

Effect of Seismic Bedrock Interface Depth on Surface Ground Motion Parameters of Deep Overburden Sites

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ABSTRACT: Ground response analysis and determination of site-specific ground motion parameters are necessary for evaluating seismic loads to enable sustainable design of aboveground and underground structures, particularly in deep overburden sites. This study investigates the influence of bedrock interface conditions and depth of soil deposits on obtained site-specific ground motion parameters. Employing the one-dimensional seismic response analysis program SOILQUAKE, the ground responses of five representative soil profiles and 1 050 case studies are calculated considering three different site models of seismic input interfaces. The analysis employs the actual bedrock interface with a shear wave velocity of 760 m/s as the reference input bedrock interface. The results illustrate that the selection of the bedrock interface condition significantly affects the seismic response on the ground surface of deep overburden sites. Specifically, the ground surface acceleration response spectra at longer periods are notably smaller compared to those at the actual bedrock site. This may present a challenge for designing long-period high-rise buildings situated in deep overburden sites. It is recommended to select a seismic input bedrock interface closely approximating the actual bedrock depth when conducting seismic response analyses for deep overburden sites.

KEY WORDS: seismic bedrock interface, deep overburden sites, soilquake, frequency consistent method, seismic response.

0 INTRODUCTION

Ground response analysis and determination of site-specific ground motion parameters are crucial steps in assessing the seismic hazard at a certain project site to ensure the reliable and sustainable design of structures at that site. Many studies have underscored the influence of local site effects on the distribution and extent of earthquake-induced damage to engineering structures (Gupta et al., 2025; Shen et al., 2025; Lashgari and Moss, 2024; Zhu et al., 2020a; Pitilakis and Tsinidis, 2013). Consequently, it is imperative to conduct seismic response analyses for sites of critical structures and infrastructure to facilitate their effective seismic design. The determination of site-specific seismic motion parameters and the evaluation of seismic geological hazards provide essential information for seismic design and risk mitigation in construction projects.

Several factors affect the site-specific ground motion

parameters, including seismic source characteristics, the seismic wave propagation path and the soil properties at the site. Seismic waves exhibit slower attenuation when traversing bedrock with high shear wave velocity (> 760 m/s). This effect becomes more pronounced when propagating through overlying soil layers (Falamarz-Sheikhabadi and Zerva, 2018). Site response depends on the soil, frequency and intensity of the input motion, and the water table depth (Borgohain et al., 2024; Najjar et al., 2022). In China, the process of determining site-specific ground motion parameters typically commences with a seismic hazard analysis to compute bedrock ground motion response spectra. Subsequently, a site-specific soil response analysis model is formulated based on field and laboratory tests to characterize the strength and stiffness of the site soils, which is employed to analyze the site seismic responses and derive site-specific ground motion parameters. On the other hand, the National Earthquake Hazards Reduction Program (NEHRP, 2011) guidelines utilize statistical analysis of strong motion records to derive ground motion statistical spectral characteristics for different site categories. These characteristics are used to determine site coefficients for specific sites utilizing formulas of standard spectra. Another approach involves utilizing available strong motion records

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to establish attenuation relationships for the spectral characteristics of ground motion parameters on categorized sites through statistical analysis. This method enables the determination of the site category for a specific site and the estimation of various ground motion parameters based on the seismic hazard and attenuation relationships specific to the corresponding site category.

According to the Chinese Code of Seismic Safety Assessment for Engineering Sites (GB 17741-2025, 2025), bedrock is defined as hard soil layers with shear wave velocity, $V_s \geq 500$ m/s, which is used as the ground motion input interface for site response analysis. Meanwhile, soft rock with $V_s \geq 760$ m/s is considered as the seismic input interface in Canada and the USA. The consideration of the ground motion input interface could have a significant impact on seismic design parameters, especially in areas of significant urban development such as major urban centers in China that are witnessing rapid growth and high-speed economic development. This growth comprises numerous significant construction projects, including high-rise buildings, high-speed railways, transoceanic bridges, and port terminals. These projects are often situated in deep overburden sites, exceeding 50 m of soil deposits giving rise to fundamental natural periods surpassing 1 s. In such cases, the selection of hard soil layers with $V_s = 500$ m/s or $V_s = 760$ m/s as input interface in ground response analysis can have an immense effect on seismic design for these sites. Therefore, it is crucial to investigate the impact of the seismic input interface on seismic responses in deep overburden sites.

