Novel Evaluation Method for Site Effect on Earthquake Ground Motion Based on Modified Horizontal to Vertical Spectral Ratio

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The effect of local site conditions on the earthquake ground motion is a very important factor to be considered in engineering seismic fortification. Many methods, such as numerical simulation methods based on site analysis models and statistical empirical relation methods based on the earthquake ground motion observations and numerical simulation data, have been used to consider the site effects in actual engineering seismic fortification and earthquake disaster assessment. The statistical analysis to obtain characteristic parameters of site condition effect based on strong motion and microtremor records become an economical and practical method of determining the designed ground motion of engineering sites, especially for large survey areas and engineering sites where it is difficult to carry out a site survey. In this paper, a novel evaluation method for site effect on earthquake ground motion is proposed. The new method is based on the horizontal to vertical spectral ratio (HVSR) method, but the original HVSR is replaced by a modified HVSR considering the effect of the soil layer on the vertical ground motion. In order to build the model and determine the corresponding parameters of the modified HVSR, first, the ground motions in the bedrock below the soil layer are calculated using the one-dimensional equivalent linear method. These calculated records are independent of the influence of the downgoing wavefield, and the differences between the ground surface to bedrock spectral ratio (SBSR). The HVSR for the local sites of ground motion observation stations are analyzed using the strong ground motion records from the Kiban-Kyoshin network (KiK-net) in Japan. The statistical characteristics of the relationship between SBSR and HVSR are revealed, and then, a quantitative relationship between SBSR/HVSR and HVSR is established. The proposed evaluation method for the site effect has the advantage that the original HVSR method only requires ground motion records on the ground surface of the site, and it further considers the influence of the vertical seismic effect on the accuracy of the HVSR method. The proposed method can characterize the influence of the site conditions on ground motion more reasonably than the conventional method.

Keywords: site condition, site effect, strong motion record, KiK-net, horizontal to vertical spectral ratio

INTRODUCTION

Surveys and investigations of earthquake disasters have shown that the spatial variations in the local site conditions are the main factor leading to the differences in earthquake disasters in local areas during large earthquakes (Wood, 1908; Liu, 2002). The conclusion that the important effect of local site conditions on the propagation of seismic waves has been repeatedly confirmed in large earthquakes and has been broadly studied and applied in practical engineering (Borcherdt et al., 1976; Seed et al., 1976a, 1976b, 1988; Li, 1992; Guo et al., 2013; Zhang et al., 2020). The "local site" conditions generally refer to the variations in the shallow engineering geological structures and surface topography within a region of tens to hundreds of meters. In studies of the effect of site conditions on ground motions, certain classification indicators are usually used to classify sites into different categories and to characterize the differences in the site conditions (Lee et al., 2001; Building Seismic Safety Council, 2004; Huang et al., 2009; Ministry of Housing and Urban-Rural, 2016; Li, 2013; Li et al., 2019). Based on the site classification in the statistical analysis of strong-motion records or numerical simulation methods of site models, the characteristic parameters and empirical relationships are obtained to characterize the effect of the site conditions on ground motions (Hwang et al., 1997; Li et al., 2001; Lu et al., 2008; Pitilakis et al., 2013). To provide a reference for engineering design under complex site conditions, a ground motion parameter adjustment model is used to account for the effects of the different site conditions on ground motions. A simple classification of sites is often insufficient when representing the effects of specific sites on ground motions. For this reason, it is necessary to carry out a drilling survey of the site conditions for important engineering projects and to perform site seismic response simulations for the specific site conditions to account for their impact on the ground motion. For sites that involve a large scope (such as new district construction planning and old city reconstruction) and for sites that pose difficulties to the execution of drilling survey (such as construction sites in alpine canyon areas or on islands and reefs), economical and practical methods need to be utilized for acquiring the characteristics of the site effects and to determine the seismic design of the engineering site, such as methods based on the analysis and statistics of strong-motion records and microtremors.

As early as 1970, Borcherdt (1970) proposed a transfer function spectral ratio method for calculating sedimentary site effects using records of strong motions observed by site stations and referencing bedrock stations. This type of method is the most direct method of site effect analysis and is referred to as the classical standard spectral ratio method. The surface to bedrock spectral ratio (SBSR) method is based on the records of borehole arrays (Wen et al., 1995; Régnier et al., 2013), and the ground motion records at the borehole bedrock are used as the reference ground motion. Compared with the standard spectral ratio method, the SBSR method can effectively solve the difficult problem of selecting a reference free-surface bedrock. In addition, since it is believed that the ground motion records of a vertical array on the ground surface and those of borehole

bedrock contain the same source effect and propagation path effect, the SBSR can better characterize the effect of the site conditions on ground motions. Nevertheless, it is imperative to note that the records for the bedrock below the soil layers are disturbed by the downgoing wavefield (Bonilla et al., 2002; Régnier et al., 2013).

