for the Izmir region. Apply necessary improvements for the prediction equations to comply with the specific directivity and near fault effects.
d. 1D site response analysis were firstly validated with the available recordings and then set up for the future earthquake scenarios.
e. Developing target spectra using the outcomes of 3rd step, evaluating future earthquakes in the region and comparison with the current TEC results.
f. The study concludes with recommendations on refining seismic hazard models to account for local site effects and improving the predictive accuracy of GMPEs in areas with complex soil profiles. These findings have implications for earthquake-resistant design and site-specific seismic risk mitigation strategies.

1.2. The Geological and Geotechnical Settings of Izmir Bay

The geological structure of Izmir is highly variable, consisting of sedimentary basins with alluvial soils and rock outcrops. These heterogeneous ground conditions play a crucial role in amplifying seismic waves and influencing the distribution of damage during earthquakes. This is particularly important in areas with soft soils or complex geological features, which can greatly affect the intensity and frequency content of seismic waves at the surface. As part of the Aegean region, Izmir is situated within an active tectonic zone characterized by extensional processes and numerous fault systems, contributing to its significant seismic hazard. The Izmir Bay region is located in the western part of Turkey and is part of the larger Aegean Extensional Province. This region is influenced by the ongoing tectonic extension between the African and Eurasian plates, creating a highly active fault system that includes both normal and strike-slip faults (Akyol et.al. 2006). The geological makeup of Izmir Bay consists of a variety of rock types and sedimentary deposits that influence the behavior of seismic waves during an earthquake:

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- Sedimentary Basins: The region includes several sedimentary basins, including the Gediz Graben and the Menderes Massif. These basins are filled with younger, unconsolidated sediments that can amplify seismic waves.
- Alluvial Deposits: Much of the coastal region, including areas surrounding the bay, is composed of alluvial deposits. These sediments, deposited by rivers, are loosely consolidated and can exacerbate ground shaking during an earthquake.

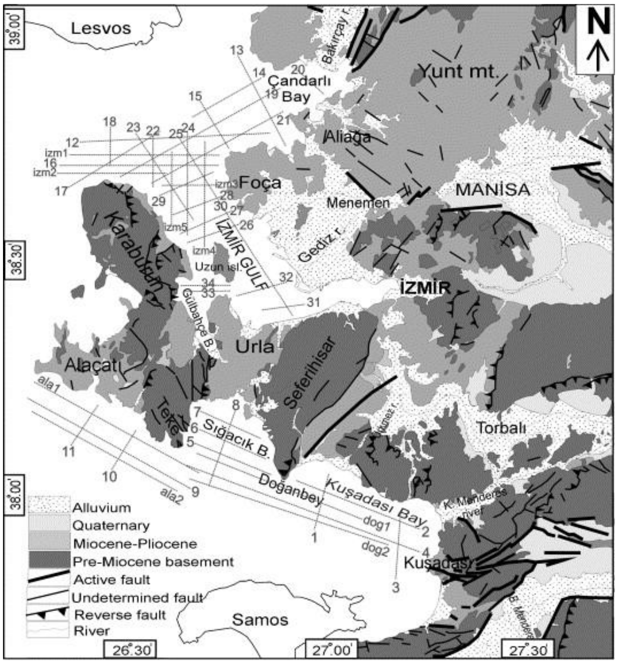

Figure 2. Geology map of the study area and location of the seismic fault lines (Adapted from Ocakoglu et.al, 2005).

2. Compilation of the strong motion dataset and predictive performance of current ground motion models

Ground Motion Prediction Equations (GMPEs) are empirical or semi-empirical mathematical models used to estimate the expected level of ground shaking (ground motion) at a specific location during an earthquake. GMPEs play a critical role in seismic hazard analysis and earthquake engineering by predicting key seismic parameters based on several factors such as earthquake magnitude, distance to the fault, and local site conditions (Gulerce et.al 2022). The Izmir region, located in Western Anatolia, is seismically active and has complex fault systems and varying soil conditions. Therefore, selecting an appropriate target spectrum for this region requires a detailed comparison of GMPE predictions with observed earthquake records.

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For that aim, historical earthquake data from the Izmir region, including earthquake magnitudes, source-to-site distances, and PGA measurements were gathered. Historical ground motion records were compiled from Turkish Ministry of Interior Disaster and Emergency Management Presidency (AFAD). A total 33 earthquake events, dating from 1996 to 2024 were selected and given in Table 1 with the recorded peak ground acceleration (PGA) values. A total of 8 different GMPEs were used for comparison and validation purpose (Table 2). The predicted peak ground acceleration (PGA) values from various GMPEs with the actual observed values from historical earthquakes were compared (Figure 3).

Table 1.Important characteristics of the historical seismic events

Event No	Event Name	Mw	Epicentral Distance - km	Fault Mechanism	Event Depth -km	PGA Max - cm/s2
1	10.04.2003 - Seferihisar	5.7	37.45	Strike Slip	18.7	78.57
2	17.10.2005 - Urla	5.8	58.21	Strike Slip	11	13.12
3	17.10.2005 - Urla	5.4	56.17	Strike Slip	20.5	16.51
4	20.10.2005 - Urla	5.9	58.98	Strike Slip	15.4	31.773
5	30.10.2022- Sisam	7	75.57	Normal	16.54	73.72
6	12.06.2017-Karaburun	6.2	43.87	Normal	15.86	58.306
7	11.04.2022- Buca - İzmir	4.9	9.81	Strike Slip	14.47	48.59
8	19.07.2014 - Konak- İzmir	3.7	10	Strike Slip	6.98	9.47
9	21.04.2021-Sehzadeler-Manisa	4.9	40.19	Normal	13.2	9.673
10	12.06.2017-Karaburun	6.2	89.62	Normal	15.86	25.499
11	26.06.2020- Saruhanlı-Manisa	5.5	64.1	Normal	9.29	7.109
12	8.01.2013 - Aegean Sea	6.2	194		26.83	3.642
13	24.05.2014 - Aegean Sea	6.5	255.78		25	7.659
14	02.06.2017 Ayvacik (Canakkale)	5.3	154.13	Normal	14.16	1.466
15	06.17.2017 Aegean Sea	5.3	81.15	Normal	9.11	9.42
16	07.20.2017 Aegean Sea(Bodrum)	6.5	169.93	Normal	19.44	4.44
17	18.02.2020 Kırkağaç (Manisa)	5.2	91.02	Normal	6.98	4.662
18	19.05.2011 Simav (Kutahya)	5.7	180.7	Normal	24.46	5.533
19	08.08.2019 Bozkurt (Denizli)	6	218.49	Normal	10.92	0.39
20	28.06.2020 Ege Denizi (Mugla)	5.2	214.57	Normal	61.42	3.375
21	30.10.2020 Sisam	5.1	72.95	Normal	7.71	7.056
22	21.06.2021 Aegean Sea (Datca)	5.3	228.34	Normal	14.74	0.61
23	01.10.2023 Lesvos	5	130.95	Normal	14.95	1.708
24	27.01.2024 Aegean Sea (Kusadası)	5.1	52.46	Normal	8.51	7.632
25	2.04.1996	4.9	71.81	Normal	12	18.42
26	14.11.1997 Aegean Sea (Kusadası)	5.8	128.79	Normal	12	6.03
27	09.07.1998 Aegean Sea	5	75.48	Normal	12.5	27.06
28	17.08.1999 Golcuk (Izmit)	7.6	346.5	Strike Slip	15.9	10.8
29	21.01.2002 Turgutlu (Manisa)	4.8	60.11	Normal	11.7	6.981
30	17.04.2003 Seferihisar (Izmir)	5.2	61.55	Strike Slip	11.5	8.851
31	29.01.2005	4.9	47.67	Normal	20	6.131
32	22.01.1999 Buca-İzmir	3.4	9.95	Strike Slip	5	2.985
33	24.12.2005 Akhisar (Manisa)	4.9	64.85	Normal	6	3.14