Several studies (Molnar et al., 2022; Chaudhary, 2021; Zhu et al., 2020b; Raptakis et al., 2000) have emphasized the significant seismic hazard associated with deep overburden sites, which underscores the potential unsafe seismic design in case the V_s profile is limited to a depth of 30 m when conducting the site response analysis for such deep overburden sites. Hong et al. (2013) investigated the seismic response of deep overburden sites in Yancheng, China, with a focus on establishing a linear extrapolation model for these sites using the shear wave velocity estimation method. They suggested that the depth of the seismic input interface in the Yancheng region should not exceed, and the shear wave velocity should be 500 m/s; they reported that considering the input interface depth greater than 125 m had a relatively minor impact on peak ground acceleration and the characteristic period at the ground surface. Peng et al. (2017) considered weak interlayers and adopted a firm bedrock assumption in their ground response analysis of deep overburden sites and concluded that deep overburden sites with soil depth larger than 100 m and $V_s < 500$ m/s can utilize the firm bedrock assumption. Meanwhile, Fang et al. (2018) reported that for moderately stiff sites, the seismic input interface should be selected as the top surface of a soil layer with $V_s \geq 800$ m/s.

Luke and Liu (2008) identified salient nonlinear site effects through site response analyses conducted in deep soil deposits. The impact of soil deposit depth on

the site response has also been acknowledged in the Mississippi Embayment, with studies (Miao et al., 2022; Malekmohammadi and Pezeshk, 2015; Hashash et al., 2008) highlighting the significance of a depth of approximately 1 000 m. Neglecting the depth of the soil deposits may result in underestimated amplifications, particularly for longer periods. Site response analyses conducted by Jishnu et al. (2013), Rahman et al. (2018) and Poovarodom et al. (2017) on deep and soft sediments revealed a notable shift in maximum amplification towards longer periods when compared to VS30-based results. Bradley (2012) documented a wide range of ground motions observed at both liquefiable and non-liquefiable soil sites during the 2010–2011 Christchurch earthquakes. The reduction in stiffness and strength of the liquefiable soil, coupled with alterations in energy dissipation mechanisms post-liquefaction, affected the recorded surface ground motion, and the corresponding response spectra at the respective sites. Bajaj and Anbazhagan (2019) investigated the site amplification coefficients and acceleration response spectra at 275 deep soil profiles by selecting the input motion based on 10% probability of exceedance in 50 years. This was the first time such an extensive study was done to determine the site factors at zero period and site factors at short period for deep sites. Chen et al. (2021) proposed a generalized loosely coupled effective stress method for nonlinear site seismic response analysis, extending it from one-dimensional to two-dimensional and three-dimensional spaces and demonstrating its accuracy and efficiency. Wang et al. (2024) utilized the equivalent linear and pressure-dependent hyperbolic nonlinear time-domain methodologies to simulate and analyze the dynamic response of the deep overburden sites. The results showed that the predictive differences of the nonlinear time-domain method align with those observed under minor strains.

Selection of the seismic bedrock interface location based on the considered range of stiffness for the input motion interface directly impacts the thickness of the soil overburden at the site. As concluded from the preceding section, this would influence ground motion characteristics such as peak acceleration and spectral features at the ground surface. Hence, the objective of this study is to investigate the influence of different seismic bedrock interfaces along with the depth of soil deposits on ground motion characteristics. Therefore, the peak acceleration and spectral features at the ground surface are investigated considering different bedrock stiffness at the soil interface and varying depths of soil deposits. Ground response analyses were conducted on five representative site profiles of deep overburden sites in Shanghai considering three distinct site models that adopted different seismic input interfaces. The ground motion inputs involved an ensemble of 14 acceleration time histories with each ground motion scaled up to eight levels. The frequency-consistent equivalent linearization method is then employed to analyze the seismic response at deep overburden sites for different cases based on the five site profiles.

1 ANALYSIS MODEL

1.1 Site Models

Shanghai, situated in the alluvial plain of the Yangtze River Delta in China, predominantly features horizontal layers of loose sediments across most of the region. The urban areas of Shanghai are characterized by soft soil deposits extending to depths ranging from 200 to 300 m. This study is focused on the deep overburden sites in Shanghai and five representative borehole profiles (ZK1 to ZK5) are considered in this analysis. The thickness of the overlying soil layers varies from 230 to 280 m, and the depth of soil layers with $V_s < 500$ m/s exceeds 100 m in all cases. Table S1 presents the distribution of soil layers and shear wave velocity data for boreholes ZK1, ZK2, ZK3, ZK4 and ZK5.

Zhang et al. (2010) conducted an extensive statistical analysis of a substantial volume of test results in the Shanghai area and provided fitting curves for the dynamic shear modulus and damping ratio across various soil types. The applicability and reliability of these curves in

the Shanghai region are supported by their extensive sample size and wide distribution range. For soils within the upper 100 m, the dynamic shear modulus and damping ratio values are based on the statistical results recommended by reference (Zhang et al., 2010). However, for soils deeper than 100 m, the dynamic shear modulus and damping ratio curves are determined using the overburden pressure correction method proposed by Jiang and Xing (2007). The correction parameters (k) for sandy and clay soils are set at 0.5 and 0.4, respectively. The shear modulus ratio and damping ratio curves for sandy gravel are derived from Rollins et al. (1998). The variation curves of the shear modulus ratio and damping ratio concerning shear strain for different soil types in the Shanghai area are depicted in Figure 1.