In the late 1980s, the Japanese scholar Nakamura proposed a method for estimating the influence of the characteristics of a site on ground motions based on the Fourier amplitude spectral ratio of the horizontal and vertical components of a microtremor (Nakamura, 1989), which later became known as the horizontal to vertical spectral ratio method (referred to as the HVSR method or the Nakamura method). The HVSR method includes the following basic assumptions: 1) for site microtremor observations in different periods, the spectral characteristics of the microtremors are basically the same, and the amplification effect is mainly related to the dynamic characteristics of the soil media; 2) the value of HVSR at the bedrock is 1; 3) the horizontal component of the microtremors is amplified by the soil layers, but the vertical component is basically not amplified.

The HVSR method derives from microtremor observations and analysis, and it was first used in the study of microearthquakes (Konno et al., 1998; Chen et al., 2009). It was later applied to the analysis of strong-motion observations and then, it was expanded into the research of site effects on ground motions (Lermo et al., 1993; Yamazaki et al., 1997; Zhao et al., 2006; Fukushima et al., 2007; Wen et al., 2010; Kawase, 2011; Nagashima et al., 2014; Rong et al., 2016). The validity and scope of the application of the HVSR method in the analysis of the site effect on ground motions have always been subject to some debate and controversy. This is mainly because the HVSR method assumes that the HVSR at the bedrock is one and the vertical component is basically not amplified. At present, there still is no consistent conclusion regarding these issues, but a common notion is that the HVSR method can effectively extract the predominant period of the site effects on ground motions. However, there can be large errors in the estimation of the site effect amplification (Rong et al., 2016).

In this study, we present our results of the study on the strong motion records of the Kiban-Kyoshin network (KiK-net) in Japan, and we examined the different characteristics of the SBSR and HVSR at the sites of strong-motion recording stations and the variations in the SBSR/HVSR with the spectral period. Then, a novel site effect evaluation method that uses seismic records was developed based on a modified HVSR and the statistical relationship between the SBSR and HVSR.

THE IDEA OF THE NEW METHOD

Theoretically, compared with the HVSR method, the SBSR method can more reasonably evaluate the effects of the site conditions under a seismic, but it needs to use the observed ground motion records on the ground surface of the site and the corresponding bedrock below soil layers, separately. Therefore, it is necessary to conduct site drilling and borehole observations,

No.	Site code	Latitude N/(°)	Longitude E/(°)	Depth/m	$V_{S,30}$/(m·s^{-1})	NEHRP classification
1	AKTH02	39.6634	140.5721	100	620.404	C
2	AKTH13	39.9819	140.4072	100	535.723	C
3	AOMH05	40.8564	141.1033	312	238.302	D
4	AOMH13	40.5794	141.4451	150	154.274	E
5	AOMH16	40.4624	141.0923	150	225.750	D
6	AOMH17	40.4624	141.3374	114	378.362	C
7	FKSH11	37.2006	140.3386	115	239.826	D
8	FKSH14	37.0264	140.9702	147	236.561	D
9	FKSH20	37.4911	140.9871	109	350.000	D
10	HDKH01	42.7031	142.2296	100	368.252	C
11	HDKH04	42.5126	142.0381	220	235.026	D
12	IBRH10	36.1112	139.9889	900	144.138	E
13	IBRH13	36.7955	140.575	100	335.369	D
14	IBRH17	36.0864	140.314	510	300.774	D
15	IBUH01	42.8739	141.8191	101	306.785	D
16	IWTH02	39.825	141.3826	102	389.567	C
17	IWTH06	40.2611	141.1709	100	431.655	C
18	IWTH08	40.2686	141.7831	100	304.521	D
19	IWTH24	39.1979	141.0118	150	486.412	C
20	IWTH27	39.0307	141.532	100	670.313	C
21	KMMH01	33.109	130.695	100	574.631	C
22	KSRH06	43.22	144.4285	237	326.193	D
23	KSRH07	43.1359	144.3274	222	204.104	D
24	KSRH10	43.2084	145.1168	255	212.875	D
25	MYGH13	38.699	141.418	100	570.591	C
26	NIGH11	37.1728	138.744	205	375.000	C
27	NMRH04	43.3978	145.1224	216	168.103	E
28	SMNH12	35.1634	132.8558	101	590.200	C
29	TCGH12	36.6959	139.9842	120	343.678	D
30	TKCH08	42.4865	143.152	100	353.208	D

which is expensive and time-consuming. The HVSR method only requires ground motion records, but there are some unreasonable problems in the basic assumptions listed above. Therefore, the construcuion of an indirect evaluation method for the SBSR was developed in this study.

Based on the SBSR method the following relationship can be assumed,

$$SBSR_H = \frac{S_{S,H}}{S_{B,H}}, \qquad (1)$$

where $SBSR_H$ is the SBSR value of the horizontal motion on the ground surface and in the corresponding bedrock, $S_{S,H}$ is the Fourier amplitude spectrum of the horizontal-component on the ground surface, $S_{B,H}$ is the Fourier amplitude spectrum of the horizontal-component in the bedrock. **Eq. 1** can be rewritten as

$$SBSR_H = \frac{S_{S,H}}{S_{S,V}} \times \frac{S_{S,V}}{S_{B,V}} \times \frac{S_{B,V}}{S_{B,H}} = \frac{S_{S,H}}{S_{S,V}} \times \frac{S_{S,V}}{S_{B,V}} \times \frac{1}{S_{B,H}/S_{B,V}}$$
$$= HVSR_S \times \frac{SBSR_V}{HVSR_B}. \qquad (2)$$

where $S_{S,V}$ is the Fourier amplitude spectrum of the vertical motion on the ground surface, $S_{B,V}$ is the Fourier amplitude spectrum of the vertical motion in the bedrock, $HVSR_S$ is the HVSR value in the ground surface, $HVSR_B$ is the HVSR value in

the bedrock, $SBSR_V$ is the SBSR value of the vertical on the ground surface and in the corresponding bedrock.