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Table 2. GMPEs Used In this Study

NO	GROUND MOTION PREDICTION EQUATIONS
1	AS08: Abrahamson & Silva 2008 NGA Model
2	BA08: Boore & Atkinson 2008 NGA Model
3	CB08: Campbell & Bozorgnia 2008 NGA Model
4	CY08: Chiou & Youngs 2008 NGA Model
5	Abrahamson & Silva & Kamai 2014 NGA West-2 Model
6	Boore & Stewart & Seyhan & Atkinson 2014 NGA West-2 Model
7	Campbell & Bozorgnia 2014 NGA West-2 Model
8	Chiou & Youngs 2014 NGA West-2 Model

To quantify the accuracy of GMPE predictions, error analysis were conducted using statistical metrics in which the goal is to determine which GMPE provides the closest predictions to the observed data across various earthquake magnitudes and site conditions. As per the error analysis in GMPE evaluations, two methods were chosen, R^2 (Coefficient of Determination) and RMSE (Root Mean Square Error) and the results were given in Table 3.

RMSE is a commonly used metric for quantifying the difference between observed and predicted values. It measures the square root of the average of the squared differences between the predicted PGA values from GMPEs and the actual observed values. RMSE gives more weight to larger errors, making it particularly useful when larger deviations in predictions need to be minimized. RMSE can be calculated as:

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(PGA_{observed,i} - PGA_{predicted,i})^2}$$

Where:

- N is the number of the earthquake records
- PGA,observed,i is the observed PGA for the i-th earthquake
- PGA, predicted,i is the predicted PGA for the i-th earthquake based on the GMPE.

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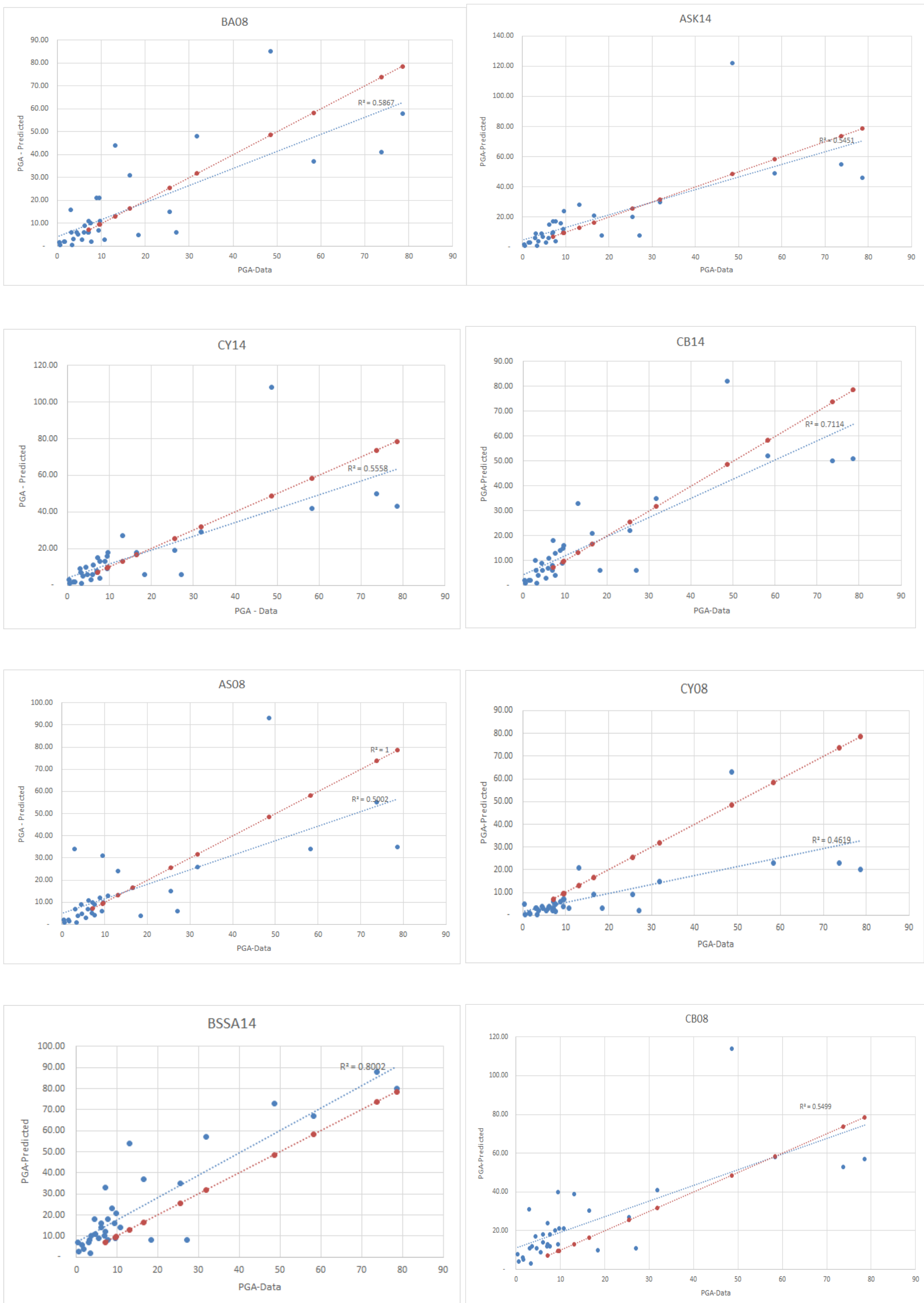

Figure 3. The results of the analysis are given in the table below.

