J	ABSH01	4.68	5.3	3.8	0.59
K	ABSH02	4.67	5.5	3.7	0.59
L	ABSH05	6.99	7.4	6.6	0.18
M	ABSH06	2.92	3.3	2.4	0.15
N	ABSH07	3.46	4.1	3.1	0.15

According to the analysis of Table 2, the variation range of the natural frequency of the site is 20%, and the standard deviation of the site identified by the H/V spectrum ratio method is less than 0.25. It can be seen that the natural frequency of the site is not a fixed value, but will change within a certain range.

5. The relationship among H/V spectrum ratio method,predominant frequency f_p and 30m shear wave velocity V_{s30}

This paper uses the H/V spectrum ratio method to identify the natural frequency of strong motion records at 14 stations, and obtains the site natural frequency by averaging the calculation results of each strong earthquake record. According to the station site information published on the KiK-net website, the 30m shear wave velocity V_{s30} is calculated using Eq. (5), the site predominant period Tp is calculated using Eq. (6) , and the reciprocal is used to obtain the site predominant frequency f_p .

$$V_{s30} = \frac{30}{\sum_{i=1}^{m} \frac{h_i}{V_{si}}} \tag{5}$$

In Eq. (5), V_{s30} is the shear wave velocity of 30m of the calculated site, h_i is the thickness of each layered soil, V_{si} is the shear wave velocity of each layered soil, m is the number of soil layers, where $i = 1{:}m$ is in the order of from the surface to the underground , $\sum_{i=1}^{m} h_i = 30$.

$$T_p = \sum_{i=1}^{n} \frac{4h_i}{V_{si}} \tag{6}$$

In Eq. (6), Tp is the predominant period of the calculation site, h_i is the thickness of each layered soil, V_{si} is the shear wave velocity of each layered soil, and n is the number of soil layers.

Table 3 Classification of soil and range of shear wave velocity

Type of soil	Description of soil properties	The range of soil shear wave velocity
Hard soil or rock	Stable rock, dense gravel soil	$V_{si} > 500$
Medium hard soil	Medium-density and slightly dense gravel soil, compact and medium-density sand	$500 \geq V_{si} > 250$
Medium soft soil	Slightly dense sand, except loose silty fine sand	$250 \geq V_{si} > 140$
Soft soil	Silt and silty soil, loose sand, newly deposited cohesive soil	$140 \geq V_{si}$

The research object of this article is the soil between the borehole and the ground surface., According to Table 3 , $V_{si} >> 500$ is not be considered。

The average values of the site predominant period Tp, predominant frequency fp, 30m shear wave velocity V_{s30}, and H/V spectrum ratio method f_m of the 14 stations are summarized as shown in Table 4 below.

Table 4 Frequency calculation results of each site

Number	Station	Tp (s)	fp (Hz)	V_{s30} (m/s)	f_m (Hz)
A	ABSH10	0.13	7.5	609.76	6.32
B	ABSH13	0.42	2.372	463.61	2.07
C	AICH12	0.78	1.28	163.26	1.68
D	AKTH07	0.45	2.24	349.65	1.84
E	AKTH09	0.38	2.66	319.49	3.58
F	AKTH10	0.26	3.84	333.70	3.62
G	FKSH06	0.12	8.59	837.99	8.23

H	FKSH19	0.31	3.19	338.22	3.27
I	GIFH26	0.35	2.83	424.93	2.81
J	ABSH01	0.24	4.19	502.27	4.68
K	ABSH02	0.21	4.85	501.27	4.67
L	ABSH05	0.15	6.83	733.36	6.99
M	ABSH06	0.37	2.69	298.32	2.92
N	ABSH07	0.28	3.57	363.64	3.46

In this paper, the excellent frequencies fp and 30m shear wave speeds V_{s30} of the 15 selected sites are fitted. As shown in Fig. 7, there is a deviation between the results. Therefore, a more reliable and effective site identification method is required.