1.2 Determination of Seismic Bedrock Interface

This study investigates three distinct site models employing different seismic input interfaces. The first model, M1, utilizes the actual bedrock surface derived from bore-

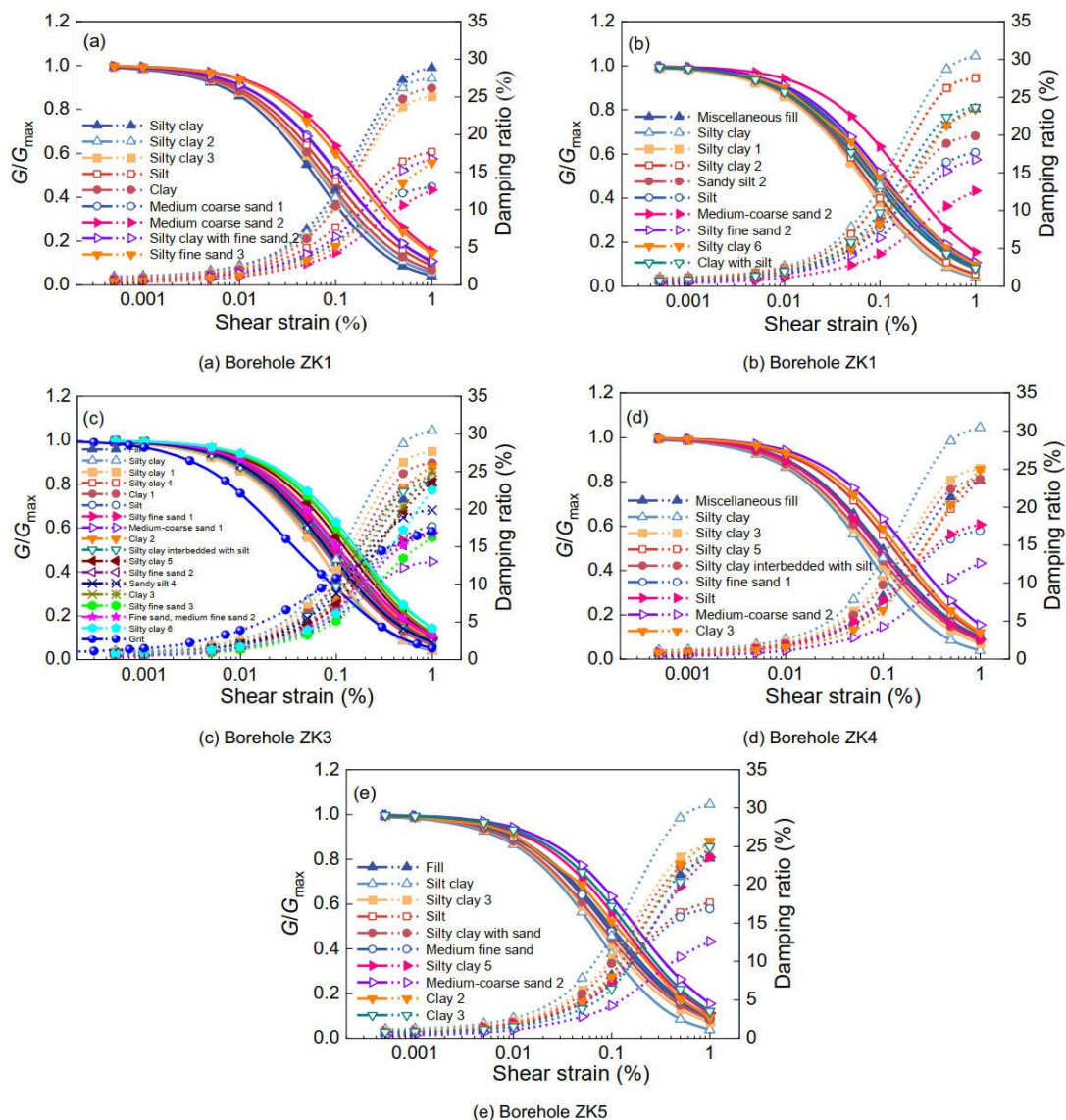


Figure 1. Variation of shear modulus ratio and damping ratio with shear strain amplitude for soils in Shanghai.

Table 1 Depths and corresponding shear wave velocities of input interfaces along borehole profiles from ZK1 to ZK5.

Site	Seismic input interface	ZK1	ZK2	ZK3	ZK4	ZK5
M1	Burial depth (m)	271.32	250	230.33	280.1	273.5
	V_s (m/s)	632	530	833	610	550
M2	Burial depth (m)	245.32	177	223.45	157.1	238.1
	V_s (m/s)	445.3	500	478	423	441.2
M3	Burial depth (m)	100	100	100	100	100
	V_s (m/s)	309	380	296	372.1	338.4

hole data. The second model, M2, adheres to the guidelines outlined in the Seismic Safety Assessment for Engineering Sites (GB 17741-2025, 2025) and selects the top surface of soil layers with a shear wave velocity of at least 500 m/s, as well as underlying soil layers with similar shear wave velocities. The third model, M3, adopts the soil profile to a depth of 100 m. Table 1 presents the burial depths of the soil layers at boreholes ZK1 to ZK5 and their corresponding shear wave velocities.