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Table 3. Result of GMPE Error Analysis

Root Mean Square Error							
RMSE / AS08	**RMSE / BA08**	**RMSE / CB08**	**RMSE / CY08**	**RMSE / ASK14**	**RMSE / BSSA14**	**RMSE / CB14**	**RMSE / CY14**
14.85	13.53	17.11	16.75	15.95	13.39	11.02	14.51
R^2 (Coefficient of Determination)							
R2 / AS08	**R2 / BA08**	**R2 / CB08**	**R2 / CY08**	**R2 / ASK14**	**R2 / BSSA14**	**R2 / CB14**	**R2 / CY14**
0.50	0.59	0.55	0.46	0.55	0.80	0.71	0.56

There can be several factors for the observed differences between the models, for instance site and soil amplification effects or the inconsistency in depth, magnitude or distance scaling of the models and the several constants implemented in each models. As confinement of these effects and limiting the sampling data is not possible in this study, typically the error analysis is compared and the resulting ranking is used for selecting the two most powerful predictive equation. The results indicate that Model CB14 and BSSA14 are better choices for the following analysis.

3. Site response validation analysis for future predicted events

The next step for the generation of future earthquakes is to evaluate and correctly determine the site properties. For that aim, 1D site response analysis (SRA) was set up and validated with the available records from 2020 Sisam earthquake. For SRA's, Deepsoil software (Hashash et.al. 2020) was used as the program was previously used by many researchers and the adaptive nature of the program was well calibrated (Cetin et.al. 2022).

For calibration and validation purpose, a well recorded and data riched event was needed. The 2020 Izmir earthquake struck on October 30, 2020, with a moment magnitude (Mw) of 6.9. Its epicenter was located in the Aegean Sea, approximately 14 kilometers northeast of the Greek island of Samos, but it caused significant damage in Izmir due to its shallow depth and local site effects. Event was recorded by several seismograms located around the city (Figure 4), some of which are located on alluvial plains and some on rock outcrops, which allows researchers to further evaluate site effects (Kramer,1996). The city covers large areas of alluvial soil conditions, therefore different regions were selected for the validation purposes. One of the site is located in Karsiyaka, western part; the other sites are located in Konak- Bayrakli and Bornova.

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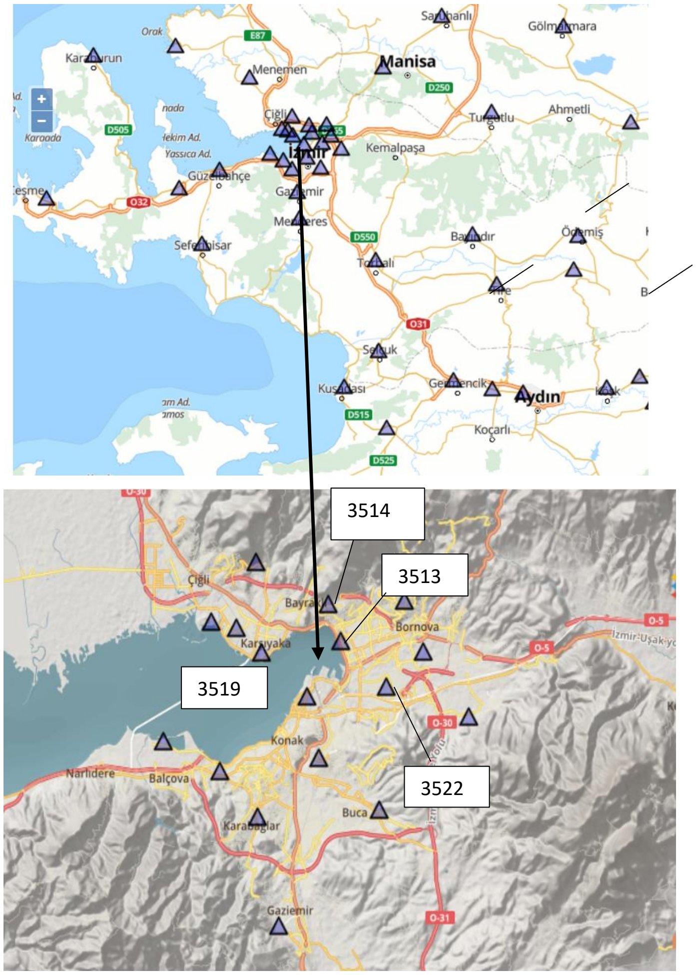

Figure 4. Overview of Stations in Izmir

The procedure was to use and select an appropriate outcrop rock site and use its corresponding data to further determine the site response analysis of the selected soil sites. The selected stations were given in Table 4, with the corresponding location and PGA data's. The outcrop station was selected as station 3514, which is very close to the basin area. Geotechnical and geophysical properties of the selected stations are given in Figure 5.

