Local Soil Properties and 1D Nonlinear Site Response Analysis: A Case Study of Arifiye (Sakarya Discrit) Turkey

Ali Silahtar (asilahtar@sakarya.edu.tr)
Sakarya Universitesi - Esentepe Kampusu https://orcid.org/0000-0002-7259-4560

Research Article

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Abstract

The strong ground motion effect is amplified or de-amplified due to the change in subsoil condition. Local soil properties prediction is critical for earthquake-safe areas and the earthquake hazard assessment of existing structures. This study was carried out with time-domain 1D Non-linear analysis to understand the soil response characteristics of the Arifiye district. In this sense, geotechnical drilling at 47 points and surface wave analysis at 44 points were performed. Site response profiles in the study area were analyzed with the DeepSoil program for M_w:7.0 1967 Mudurnu and M_w:7.4 1999 Kocaeli earthquake scenarios. Peak spectral acceleration (Pga) and spectral acceleration (Sa) values were determined in the analysis of the Mudunu scenario as 0,11-0,24 g and 0,44-1 g, respectively. The Kocaeli scenario's Pga and Sa distribution were obtained in a wide range of 0.2-0.56 g and 0.47-2.3 g, respectively, compared to the Mudurnu scenario. Especially in the M_w:7.4 model, high Pga (>0.3g) and Sa (>1g) values were obtained in the uncemented units located north of the study area. Kocaeli scenario results showed that the spectral accelerations at the surface in soil groups D and E were higher than the Turkish Building Earthquake Code (TBEC) building requirements, and it is necessary to update the earthquake design spectra site-specific. On the other hand, it can be said that the southwest of the study area is safer and more suitable residential versus throughout the study area. The results clearly showed the effect of ground conditions and strong ground motion selection on earthquake-resistant building design.

Full Text

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Tables

Table 1

MASW data acquisition parameters

Number of channels	24
Sample rate (ms)	0.5
Record Length (ms)	1024
Receiver spacing (m)	3
Minimal offset (m)	12
Array length (m)	72
Geophone frequency (Hz)	4.5
Number of stack	8-10
Souce	10 kg Sledge hammer

Table 2

Physical properties of selected earthquake records compatible with the target spectrum. These ground motion records were downloaded from the PEER NGA West-2 database

Earthquake name	Year	Station number	Magnitude (M_w)	Mechanism	Rjb (km)	Rrup (km)	Vs_{30} (m/sec)
Duzce-Turkey	1999	1614	7.1	strike slip	11.46	11.46	481
Darfield-New Zealand	2010	6948	7.0	strike slip	30.63	30.63	482
Darfield-New Zealand	2010	6971	7.0	strike slip	29.86	29.86	390
Darfield-New Zealand	2010	6988	7.0	strike slip	24.36	26.93	344

Table 3

TBEC-2018 soil classification criteria

TBEC-2018 site class	Rock/Soil type	Vs_{30} (m/s)
A	Hard rock	> 1500
B	Rock	760-1500
C	Dense soil/soft rock	360-760
D	Stiff soil	180-360
E	Soft soil	< 180

Table 4

1D site response analysis results obtained in the study area

Borehole ID	Latitude (^{0})	Longitude (^{0})	Sa 6948 (g)	Pga 6948 (g)	Sa 5401 (g)	Pga 5401 (g)	Vs_{30} (m/sec)	TBEC site class
BH-1	40.6890	30.3595	0.84	0.21	1.47	0.43	354	D
BH-2	40.7038	30.3658	0.65	0.14	0.76	0.34	277	D
BH-3	40.7114	30.3633	0.77	0.18	0.82	0.39	204	D
BH-4	40.7058	30.3530	0.83	0.20	1.56	0.47	339	D
BH-5	40.6885	30.3561	0.57	0.17	0.96	0.32	320	D
BH-6	40.6982	30.3386	0.44	0.12	0.55	0.20	480	C
BH-7	40.7078	30.3523	0.79	0.19	0.89	0.31	340	D
BH-8	40.6916	30.3353	0.71	0.18	1.03	0.38	310	D
BH-9	40.6918	30.3421	0.74	0.18	1.26	0.38	346	D
BH-10	40.6965	30.3562	0.57	0.16	0.92	0.28	395	C
BH-11	40.7307	30.3712	0.85	0.22	1.08	0.38	295	D
BH-12	40.7100	30.3381	0.66	0.12	0.86	0.26	414	C
BH-13	40.6962	30.3391	0.74	0.17	0.66	0.32	427	C
BH-14	40.7029	30.3616	0.82	0.20	0.76	0.34	277	D
BH-15	40.6994	30.3622	0.50	0.11	0.47	0.25	500	C
BH-16	40.7012	30.3457	0.68	0.20	0.66	0.32	363	C
BH-17	40.7189	30.3530	0.86	0.19	1.88	0.44	200	D
BH-18	40.7276	30.3895	0.80	0.22	1.10	0.41	219	D
BH-19	40.6906	30.3607	0.61	0.11	0.65	0.21	422	C
BH-20	40.7217	30.3700	0.81	0.24	1.20	0.40	324	D
BH-21	40.7194	30.3601	0.79	0.17	1.22	0.38	204	D
BH-22	40.7133	30.3465	0.82	0.20	1.44	0.46	179	E
BH-23	40.6972	30.3487	0.80	0.21	0.99	0.36	330	D
BH-24	40.7156	30.3464	0.77	0.20	1.98	0.48	148	E
BH-25	40.7012	30.3546	0.67	0.18	0.82	0.31	345	D
BH-26	40.7079	30.3297	0.68	0.19	0.81	0.33	374	C
BH-27	40.7064	30.3629	0.75	0.16	0.84	0.31	320	D