1.3 Bedrock Input Ground Motion

Due to the absence of actual ground motion records for bedrock in the Shanghai area, an ensemble of 14 acceleration time histories recommended in Appendix A of the Shanghai Building Seismic Design Code (DG/TJ 08-9-2023, 2023) is utilized as the input ground motions. These selected acceleration time history records aim to capture the characteristics of input ground motion that can impact site-specific parameters. The average seismic influence coefficient curve selected from multiple sets of ground motion time histories statistically corresponds to the seismic influence coefficients used in the response spectrum method based on mode decomposition. The input ground motions are categorized into two groups based on the characteristic period (T_g) of the standard response spectrum, corresponding to 0.9 s (SHW1–SHW7) and 1.1 s (SHW8–SHW14), respectively. Figure S1 of Appendix shows the acceleration response spectra of the input ground motions. To study the influence of input ground motion amplitudes on the seismic response of deep overburden sites, the peak acceleration values of the input motions were adjusted across five levels: 0.10, 0.15, 0.20, 0.25 and 0.30 g, resulting in a total of 1 050 cases.

2 SITE SEISMIC RESPONSE ANALYSIS

Yuan et al. (2016) introduced the load frequency correlation of the soil dynamic shear modulus and damping ratio with the equivalent shear strain to be used in site response analysis based on the traditional equivalent linearization method and developed the Frequency Consistent Equivalent Linearization Site Seismic Response Analysis Method (FCM), corresponding the site seismic response analysis program, SOILQUAKE (Yuan et al., 2016). The SOILQUAKE program conducts one-dimensional soil frequency domain analysis, providing outputs such as peak ground acceleration, acceleration response

spectrum, and the variation curve of shear strain with depth in the soil layers. The program employs an iterative process similar to SHAKE, but modifies the method of calculating the equivalent shear strain from $0.65\gamma_{\max}$ to a frequency-domain consistent equivalent shear strain. Furthermore, based on the dynamic triaxial test, the relationships between nonlinear soil parameters and load frequency are established. Using fitted parameters obtained from these tests, SOILQUAKE adjusts the dynamic shear modulus and damping of soil layers in a frequency-dependent manner. This frequency-dependent approach resolves issues in SHAKE where the dynamic characteristics of soil due to load frequency variations cannot be accurately reflected. Also, this approach addresses the shortcomings of SHAKE2000 (Schnabel et al., 1972) and DEEPSOIL (Hashash et al., 2017), which tend to underestimate the amplification effect of soft soil sites. Therefore, the SOILQUAKE program is utilized herein to compute the seismic response of deep overburden sites.

According to the Code for Seismic Design of Buildings (GB 50011-2010, 2016), it is considered acceptable to employ no fewer than seven ground motion records for seismic response analysis to derive the mean analysis of ground responses. To mitigate the influence of randomness in input ground motions on the site seismic responses and to present results concisely, the mean values of peak acceleration and acceleration response spectra at the ground surface for each set of 7 ground motions are considered as the analysis results for boreholes ZK1 to ZK5.

2.1 Peak Ground Acceleration

With the peak ground acceleration derived from the basic site model M1 serving as the reference value, the relative difference in peak ground acceleration for the site models M2 and M3, in comparison to the basic site model M1, is defined as follows.

$$R(PG_a) = (PGA_{M_i} - PGA_{M_1}) / PGA_{M_1} \times 100\% \quad (1)$$

where PGA_{M_i} is the peak ground acceleration of site models M2 and M3; PGA_{M_1} is the peak ground acceleration of site model M1.

Figure S2 illustrates the mean peak ground acceleration and its standard deviation for boreholes ZK1 to ZK5. Table 2 and Table 3 present the relative differences in peak ground acceleration for boreholes ZK1 to ZK5 under two sets of ground motions for site models M2 and M3, compared with the basic site model M1, respectively. As depicted in Figure S2, the amplitude and spectral characteristics of input ground motions, coupled with the distribution of soil layers in different boreholes, exert an influence on the peak ground acceleration of deep overburden sites. For different boreholes, ground motions featuring a characteristic period of 0.9 s yield slightly higher peak ground accelerations compared to those with a characteristic period of 1.1 s. The peak ground acceleration and its standard deviation exhibit a gradual increase with the increase in the peak bedrock acceleration. At the

relatively low peak bedrock accelerations, soil response approximates a linear elastic state. However, as the peak bedrock acceleration increases, the soil manifests distinct nonlinear characteristics, augmenting the variability in peak ground acceleration. Moreover, when the peak bedrock acceleration is less than 0.20 g, the differences in peak ground acceleration between site models M1, M2 and M3 for boreholes ZK1 to ZK5 are relatively small. However, as the peak bedrock acceleration exceeds 0.20 g, the differences in peak ground acceleration among the three sites for each borehole become more pronounced.