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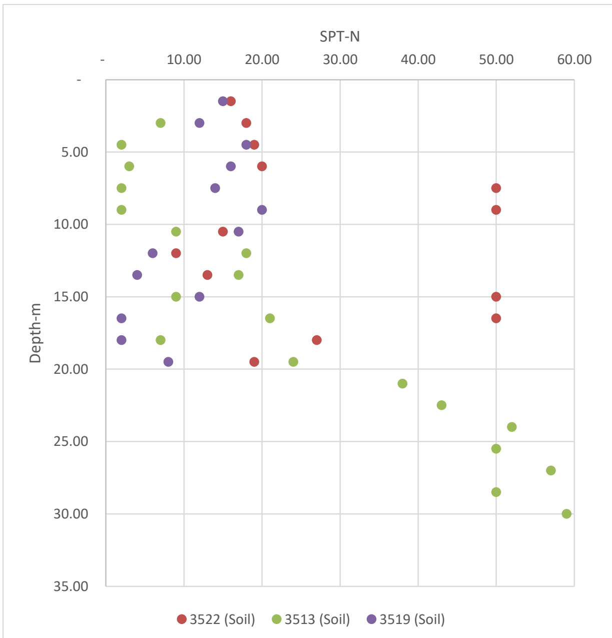
Table.4 Selected Soil/Rock Sites

Site Name	Region	Vs30 (m/sec)	Coordinates	PGA (g)
3514	Bayrakli	836.00	38.4762 27.1581	0.057 (E-W)
3513	Bayrakli	195.00	38.4584 27.1671	0.108 (N-S)
3519	Karsiyaka	131.00	38.4525 27.1112	0.153 (N-S)
3522	Bornova	249.00	38.4357 27.1987	0.075(E-W)

Depth/St.Name	3513 (Soil)	3522 (Soil)	3519 (Soil)
1.50		16.00	15.00
3.00	7.00	18.00	12.00
4.50	2.00	19.00	18.00
6.00	3.00	20.00	16.00
7.50	2.00	50.00	14.00
9.00	2.00	50.00	20.00
10.50	9.00	15.00	17.00
12.00	18.00	9.00	6.00
13.50	17.00	13.00	4.00
15.00	9.00	50.00	12.00
16.50	21.00	50.00	2.00
18.00	7.00	27.00	2.00
19.50	24.00	19.00	8.00
21.00	38.00		
22.50	43.00		
24.00	52.00		
25.50	50.00		
27.00	57.00		
28.50	50.00		
30.00	59.00		
31.50			
33.00			
34.50	SOIL TYPE DESCRIPTION INDEX (PER ASTM)		
36.00		CL/CH	
37.50			
39.00		SM	
40.50			
42.00		SC	
43.50			
45.00		GM	
46.50			
48.00		GC	
49.50			



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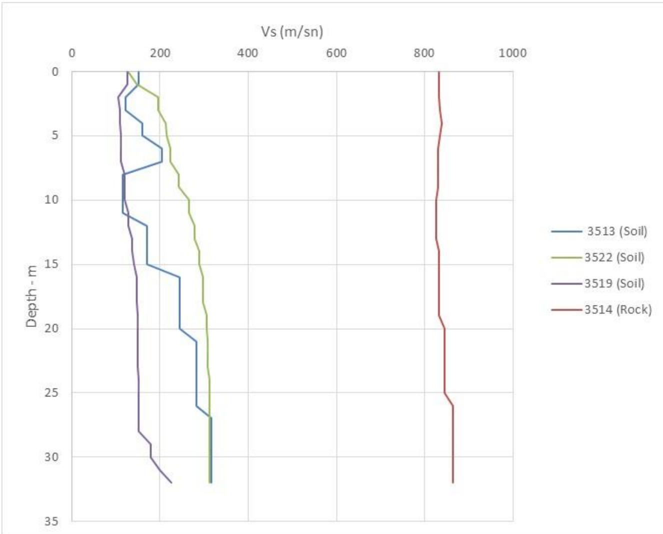

Figure 5. Geotechnical / Geophysical properties of the selected rock / soil stations

Detailed soil profiles and parameters were gathered from available deeper site profiles and deep geophysical measurements that were used from the wide range of database. (Cetin et al, 2022) The modulus reduction and damping curves were used from the literature by adopting soil parameters and the general trend of the curves were given in Figure 6.

The results of the analysis were given for 3 different locations in the city center as previously stated. The motivation for selecting 3 different regions was to take into account of different soil/geophysical properties of soils which have alluvial soil deposits. The second motivation come from the fact that, to be able to generate a general response spectrum, a more representative solution should be taken into account which represents the different soil conditions and regions of the city (Figure 7-8-9).

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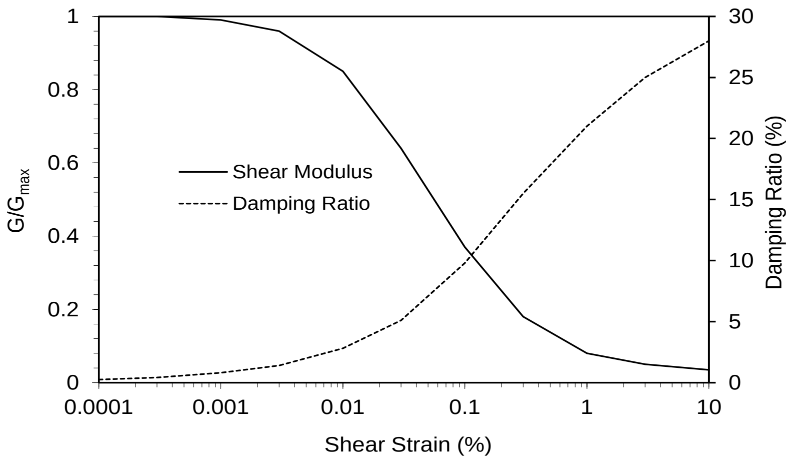

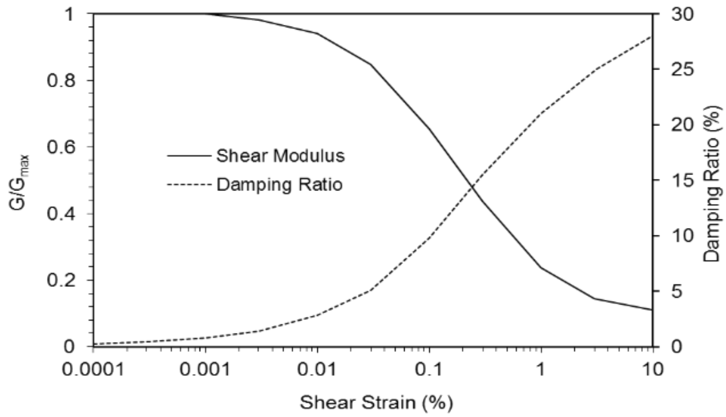

Figure 6. Modulus Reduction/Damping Curves for Sandy-Cohesionless Soils (Seed and Idriss, 1970) and Cohesive Type Soils (Vucetic-Dobry, 1991)

In the results, comparison of the response spectrum graphs of SRA with the recorded site motion and corresponding amplification function S_amp= SR (site) / SR (outcrop) were given for the 3 selected stations. It can be seen that the 3513 station amplifications increased up to 4 - 4.5 times in 1.50 s periods. Similar to 3513 station, at 3522 Bornova station, amplifications were observed for the same period region with 3.0 – 3.5 times increase. These two regions were close to each other and the geotechnical site conditions were similar to each other compared to the Karsiyaka station. When the outcomes of Karsıyaka station (3519) was examined, similar amplification data was obtained but in higher period regions, 2.50 seconds and later.