BH-28	40.6989	30.3448	0.74	0.18	1.18	0.35	330	D
BH-29	40.6906	30.3492	0.73	0.20	0.57	0.26	422	C
BH-30	40.6956	30.4092	0.75	0.18	0.99	0.36	260	D
BH-31	40.6970	30.3924	0.86	0.19	1.88	0.44	171	E
BH-32	40.7264	30.3996	0.82	0.20	1.44	0.46	160	E
BH-33	40.7148	30.4110	0.85	0.21	1.28	0.49	168	E
BH-34	40.7344	30.4139	0.72	0.20	1.81	0.44	200	D
BH-35	40.7178	30.3877	0.75	0.19	1.36	0.43	220	D
BH-36	40.7259	30.4033	0.91	0.21	1.96	0.50	162	E
BH-37	40.7302	30.4248	0.90	0.22	1.23	0.37	201	D
BH-38	40.7065	30.3971	0.92	0.23	1.39	0.42	207	D
BH-39	40.7300	30.3630	0.8	0.18	1.12	0.40	160	E
BH-40	40.7252	30.3602	0.91	0.20	2.15	0.56	172	E
BH-41	40.7134	30.3523	0.74	0.20	1.81	0.44	142	E
BH-42	40.7215	30.3421	1.02	0.19	2.31	0.49	148	E
BH-43	40.7141	30.3362	0.82	0.20	1.72	0.48	142	E
BH-44	40.7298	30.3552	0.87	0.19	1.38	0.41	154	E
BH-45	40.7245	30.3539	0.93	0.20	1.46	0.42	166	E
BH-46	40.7173	30.3417	0.85	0.22	2.15	0.56	146	E
BH-47	40.6940	30.3798	0.72	0.20	1.18	0.35	232	D

Figures

Figure 1

a) North Anatolian Fault Zone (NAFZ) and large-scale earthquakes (Barka et al. 2002); b) The distribution of earthquake epicenters (M>3.0) in the eastern Marmara region (Faults modified from Emre et al. 2018)

Figure 2

Geological features of the study area and its vicinity. 1: Alluvium, 2: Alluvial fan, 3: Örencik Formation, 4: Yığılca Formation, 5: Çaycuma Formation, 6: Akeren Formation (modified from Sarıaslan et al. 1998)

Figure 3

a) General tectonics and location map of the study area (Faults modified from Emre et al. 2018); b) Data acquisition points in the study area (borehole: orange circles, seismic data: black triangles)

Figure 4

Borehole examples selected to represent the soil lithology distribution of the study area

Figure 5

MASW data processing steps at the M1 data acquisition point. a) Raw data; b) Processed data; c) Dispersion curve selection; d) 1D Velocity-depth model

Figure 6

Example of shear modulus reduction and material damping curves

Figure 7

a) Target spectrum compatible with the Mudurnu earthquake parameters; b) Spectral accelerations matching the target spectrum

Figure 8

The time history data used in the site response analysis and response spectrums. a) The time history data of station number 5401 of the 1999 Kocaeli earthquake; b) The time history data of station number 6948 of the 2010 Darfield earthquake; c) Response spectrum of Kocaeli time history data; d) Response spectrum of Darfield time history data

Figure 9

The average shear wave velocity level maps. a) Vs_5; b) Vs_{10}; c) Vs_{15}; d) Vs_{20}; e) Vs_{25}; f) Vs_{30}

Figure 10

Surface Pga distribution of the Kocaeli (a) and Mudurnu (b) scenario

Figure 11

Surface Sa distribution of the Kocaeli (a) and Mudurnu (b) scenario

Figure 12

Comparison of the surface response spectra obtained from the Mudurnu scenario with the TBEC earthquake design spectra. a) For soil class C; b) For soil class D; c) For soil class E

Figure 13

Comparison of the surface response spectra obtained from the Kocaeli scenario with the TBEC earthquake design spectra (The dashed lines represent response spectra that exceed the earthquake design spectrum). a) For soil class C; b) For soil class D; c) For soil class E