If the Fourier amplitude spectrum transfer function of the horizontal motion from the bedrock to the ground surface (TF_H) i.e., the $SBSR_H$, is used to express the effect of the site conditions on the horizontal motion, then based on **Eq. 2**,

$$TF_H = HVSR_S \times SBSR_V / HVSR_B, \qquad (3)$$

According to the basic assumption of the HVSR method,

$$\begin{cases} HVSR_B = 1 \\ SBSR_V = 1 \end{cases}, \qquad (4)$$

Then, based on **Eq. 3**,

$$TF_H = HVSR_S, \qquad (5)$$

Therefore, TF_H can be approximately calculated using the HVSR method. However, there are some errors that needed to be considered in order to obtain a more reasonable evaluation value of TF_H. A novel evaluation method for site effect was developed to evaluate the site effect on earthquake ground motions.

$$TF_H = \alpha \bullet HVSR_S, \qquad (6)$$

where α is a modified parameter that describes the impacts of $SBSR_V$ and $HVSR_B$, which needs to be obtained via statistical

analysis of ground motion records. This is a special issue investigated in this study.

SELECTION AND PROCESSING OF STRONG MOTION RECORDS

Japan's National Institute of Earth Science and Disaster Prevention (NIED) has established two strong motion observation networks, K-NET and KiK-net, with a total of more than 1,700 stations nationwide. The average distance between stations is less than 20 km. The stations in the KiK-net strong motion observation network are all multi-point borehole arrays (i.e., a vertical array). Each station is equipped with tri-axial strong motion observation instruments on the ground surface and at the bottom bedrock in the borehole. They can simultaneously observe ground motions on the ground surface and in the bedrock below the soil layers. The borehole depths of the KiK-net stations are all 100 m or greater. Except for a few individual station sites, the boreholes all reach the engineering bedrock surface ($V_S > 760$ m/s). The KiK-net was put into service in 1997, and a large number of observation records have been obtained.

Selection of Strong Motion Records

The focus of this study was analysis of the influence of the soil layers on the ground motion. Therefore, when selecting the KiK-net observation records for this study, it was necessary to examine whether the observation station site could be regarded as a layered site, i.e., whether it could be simplified to a one-dimensional site model. First, the stations used in this study were selected from the 662 stations in the KiK-net network that had obtained a certain number of strong-motion records. The selection criteria were as follows. 1) The number of records with a peak ground acceleration (PGA) of $PGA > 100$ gal was two or more. 2) The number of records with $PGA > 10$ gal was at least 100. Then, for the stations with ground motion records met the above criteria, their transfer functions of the horizontal ground motions were calculated according to the one-dimensional site models (referred to as the calculated transfer function TF_{HC}), and the $SBSR_H$ of the horizontal ground motions were calculated using the ground motion records (referred to as the statistical transfer function TF_{HS}). To obtain the calculated transfer function TF_{HC}, the one-dimensional site models were established using the borehole and test data of the station sites. We statistically analyzed the logarithmic mean standard deviation σ of TF_{HS} and the correlation coefficient r between TF_{HS} and TF_{HC} for each station site. We selected the station sites that satisfied both $\sigma < 0.35$ and $r > 0.6$ as the sites that met the criteria of this study. In total, 30 stations were finally selected, as shown in **Table 1**.