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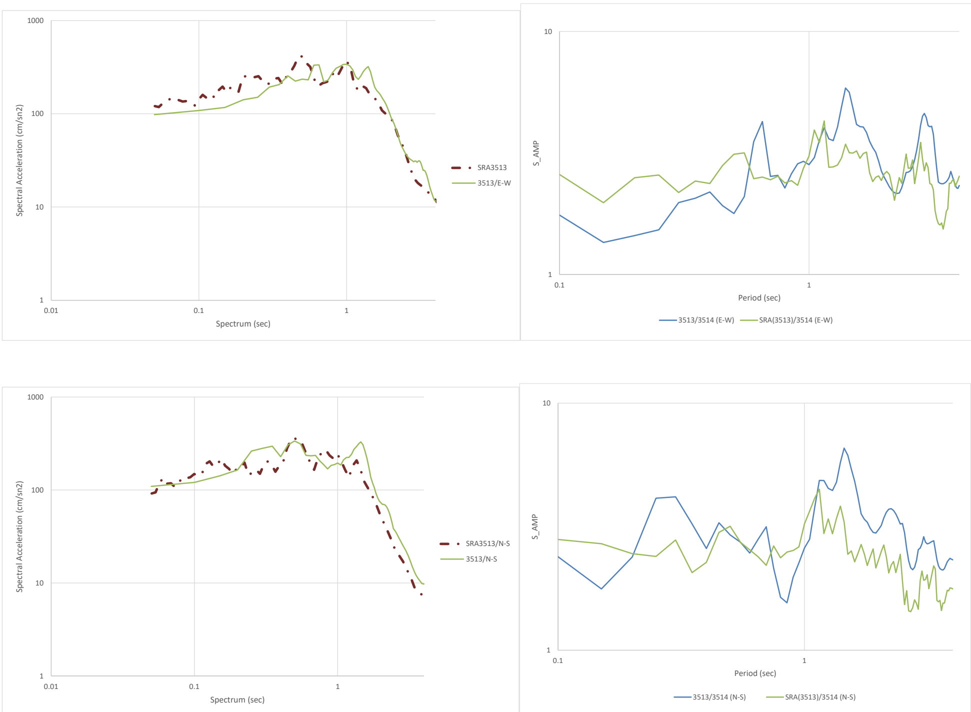
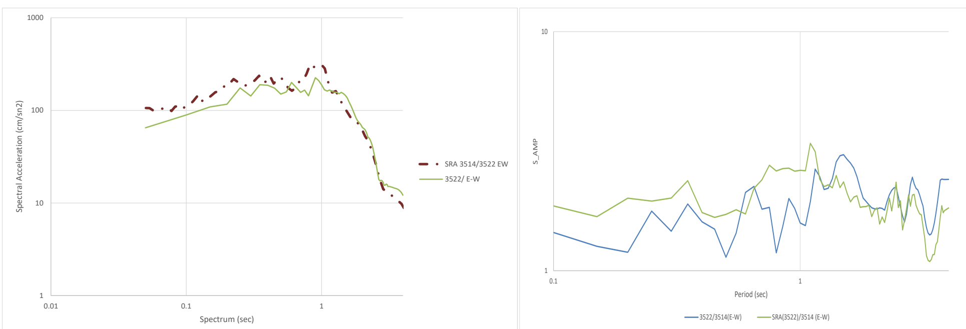


Figure 7. The comparison of recorded and estimated (SRA) elastic response and amplification spectra for 2020 Samos event@station 3513



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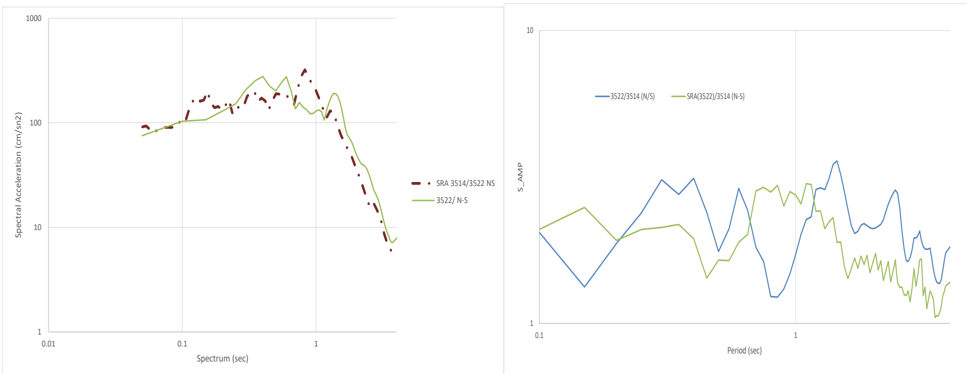

Figure 8. The comparison of recorded and estimated (SRA) elastic response and amplification spectra for 2020 Samos event@station 3522