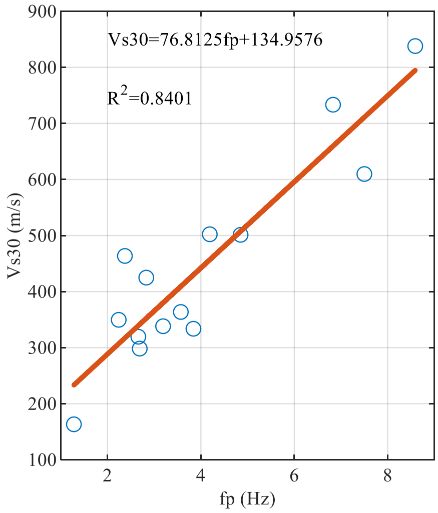

Fig. 7 Comparison of V_{s30} and fp

The fitting of the fp and the fm is shown in the Fig. 8 and the fitting of the V_{s30} and the fm is shown in the Fig. 9.

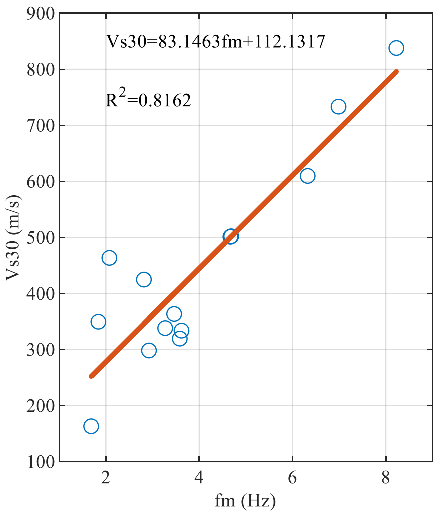

Fig. 8 Comparison of V_{s30} and f_m

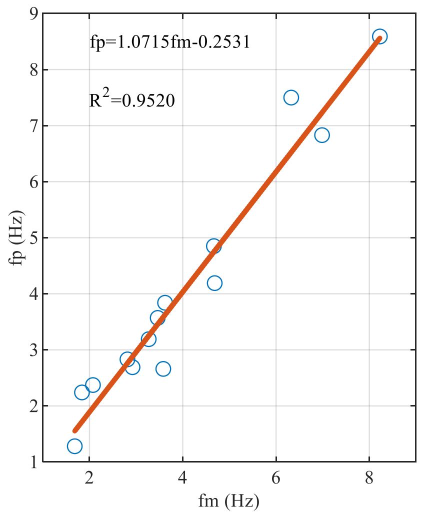

Fig. 9 Comparison of fp and f_m

Through comparison, it is found that fp is a more reliable indicator to measure site natural frequency in John (2014).It also provides a method for predicting the site Tp without knowing the shear wave velocity.

6. Conclusion

Based on nearly 4000 seismic wave records from 14 strong motion stations on the KiK-net website, this paper uses two spectrum ratio methods to identify the natural frequency of the site, and compares the two results. Get the following conclusions:

Using the single-point H/V spectrum ratio method to identify the natural frequency of the site is in good agreement with the multi-points spectrum ratio method, and there is no need to install a strong motion recorder on the bedrock, which saves a lot of manpower, material and financial resources. After an earthquake disaster occurs, technicians can use the aftershock records measured on-site and use the single-point H/V spectrum ratio method to quickly and accurately determine the natural frequency of the area, providing reference data for post-earthquake rescue and reconstruction.

The natural frequency of the site is not a fixed value, but a range of variation. Therefore, when determining the seismic magnification factor, the designer should take into account the fixed value given by the code and pay attention to the influence of the change range of the natural frequency on the structure.

In this paper, it is found that the predominant frequency fp is a parameter that can better reflect the natural frequency of the site by comparing the fitting degree of the fp and V_{s30} with f_m,and has a clearer physical meaning. Therefore, fp is a suitable site parameter for the ground motion prediction equation.

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