Based on a comparison of the site responses to the main shocks and aftershocks of large earthquakes, earlier researchers have speculated that the threshold for nonlinear site responses is 100–200 gal (Wen et al., 1994; 1995). However, recent studies have shown that a slight nonlinearity of site responses appears in records with medium-level intensities ($PGA = 20$–80 gal) (Baise, 2000; Régnier et al., 2013). Thus, we divided the 19,002 sets of
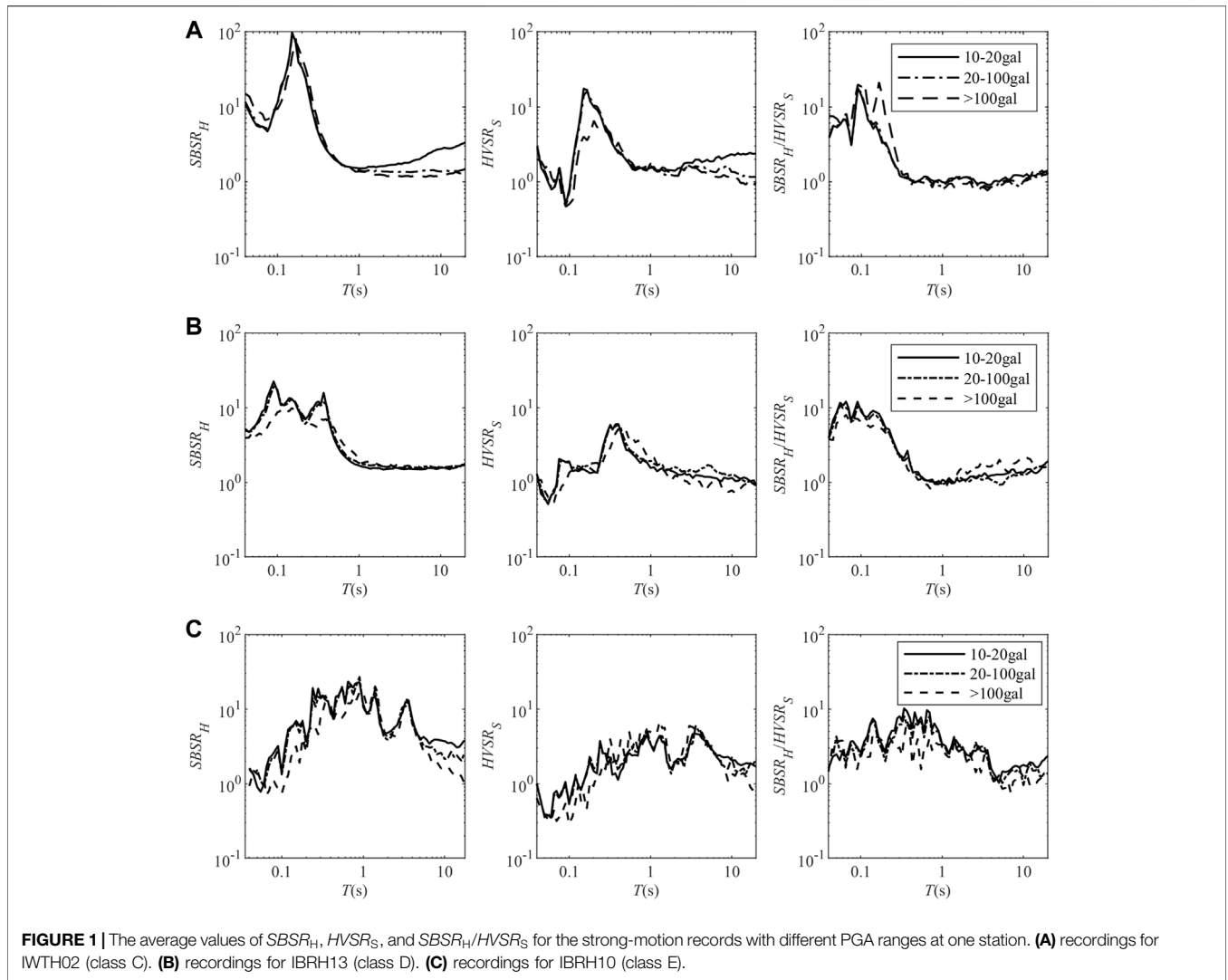
TABLE 2 | The number of strong-motion records in the different PGA groups.

Site class	Site code	PGA/gal				
		10~20	20~100	100~200	200~300	>300
C	AKTH02	74	54	2	0	0
	AKTH13	122	79	9	0	0
	AOMH17	299	106	9	4	0
	HDKH01	127	60	3	0	4
	IWTH02	876	667	42	11	14
	IWTH06	181	85	6	0	0
	IWTH24	185	112	10	3	2
	IWTH27	1,079	504	31	8	8
	KMMH01	99	39	6	2	0
	MYGH13	675	311	13	1	2
	NIGH11	146	110	9	3	3
	SMNH12	52	52	6	4	0
D	AOMH05	417	207	15	3	0
	AOMH16	428	171	9	2	0
	FKSH11	622	285	12	2	3
	FKSH14	635	283	18	2	2
	FKSH20	393	238	21	0	2
	HDKH04	119	56	4	1	2
	IBRH13	1,175	732	79	23	33
	IBRH17	796	424	21	2	3
	IBUH01	317	136	10	3	4
	IWTH08	423	182	13	0	2
	KSRH06	349	155	3	1	8
	KSRH07	286	149	8	1	4
	KSRH10	273	174	11	3	5
	TCGH12	680	338	6	0	2
	TKCH08	197	117	10	0	1
E	AOMH13	213	86	7	0	0
	IBRH10	522	248	16	2	0
	NMRH04	328	150	8	0	2

three-component strong motion records obtained from the 30 stations into six groups, with peak ground accelerations of 10–20, 20–100, 100–200, 200–300, and >300 gal (**Table 2**). Since the records with $PGAs$ of < 10 gal are of little engineering significance, they were not considered in this study.