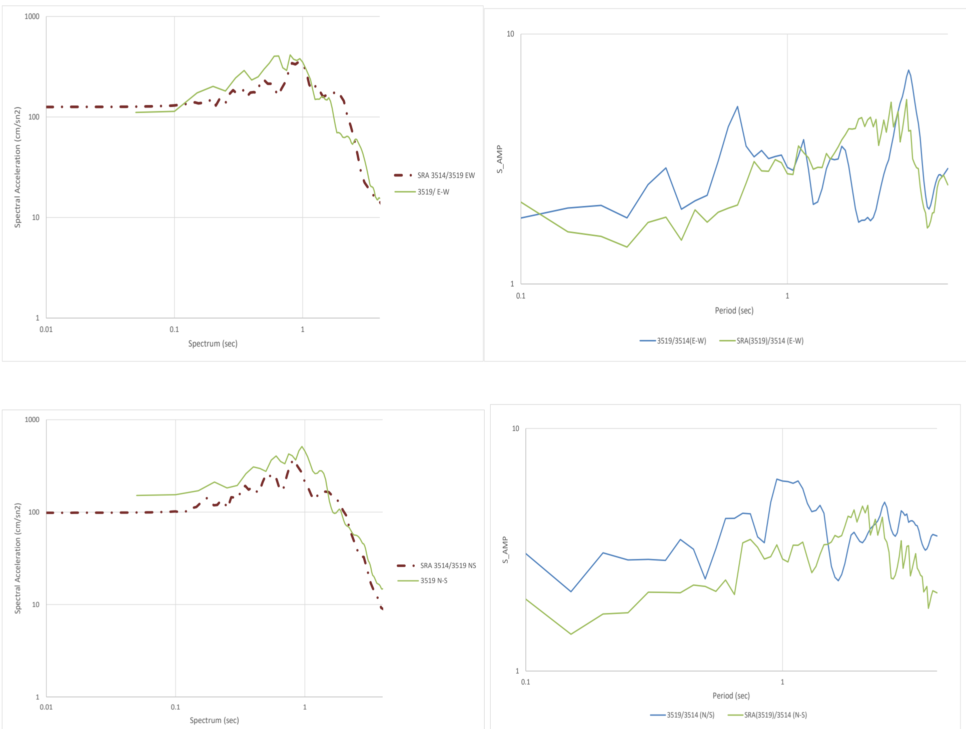

Figure 9. The comparison of recorded and estimated (SRA) elastic response and amplification spectra for 2020 Samos event@station 3519

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The results indicate a conformity in the general trend of spectrum and have been found to be consistent with the actual data especially in the period range of 0.50-1.50 sec range which coincides with the general building stock (6-10 story heights) of the city. Overall, it can be concluded that, in most instances, the average spectra of the recorded motions fall within the range of those associated with the calculated motions. The match between the 75th percentile of the recorded motions and the computed motions varies from moderate to very good. Similar results can also been seen in Cetin et.al. (2024).

By evaluating the data and analysis results obtained so far, a reasonably usable SRA model and GMPE relationships that can correspond to the seismicity of the general region have been revealed. The next stage will be selecting the target spectrum for possible future earthquakes and then determining the spectral outcomes for selected regions by performing SRA analyzes.

4. Selecting target response spectrum and evaluating the results of future events

Using the most appropriate GMPE identified through the error analysis as stated before, ground motion parameters such as Peak Ground Acceleration (PGA), Spectral Acceleration (SA), and others are predicted for a future predicted deterministic scenario conditions. The target spectrum was generated for the deterministic scenario of Radius Project (Radius, 1997) which was a detailed study for the seismicity of the region. The Project concluded with a deterministic scenario which include an Mw 6.5 event in Izmir fault with an anticipated distance of 4 km.

An important consideration in site-specific seismic hazard analyses is the near-fault effect and the maximum directional effect. Somerville et al. (1997) adjusted empirical ground motion attenuation models to account for the influence of rupture directivity on both amplitude and duration. Rupture directivity happens when seismic energy is concentrated along the path of fault rupture, leading to a substantial increase in ground motions in that direction. This phenomenon is particularly significant for sites near faults, where rupture directivity can cause ground motions to be considerably stronger in one direction, especially at longer periods, compared to others. This behaviour can be observed in 2000 Samos event after investigating the N-S and E-W spectrums. The directivity of the fault enhance the motions in N-S directions, which can also be associated with the damage behaviour of buildings in Mavisehir- Karsiyaka region, specifically at station 3519. Therefore, this effect has been considered in future earthquake simulations as well and the selected GMPE were revised accordingly. Target spectrum was selected taking into account that the TEC and GMPE spectrums will not be underscored at ant period point. Therefore, a new spectrum is generated which takes into account of the historical seismicity of the region as well as the current regulations (Figure 10).

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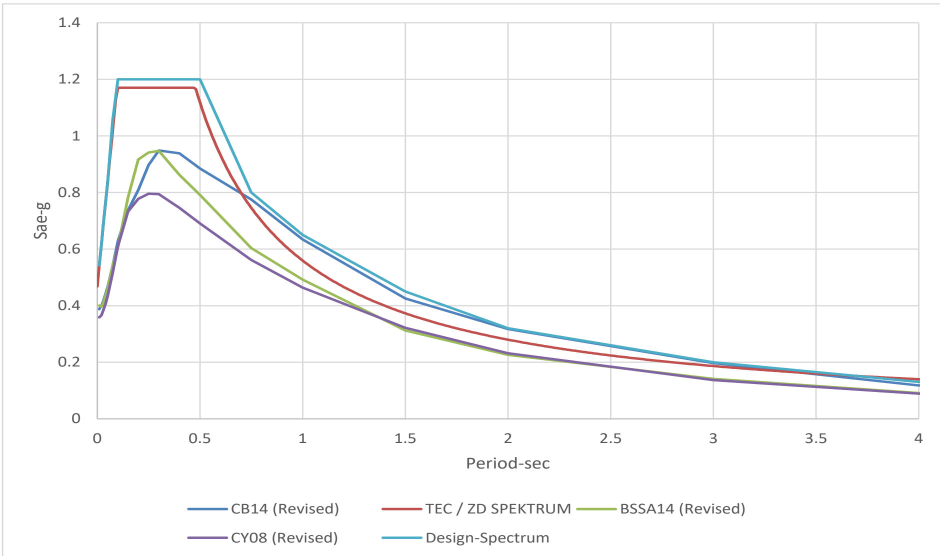

Figure 10. Design Spectrum for the site with comparisons

There are a total of 11 records were selected (Table 5) and scaled to the given target spectrum (Figure 11). The scaling of the records are generated through Seismosoft software. The results of the selected and scaled ground motions are given together in Figure 11.