Based on the above analysis, the seismic input interface significantly influences the peak ground acceleration of deep overburden sites. This influence is determined by the shear wave velocity, the depth of the seismic input interface and the amplitude and spectral characteristics of the input motion. Compared with the peak ground acceleration of the basic site model M1, for borehole ZK1, the relative differences in peak ground acceleration with site models M2 and M3 range from -11.08% to 5.67% and -26.24% to -0.57%, respectively. Similarly, for borehole ZK2, the relative differences in peak ground acceleration with site models M2 and M3 range from -9.12% to -1.28% and -22.02% to -1.99%, respectively. Borehole ZK3 exhibits relative differences in peak ground acceleration with site models M2 and M3 within the range of -5.50% to 1.58% and -19.05% to -4.01%, respectively. For borehole ZK4, the relative differences in peak ground acceleration with site models M2 and M3 range from -16.82% to 4.41% and -21.67% to -3.36%, respectively. Finally, for borehole ZK5, the relative differences in peak ground acceleration with site models M2 and M3 range from -13.25% to 1.92% and -18.97% to -4.09%, respectively.

The relative differences in peak ground acceleration between site models M2 and M3 for all boreholes generally fall within the range of $\pm 30\%$. The mean values of peak ground acceleration for site model M2 exhibit relatively small relative differences compared to site model M1, within the engineering error range of $\pm 20\%$. However, the mean values of peak ground acceleration for site model M3 are generally smaller than those of site model M1, with the minimum relative difference being -26.24%. The mean value of peak ground acceleration with a seismic input interface featuring shear wave velocity not less than 500 m/s demonstrates relative differences within a range of $\pm 15\%$ compared to the peak ground acceleration with the actual bedrock interface. This essentially meets the typical engineering precision requirements of $\pm 20\%$. However, for the significant engineering projects, it is advisable to select the seismic input interface as close as possible to the actual bedrock interface.

2.2 Acceleration Response Spectrum

Figures 2 to 7 illustrate the mean acceleration response spectra of the ground surface for boreholes ZK1, ZK3 and ZK4 under the seismic actions with characteristic periods of 0.9 and 1.1 s. The overall shape of the mean acceleration response spectra for boreholes ZK1,

Table 2 Relative difference values (%) of peak ground accelerations ($T_g = 0.9$ s)

Borehole	Site	Peak bedrock acceleration (g)				
		0.10	0.15	0.20	0.25	0.30
ZK1	M2	-11.08	-5.48	-3.65	2.36	-0.17
	M3	-26.24	-21.67	-14.16	-11.81	-15.15
ZK2	M2	-1.28	-1.56	-2.37	-1.72	-2.62
	M3	-10.00	-4.44	-4.74	-3.60	-2.91
ZK3	M2	-2.64	-2.58	-1.20	-5.50	-5.17
	M3	-15.18	-8.31	-4.10	-9.98	-12.36
ZK4	M2	-5.54	0.00	4.41	-5.28	-7.12
	M3	-12.54	-16.95	-3.36	-12.10	-15.28
ZK5	M2	-2.45	-4.71	-5.21	-3.97	-7.41
	M3	-13.99	-16.07	-5.69	-7.51	-4.09

Table 3 Relative difference values (%) of peak ground accelerations ($T_g = 1.1$ s)

Borehole	Site	Peak bedrock acceleration (g)				
		0.10	0.15	0.20	0.25	0.30
ZK1	M2	-3.07	0.57	5.67	-0.95	-3.70
	M3	-3.07	-0.57	-9.93	-20.42	-20.60
ZK2	M2	-6.90	-2.97	-2.10	-1.56	-1.68
	M3	-22.02	-8.24	-11.05	-2.25	-1.99
ZK3	M2	-1.07	-3.27	-0.50	1.58	-0.61
	M3	-8.57	-6.85	-10.28	-10.84	-5.50
ZK4	M2	2.17	1.61	-4.42	-6.35	-10.50
	M3	-13.04	-4.97	-9.92	-10.00	-15.19
ZK5	M2	-5.56	-5.23	-5.85	-4.62	-8.91
	M3	-11.90	-5.23	-7.38	-7.22	-6.68

ZK3 and ZK4 in site models M1, M2 and M3 exhibits a similar pattern. As the input peak bedrock acceleration increases, the ground surface acceleration response spectrum gradually amplifies, particularly in the long-period range, resulting in a broader spectral shape, demonstrating the significant high-frequency component filtering and low-frequency component amplification in deep overburden sites.