Processing of Strong Motion Records

In studies of site condition effects using strong motion records, as much attention as possible should be given to the recorded S-wave time section. Therefore, before calculating the Fourier amplitude of the ground motion, a time window with a reasonable length should be chosen. The time window should not only contain the main energy of the shear waves, but it should also avoid the influence of the surface waves on the amplitude spectrum. For this reason, the time window for the ground motion record was chosen to be from the first arrival of the P wave to the time when the seismic wave energy reached 80% of the total energy (the cut-off time). In the specific analysis, the cut-off time was calculated using the ground motion energy by the Arias intensity formula (**Eq. 7**), and the signal-to-noise ratio (SNR) was calculated using **Eq. 8**. The first 15 s of the record were treated as noise to eliminate the records with an SNR of less than 5 dB in the 0.05–20 Hz frequency, to reduce the dispersion of the results caused by unreasonable statistical data,

FIGURE 1 | The average values of $SBSR_H$, $HVSR_S$, and $SBSR_H/HVSR_S$ for the strong-motion records with different PGA ranges at one station. **(A)** recordings for IWTH02 (class C). **(B)** recordings for IBRH13 (class D). **(C)** recordings for IBRH10 (class E).

and to improve the accuracy of the analysis results. The ground motion energy I_a is defined as

$$I_a = \frac{\pi}{2g} \int_0^{T_e} a^2(t) dt, \qquad (7)$$

where T_e is the ground motion duration. The SNR is defined as

$$SNR(f) = 10 \log \frac{A_{signal}(f)}{A_{noise}(f)}. \qquad (8)$$

where $A_{signal}(f)$ is the Fourier amplitude spectrum of the ground motion record, and $A_{noise}(f)$ is the Fourier amplitude spectrum of the noise signal.
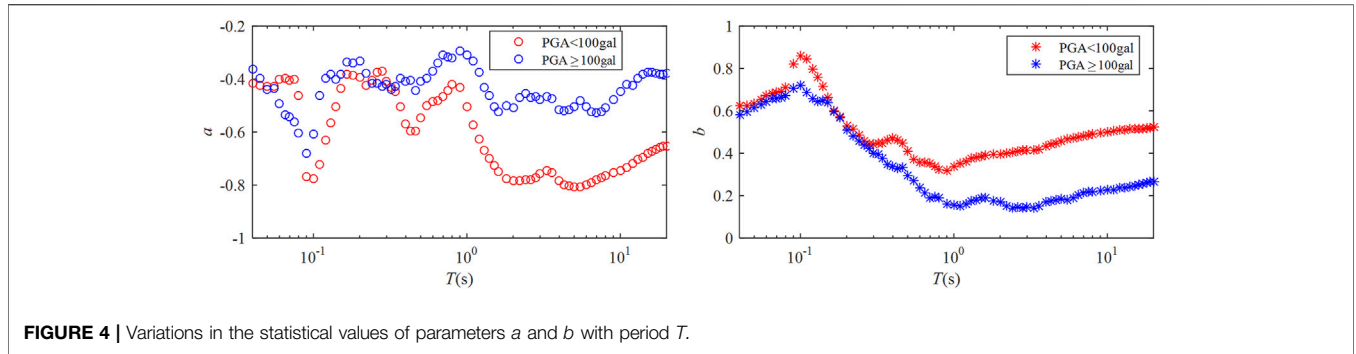
ANALYSIS OF THE DIFFERENCE BETWEEN SBSR AND HVSR

To calculate $SBSR_H$ and $HVSR_S$ of the ground motion records, the average values were obtained in three *PGA* ranges: 10–20, 20–100,

and >100 gal. Because there were few *PGA* > 200 gal records, *PGA* > 100 gal was used as the statistical range. **Figures 1A–C** show the average values of $SBSR_H$ and $HVSR_S$ in the different PGA ranges.

The data presented in **Figures 1A–C** show that the mean values of $SBSR_H$ and $HVSR_S$ of the ground motions recorded by each station did not exhibit any significant differences when *PGA* < 100 gal, but there were significant differences when *PGA* > 100 gal, which indicates the nonlinear effect of the soil layers on ground motions. For this reason, no distinction was made between the 10–20 and 20–100 gal categories in the subsequent statistical analysis.

Figure 2 shows the average $SBSR_H/HVSR_S$ values of the ground motions recorded by each station and the average value plus or minus one standard deviation. Over the entire period, the average $SBSR_H/HVSR_S$ values were greater than 1, that is, the average $SBSR_H$ values were greater than of the average $HVSR_S$ values. This confirmed the existence of the site effect on the vertical ground motion. The average value and variance of $SBSR_H/HVSR_S$ were approximately constant

FIGURE 2 | Variations in $SBSR_H/HVSR_S$ with period. **(A)** PGA = 10~20 gal. **(B)** PGA = 20~100 gal. **(C)** PGA > 100 gal. **(D)** comparison of the different PGA ranges.