Table 5. Selected Ground Motion Records

No	Record Sequence Number	Scale Factor	Earthquake Name	Year	Station Name	Magnitude	Mechanism	Rjb (km)	Rrup (km)	Vs30 (m/sec)
1	4881	2.32	"Chuetsu-oki_Japan"	2007	"Nagaoka Kouiti Town"	6.8	Reverse	11.61	20.77	294.38
2	549	1.91	"Chalfant Valley-02"	1986	"Bishop - LADWP South St"	6.19	strike slip	14.38	17.17	303.47
3	6893	1,07	"Darfield_New Zealand"	2010	"DFHS"	7	strike slip	11.86	11.86	344.02
4	8133	4.31	"Christchurch_New Zealand"	2011	"SLRC"	6.2	Reverse Oblique	31.81	31.81	249.28
5	6971	2.12	"Darfield_New Zealand"	2010	"SPFS"	7.0	strike slip	29.86	29.86	389.54
6	882	2,57	"Landers"	1992	"Desert Hot Springs"	7.28	strike slip	26.84	26.84	344.67
7	4866	1.26	"Chuetsu-oki_Japan"	2007	"Kawanishi Izumozaki"	6.8	Reverse	0.0	11.75	338.32
8	4894	0.38	"Chuetsu-oki_Japan"	2007	"Kashiwazaki NPP_Unit 1: ground surface"	6.8	Reverse	0.0	10.97	329.0
9	787	1.43	"Loma Prieta"	1989	"Palo Alto - SLAC Lab"	6.93	Reverse Oblique	30.62	30.86	425.3
10	1100	2.03	"Kobe_Japan"	1995	"Abeno"	6.9	strike slip	24.85	24.85	256.0
11	3979	2.82	"San Simeon_CA"	2003	"Cambria - Hwy 1 Caltrans Bridge"	6.52	Reverse	6.97	7.25	362.42

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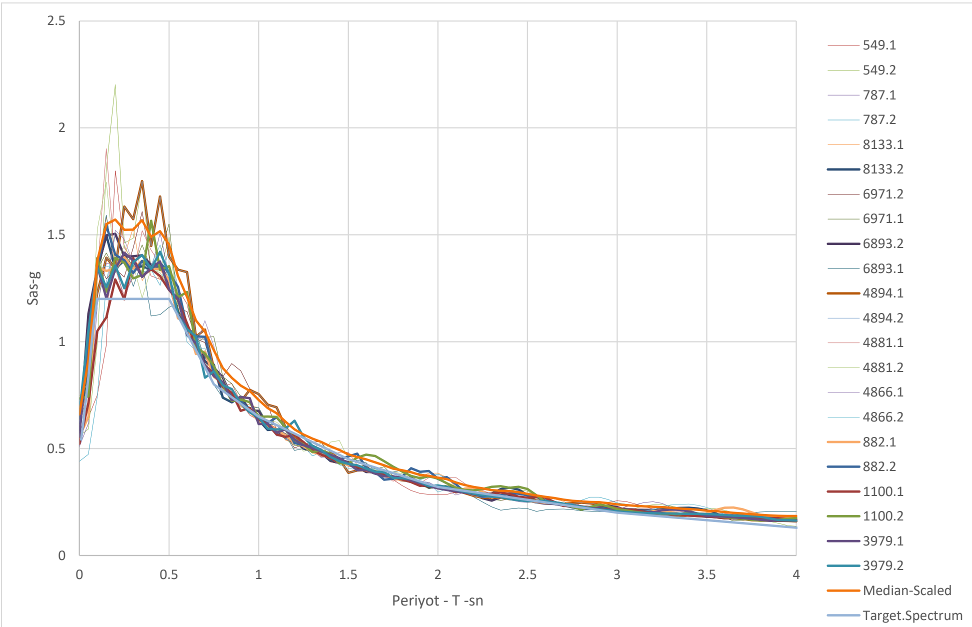
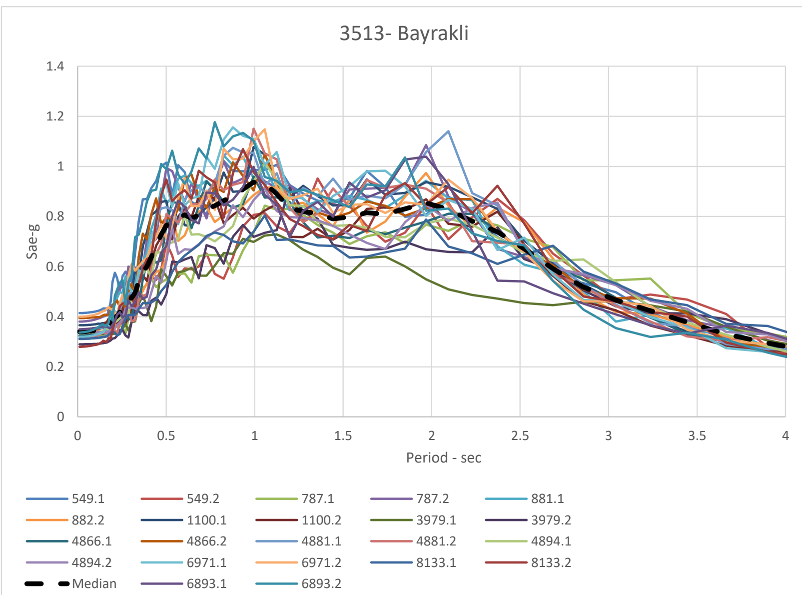


Figure 11. Selected and Scaled Ground Motion with respect to target spectrum

Using the deepsoil model calibrated in previous sections, site-specific earthquake analyzes wıth selected records were carried out for each region/station and results were given in Figure 12.



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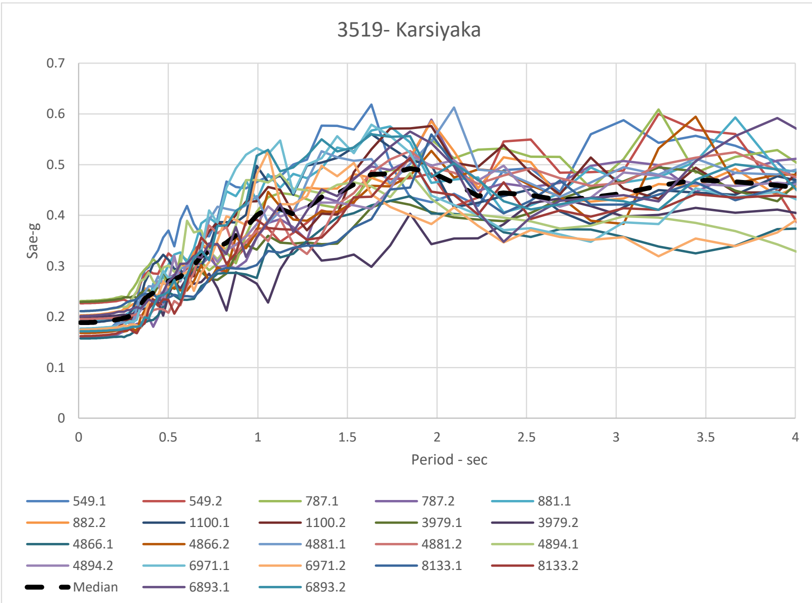