2.2.1 Borehole ZK1

The selection of soil layers at different depths affects the site's natural period to some extent. Comparing the ground surface acceleration response spectrum of borehole ZK1 in the standard site model M1 to site model M3, it is observed that the predominant period of the response spectrum in M3 generally occurs earlier. This difference can be attributed to the natural periods of 3.17 and 1.71 s for site models M1 and M3, respectively. In comparison to site model M1, the acceleration response spectrum of site model M2 exhibits certain differences. For bedrock ground motions with a characteristic period of 0.9 s and input peak accelerations of 0.10, 0.20 and 0.30 g, the relative differences in acceleration response spectrum between site models M2 and M1 range from

-25.54% to 11.43%, -21.37% to 14.02% and -16.66% to 25.26%, respectively. Similarly, for bedrock ground motions with a characteristic period of 1.1 s and the same peak accelerations, the relative differences in acceleration response spectrum between site models M2 and M1 range from -22.19% to 27.93%, -27.99% to 8.19% and -21.48% to 14.83%.

The acceleration response spectrum of site model M3 is generally smaller than that of site model M1. The minimum relative difference in response spectrum between the two site models is -80%, with most of the relative differences around -30%. In other words, conducting seismic response analysis for deep overburden sites directly using the 100 m depth layer as the seismic input interface leads to significant discrepancies compared to the actual site conditions. This is particularly disadvantageous for high-rise buildings or structures constructed on deep overburden sites, especially those susceptible to long-period effects.

2.2.2 Borehole ZK3

The acceleration response spectra at site model M2 of borehole ZK3 under different seismic intensities are closely similar to those of site model M1 across the full frequency bands. The relative differences between the acceleration response spectra of site models M3 and M1 range from -13.22% to 2.06%, -9.84% to 4.93% and -14.34% to 6.50% for ground motion with a characteristic period of 0.9 s, respectively. Similarly, for ground motion with a period of 1.1 s, the relative differences between the acceleration response spectra of site models M2 and M1 range from -9.87% to 8.09%, -9.05% to 4.36% and -10.98% to 4.40%, respectively. In both cases, the rela-

tive differences between the response spectra of site models M2 and M1 fall within $\pm 20\%$. The difference between the depth of the top surface of the soil layer (223.45 m) and the actual bedrock interface (230.33 m) in borehole ZK3 with a shear wave velocity of about 500 m/s is only 6.88 m. Therefore, the difference in the seismic response analysis results between a shear wave velocity of 500 m/s and the actual bedrock interface as the seismic input interface is relatively small.

The increase in peak bedrock acceleration causes the acceleration response spectrum curve of site model M3 to gradually approach that of site model M1. Under the influence of ground motions with a characteristic period of 0.9 s, the relative differences between the acceleration response spectra of site models M3 and M1 range from -47.56% to 13.16%, -39.74% to 10.40% and -29.07% to 13.40%, respectively. Similarly, under the influence of ground motions with a characteristic period of 1.1 s, the relative differences range from -45.56% to 13.94%, -40.11% to 13.12% and -35.61% to 13.84%, respectively. The minimum value of the relative difference between the acceleration response spectra of site models M1 and M3 is mainly observed for periods greater than 2.5 s, indicating that the acceleration response spectra of site model M3 are significantly smaller than those of site model M1 in this range.

2.2.3 Borehole ZK4

The acceleration response spectra of site models M2 and M3 for borehole ZK4 exhibit slightly smaller values compared to those of site model M1. As the peak bedrock acceleration increases, the acceleration response spectra of site models M2 and M3 gradually ap-

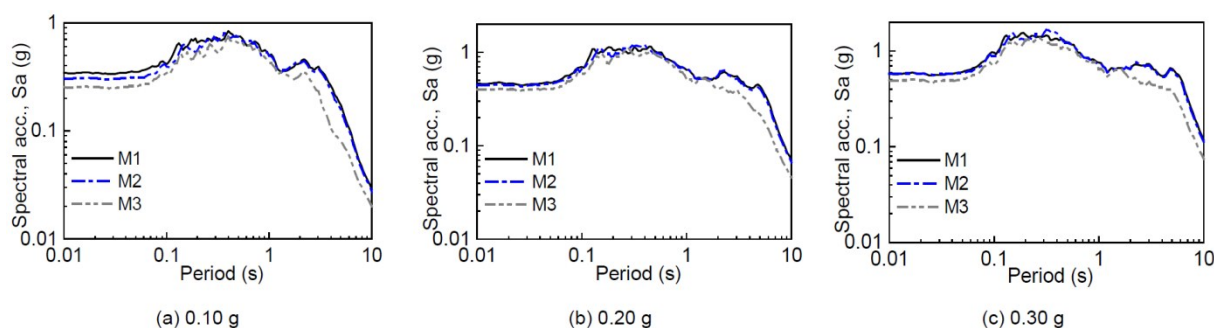


Figure 2. Mean of surface acceleration response spectra for borehole ZK1 ($T_g = 0.9$ s).