FIGURE 3 | Variations in $SBSR_H/HVSR_S$ with $HVSR_S$.
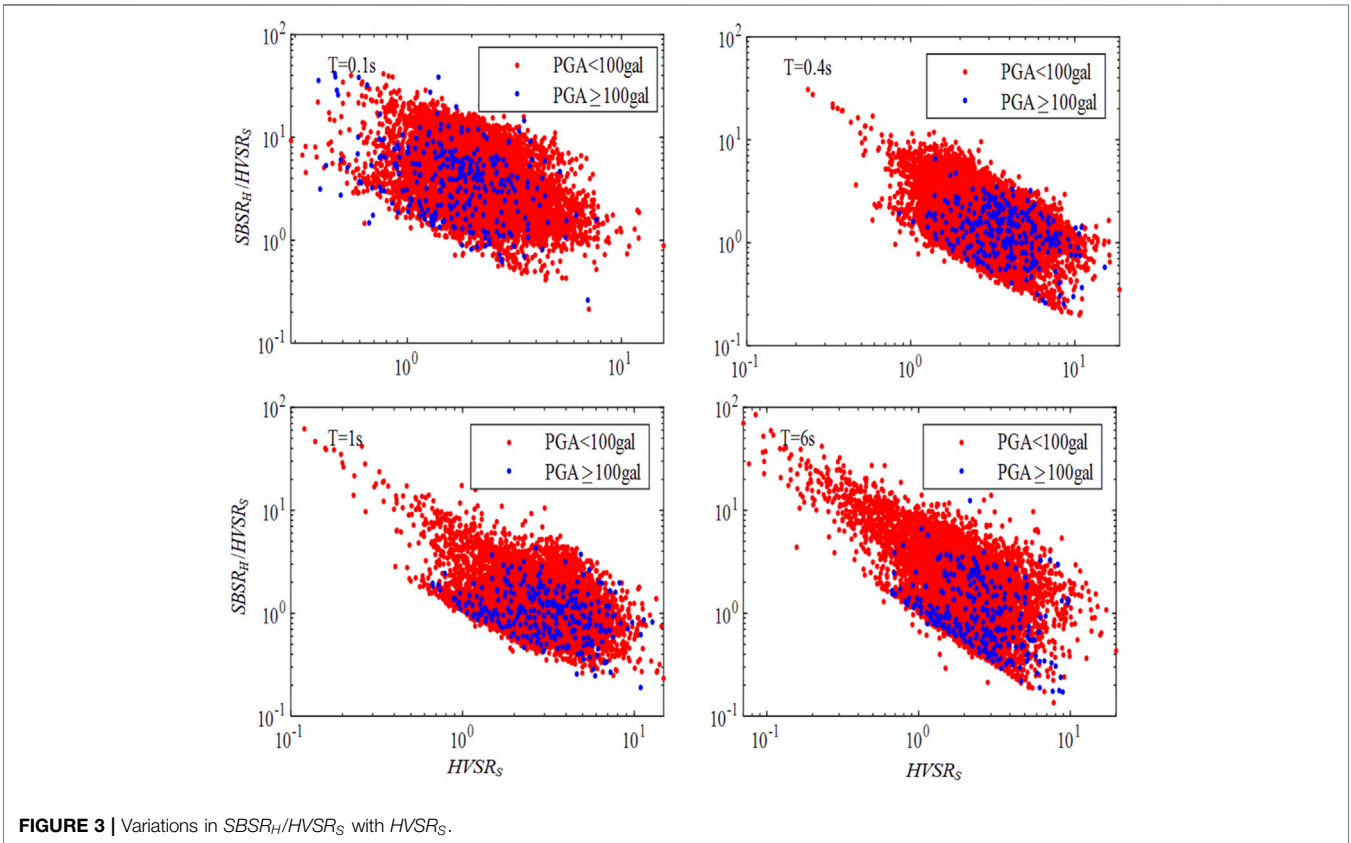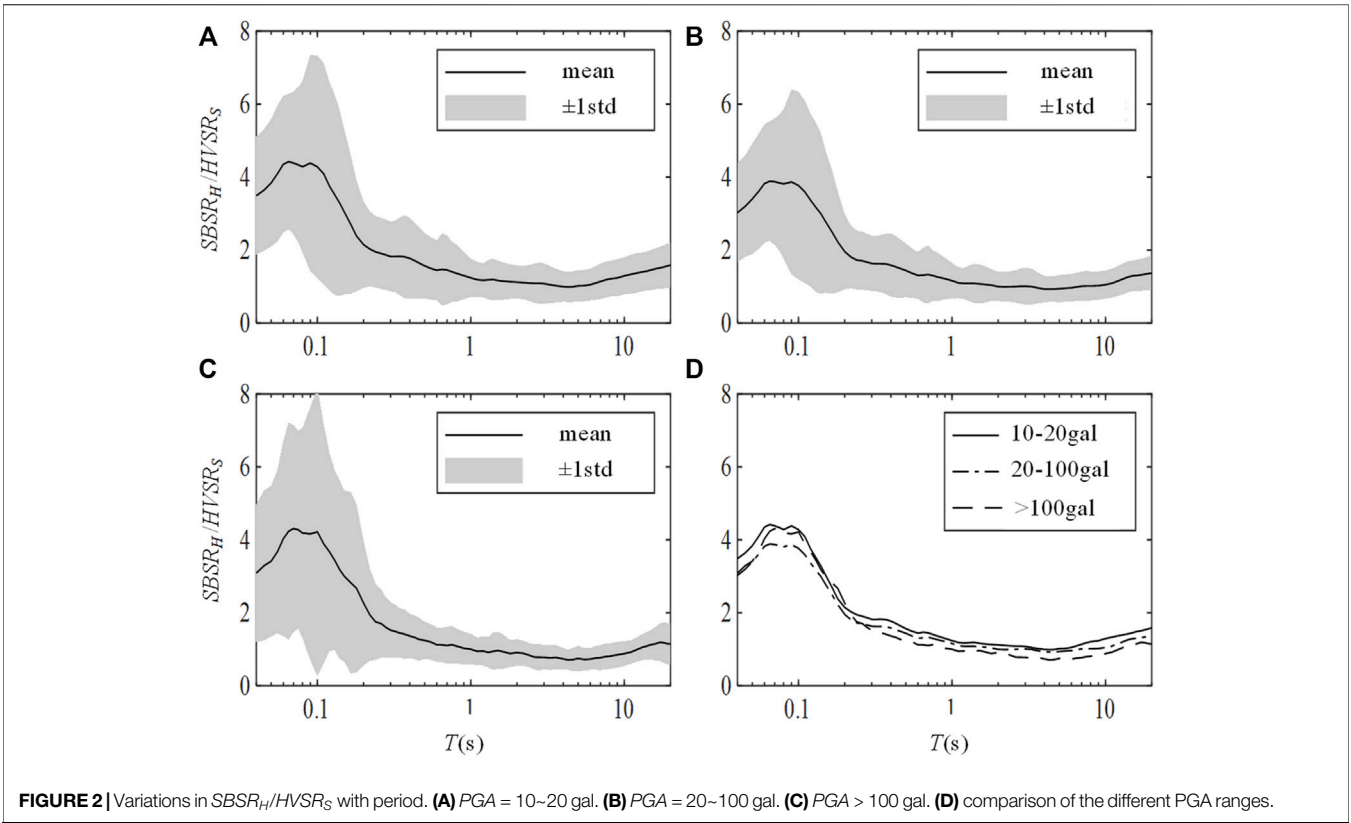
FIGURE 4 | Variations in the statistical values of parameters *a* and *b* with period *T*.