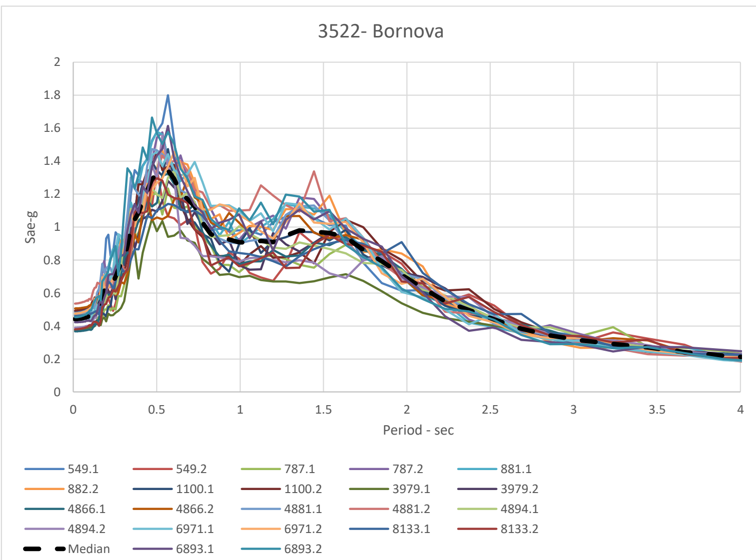

Figure 12. Outcome of the future anticipated scenario earthquake in the city with 3 different regions (Bayrakli, Karsiyaka and Bornova)

The comparison of each region with the current TEC and target spectrum were given in Figure 13.

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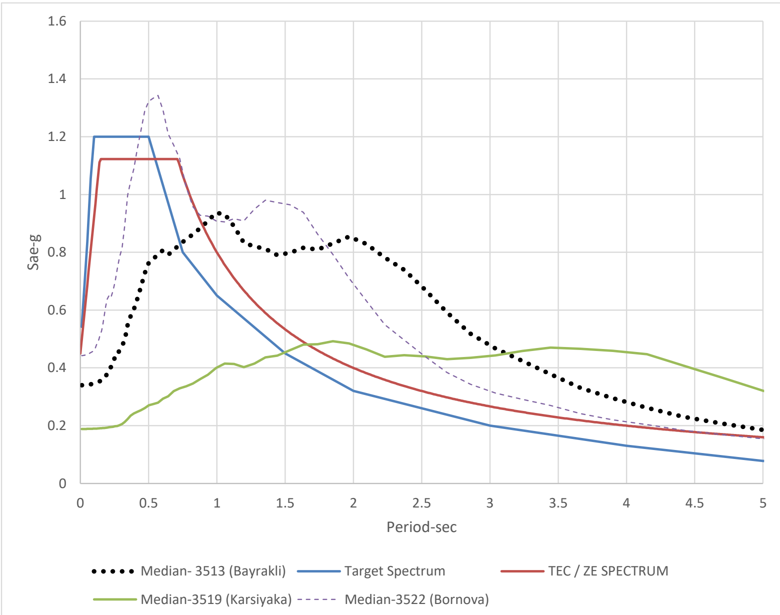

Figure 13. The comparison of stations with the current TEC and target spectrum

According to TEC, local site effects are taken into account by some modification factors. These modification factors are called F_1 and F_S values and defined by the following relationship:

$Sds = S_S F_S$ (Sds = Design Spectral Acceleration Value for short period region)

$Sd1 = S_1 F_1$ (Sd1 = Design Spectral Acceleration Value for 1sec period region)

Where S_S and S_1 are the spectral values without taking into account the local site effects.

The result of the analysis showed that the local site modification factors should be corrected by at least two times as summarized in Table 6.

Table 6. Local site modification factors (F1) according to TEC and SAR of scenario earthquake

Station	Vs30	Soil Class (Acc TEC)	F1/ TEC	F1/ SAR, t=1 sec
3513	195	ZD	2.054	4.21
3522	249	ZD	2.054	4.76
3519	131	ZE	2.935	4.40

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5. Summary and Conclusions

In this study, based on the past seismicity of the city of Izmir, potential future seismicity of the city of city has been considered and various analyses have been conducted. A summary of these studies is provided below.

- Firstly, using a dataset of past recorded earthquake events, the level of agreement with current GMPE equations was investigated. Based on the evaluations, two GMPEs were selected for use in determining target spectrum parameters for site-specific seismicity analysis.
- To perform site-specific seismic analyses, well-recorded event of İzmir-Samos earthquake data were utilized. A 1D analysis model, using the available geotechnical data was applied for 3 different stations. These stations were selected for the aim to
    - represent different alluvial soil conditions of the city
    - take in to account of the 3 most populated, therefore representative regions of the city
    - be able to arrive a more general conclusion about the possible future earthquake simulations
- Future potential earthquake scenarios have been selected. For this purpose, a target spectrum was developed for an Mw=6.5 earthquake on the İzmir fault, as part of the RADIUS 2005 project. The resulting target spectrum was modified to account for near-field and directivity effects and subsequently used in the analyses.
    - The TEC was also utilized in the selection of the target spectrum. Ultimately, the chosen target spectrum was developed to satisfy both deterministic and probabilistic approaches given by the code recommendations.
- Eleven earthquake records were selected and scaled to match the target spectrum. Subsequently, using the same validated models, possible scenario earthquake outcomes were analyzed.

The results obtained from the analyses are provided below:

- The 2020 Samos earthquake has been a significant event for site-specific seismicity studies due to the abundance of recording stations and the rich data content available. In the analyses conducted, amplifications were observed in the high-period region.
- GMPEs were evaluated and compared using the past seismic activity of the city. That further allow to generate a target spectrum for the city.
- While generating a target spectrum, particularly when considering near-field effects and directivity effects, the obtained spectra possess a broader energy content than those presented in the regulations. This condition should be taken into account in seismic design codes.
- The acceleration spectra obtained at the surface are amplified by at least a factor of 2 for periods of 1 second and longer. More specifically, the result of the analysis showed that the local site modification factors defined by TEC should be corrected by at least 2.50 times. This condition should be taken into account in all of the alluvial regions of the city especially when designing more than 8-10 stories of buildings.
- Different regions selected in this study provides a framework for a future study which will emphasize on the basin effect discussed in other papers.

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Data availability all data and models analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests the authors have no relevant financial or non-financial interests to disclosure.

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