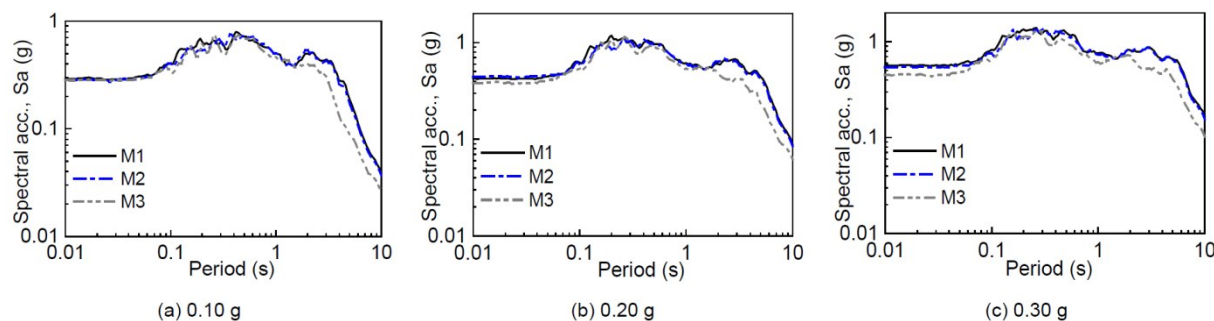


Figure 3. Mean of surface acceleration response spectra for borehole ZK1 ($T_g = 1.1$ s).

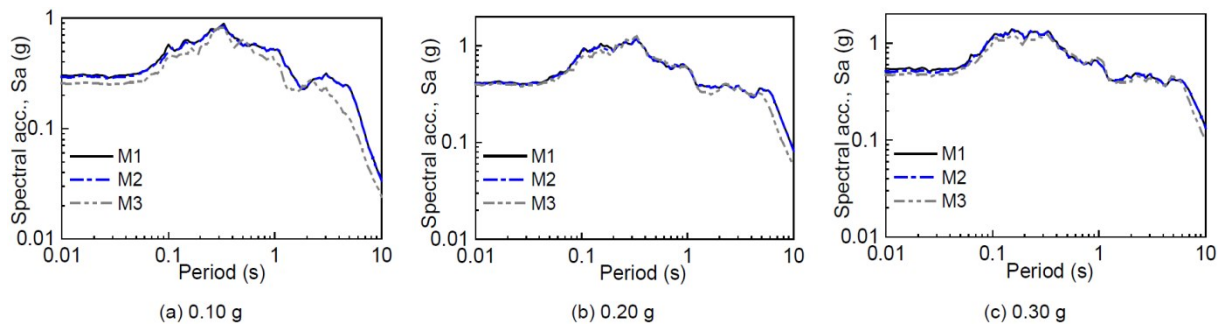


Figure 4. Mean of surface acceleration response spectra for borehole ZK3 ($T_g = 0.9$ s).

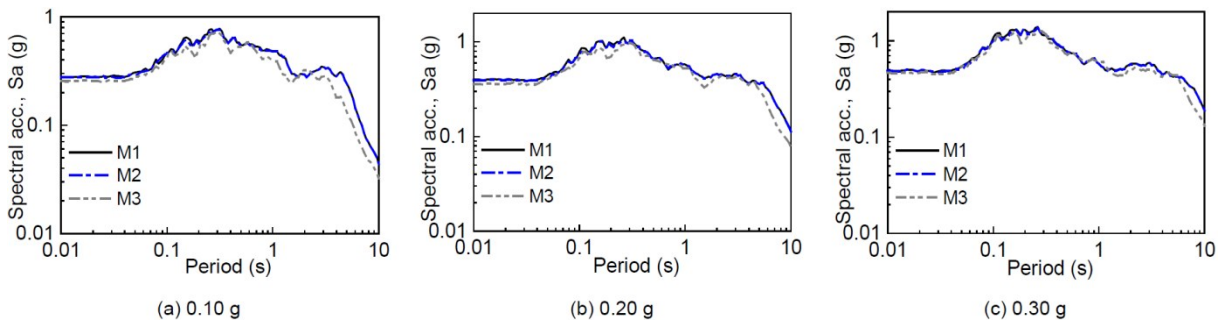


Figure 5. Mean of surface acceleration response spectra for borehole ZK3 ($T_g = 1.1$ s).