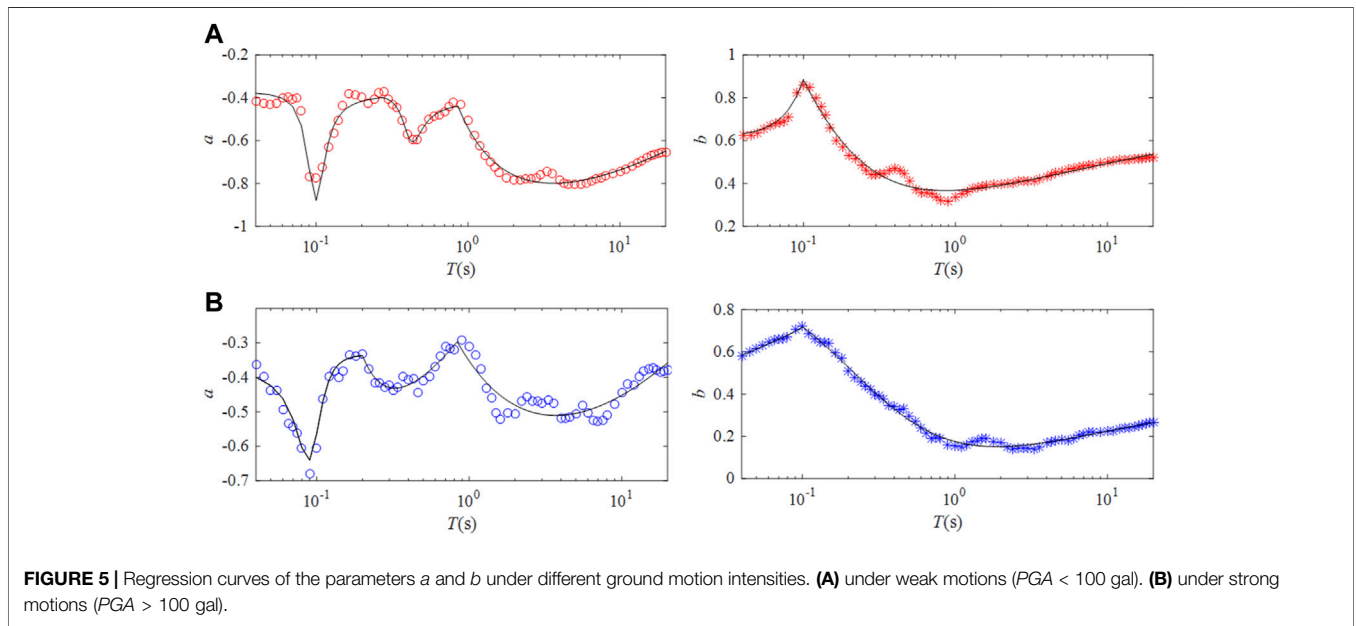
FIGURE 5 | Regression curves of the parameters *a* and *b* under different ground motion intensities. **(A)** under weak motions (*PGA* < 100 gal). **(B)** under strong motions (*PGA* > 100 gal).