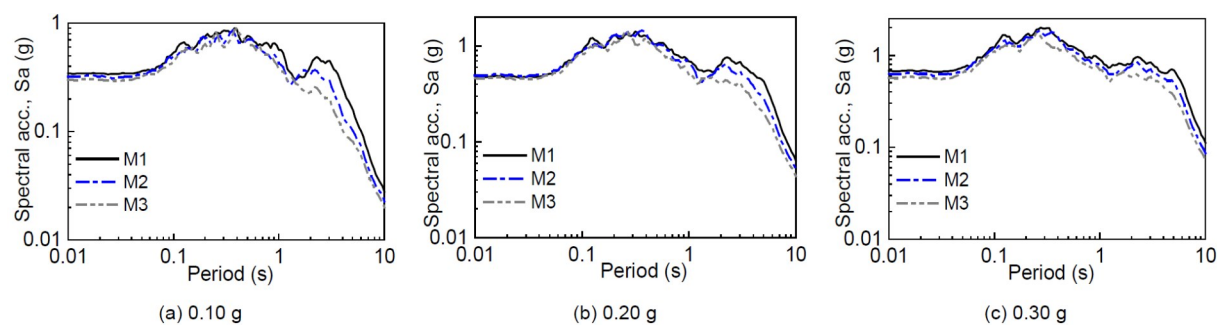


Figure 6. Mean of surface acceleration response spectra for borehole ZK4 ($T_g = 0.9$ s).

proach those of site model M1. The depth of the soil layer in the seismic input interface differs between site models M2 and M1 by 123 m, and between site models M3 and M1 by 180 m, relative to the actual depth of the bedrock interface in borehole ZK4 (280.1 m). The natural periods of site models M1, M2 and M3 are 3.16, 2.27 and 1.69 s, respectively. Due to the relatively rough shear wave velocity data of the soil layer in borehole ZK4, there is a noticeable difference between the results and the actual site, particularly for periods greater than 2 s. The seismic bedrock input interfaces have a similar impact on the acceleration response spectra of boreholes ZK2 and ZK5. Therefore, this discussion is omitted for brevity.

3 CONCLUSIONS

This study employed a frequency-consistent equivalent linearization method to assess the impact of seismic input interfaces on the peak ground acceleration and acceleration response spectra of five representative deep overburden sites, specifically those in the Shanghai area with depths exceeding 100 m and shear wave velocities

below 500 m/s. The primary findings are summarized as follows.

(1) Compared to the site with actual bedrock input ground motion, the peak ground acceleration exhibits relatively small relative differences in the site with a seismic input interface at a shear wave velocity of approximately 500 m/s, all within the engineering error range ($\pm 20\%$). However, in the site with a seismic input interface at a depth of 100 m, the peak ground accelerations are usually smaller, with the minimum relative difference being -26.24% .

(2) Selecting different soil layers as the seismic input interface causes significant differences in the seismic response of deep overburden sites. For the site with seismic input interface at a depth of 100 m, the surface response spectra are generally slightly lower across the entire frequency range compared to the site response spectrum with the actual bedrock input interface. This difference is particularly pronounced for periods exceeding 2 s. Similarly, when the depth of the soil layer with a shear wave velocity of approximately 500 m/s significantly devi-

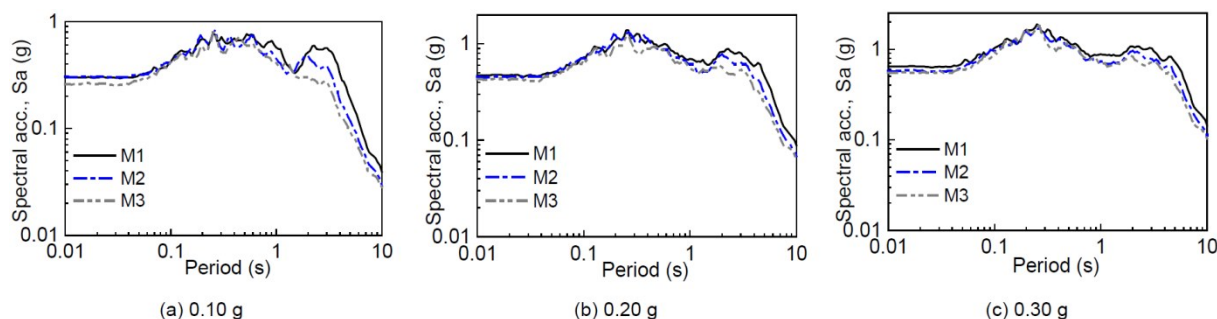


Figure 7. Mean of surface acceleration response spectra for borehole ZK4 ($T_g = 1.1$ s).

ates from the depth of the actual bedrock interface, there is a tendency for the surface acceleration response spectra of the site to be lower than those obtained using the actual bedrock input interface.

(3) When conducting seismic response analysis for deep overburden sites in the Shanghai area, it is recommended to choose the depth of the seismic input interface as close as possible to the actual bedrock interface.

This study explores the effect of ground motion intensity on the peak ground acceleration and acceleration response spectrum of deep overburden sites and the research results in this paper can provide a reference for the selection of the seismic bedrock surfaces in deep overburden sites. It is worth noting that the seismic response analysis of the deep overburden site is influenced by other factors such as the nonlinear constitutive relationship of soil, the structural distribution of the soil layers and the uncertainty of the shear wave velocity. Future research should focus on comprehensively considering the randomness of the input ground motion and other influencing factors in a unified way to obtain the universal seismic response law of deep overburden sites.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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