TABLE 3 | Coefficients for the relationships between parameters *a* and *b* and the period *T*.

Parameter	*PGA*/gal	Period *T*/s	Coefficients							
			p_1	p_2	p_3	q_1	q_2	q_3	*R*
a	<100	(0.04, 0.27)	−0.376	−0.762	−0.391	1	2.014	1.019	0.902
		(0.27, 0.86)	−0.404	−0.318	−0.067	1	0.768	0.154	0.957
		(0.86, 20.00)	0.538	−1.404	−0.354	0	1.000	0.656	0.952
	≥100	(0.04, 0.20)	−0.348	−0.707	−0.365	1	2.066	1.077	0.958
		(0.20, 0.84)	0.813	0.361	−0.277	0	1.000	1.090	0.874
		(0.84, 20.00)	0.879	−1.510	−0.634	0	1.000	1.799	0.789
b	<100	(0.04, 0.10)	−0.250	−0.118	−0.072	0	1.000	0.763	0.962
		(0.10, 20.00)	1.124	1.103	1.114	1	2.745	3.032	0.966
	≥100	(0.04, 0.10)	0.309	1.307	0.964	0	1.000	0.951	0.985
		(0.10, 20.00)	0.670	-0.117	0.282	1	1.120	1.607	0.992

in the period of 0.4–20 s, and they changed very little with the period. However, they changed significantly in the period of less than 0.4 s.

  Figure 3 shows the variations in $SBSR_H/HVSR_S$ with $HVSR_S$ for the different periods. The variations in the period range of 0.04–20 s exhibited a high regularity, and there was a logarithmic correlation between $SBSR_H/HVSR_S$ and $HVSR_S$. This provided a basis for establishing a novel evaluation method for site amplification by modifying the HVSR method to take into account the site effect on the vertical ground motion.

Based on the above calculation and analysis results and using the logarithmic coordinate linear fitting method, we obtained the following quantitative relationship between the HVSR and SBSR under different ground motion levels in the period range of 0.04–20 s:

$$\alpha(T) = \frac{SBSR_H(T)}{HVSR_S(T)} = a(T)HVSR_S(T) + b(T), \qquad (9)$$

where T is the period, and a and b are statistical constants.

Based on previous studies, the statistical values of a and b were obtained, and the results of their changes with the period T are shown in **Figure 4**. These values vary significantly with T and fluctuate up and down, especially the values of a. For this reason, we used the following parametric model to fit the curves of a and b in the period ranges.

$$Y = \frac{p_1 x^2 + p_2 x + p_3}{q_1 x^2 + q_2 x + q_3}. \qquad (10)$$

where Y represents a or b, x represents the base-10 logarithmic period, and p_1, p_2, p_3, q_1, q_2, and q_3 are the model parameters. The variations in a and b with T were obtained through fitting, as shown in **Figures 5A,B**, and the model coefficients are shown in **Table 3**.

NOVEL EVALUATION METHOD FOR SITE EFFECT

Through comprehensive consideration of **Eqs 6**, **9**, **10**, we obtained the following equations for a novel method of evaluating the site effect:

$$TF_H(T) = (a(T)HVSR_S(T) + b(T))\, HVSR_S(T), \qquad (11)$$

$$a(T) = \frac{p_{1a}(\log T)^2 + p_{2a}\log T + p_{3a}}{q_{1a}(\log T)^2 + q_{2a}\log T + q_{3a}}, \qquad (12)$$

$$b(T) = \frac{p_{1b}(\log T)^2 + p_{2b}\log T + p_{3b}}{q_{1b}(\log T)^2 + q_{2b}\log T + q_{3b}}. \qquad (13)$$

where TF_H is the Fourier amplitude spectrum transfer function of the horizontal ground motions from the bedrock to the ground surface, $HVSR_S$ is the HVSR value of the ground motion on the surface, T is the period, and p_{1a}, p_{2a}, p_{3a}, q_{1a}, q_{2a}, q_{3a}, p_{1b}, p_{2b}, p_{3b}, q_{1b}, q_{2b}, and q_{3b} are empirical constants which are listed in **Table 3**.

CONCLUSION

Using 19,002 sets of acceleration record data from 30 strong motion observation stations in Japan's KiK-net, we performed statistical analysis of the relationship between the SBSR and HVSR of the station sites and obtained a log-linear correlation between the SBSR/HVSR and HVSR. We also obtained a quantitative statistical relationship. Based on the statistical analysis results, we developed a novel evaluation method for site effect using a modified HVSR formula to characterize the influence of the soil layers on the ground motion. The modified HVSR formula accounts for the influence of the vertical ground motion effect of the site and the nonlinear characteristics of the soil layers. The proposed method can more accurately evaluate the effects of the soil layers on the ground motions.

The SBSR is similar as the transfer function of the ground motions from the bedrock to the surface, but it cannot be regarded as the complete amplification function of the site effect on the ground motion. The incident wave at the bedrock below the soil layers was obtained using a one-dimensional equivalent linearization method, which yields the recording for the reference bedrock site. Although this operation can eliminate the influence of the downgoing wavefield on the ground motion record of the bedrock below the soil layers, it also introduces errors into the calculation of the ground motion record at the reference bedrock. Improving the accuracy of the reference bedrock record will to be studied in the future.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://www.kyoshin.bosai.go.jp/kyoshin/data/index_en.html.

AUTHOR CONTRIBUTIONS

XL and NL contributed to conception and design of the study. NL performed the statistical analysis and wrote the first draft of the manuscript. XL, NL, and MR wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feart.2022.938514/full#supplementary-material

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