

Fig. 4. Comparison of RSR and FSR for each group of the 5 pairs soil and rock sites on which the spectral ratios have obvious peaks

shapes of RSR and FSR are very similar, their maximum peaks occur at about same period with the FSR one consistently exceeding the RSR one. The maximum peak values of RSR and FSR and the corresponding periods for each group are listed in Table 3. The ratio of maximum peak values as well as the ratio of the periods between RSR to FSR for each group are calculated and listed in the table. It is found that the period ratios for each group are all very near unity, and the maximum peak value ratios for each group are all smaller than unity.

Table 3. Results of the 5 pairs of soil and rock sites on which the spectral ratios have obvious peaks

Name	Group	The period of RSR	The period of FSR	Ratio of the periods	Maximum of RSR	Maximum of FSR	Ratio of The maximum	RSR value at 2 s	FSR value at 2s	Ratio of 2-s values
1	1	0.22	0.22	1.00	4.88	6.25	0.78	1.32	0.96	1.38
	2	0.27	0.23	1.21	3.66	4.55	0.81	1.04	0.97	1.07
	3	0.23	0.23	0.99	4.06	5.38	0.75	1.06	1.01	1.05
2	2	0.27	0.27	1.00	10.64	20.53	0.52	2.19	1.32	1.67
	3	0.26	0.28	0.92	9.83	17.69	0.56	1.59	1.39	1.14
3	1	0.16	0.16	1.00	3.25	4.66	0.70	0.83	1.03	0.80
	3	0.17	0.14	1.18	1.10	1.93	0.57	0.92	1.07	0.86
4	1	0.37	0.36	1.02	11.56	16.43	0.70	3.42	1.16	2.94
	2	0.39	0.38	1.03	9.01	13.84	0.65	1.70	1.18	1.44
	3	0.39	0.38	1.03	13.43	18.67	0.72	1.06	1.01	1.05
5	1	0.11	0.11	1.01	6.16	9.04	0.68	1.92	1.46	1.32
	2	0.11	0.11	0.94	5.16	8.56	0.60	1.70	1.56	1.09

Moreover, the results of the 5 pairs of soil and rock sites on which the spectral ratios have no obvious peaks are analyzed. For these sites, the values of RSR are nearly identical to those of FSR and equal about unity for each group. The dependence of the RSR-FSR relationship on magnitude and epicentral distance is not that obviously as those results in Fig. 4. Nevertheless, at long periods the difference between RSR and FSR tends to decrease as magnitude and epicentral distance increase on the whole. Although, for the sites MIE014 and ISKH07, the shapes of RSR and FSR in group 3 are more jagged and the difference between RSR and FSR in group 3 is bigger compared with those in groups 1 and 2. This perhaps is because that there is only one seismic record belonging to group 3 on the two sites, and the spectral ratios of the single record cannot be smoothed by the average like those in other groups with a lot of seismic records.

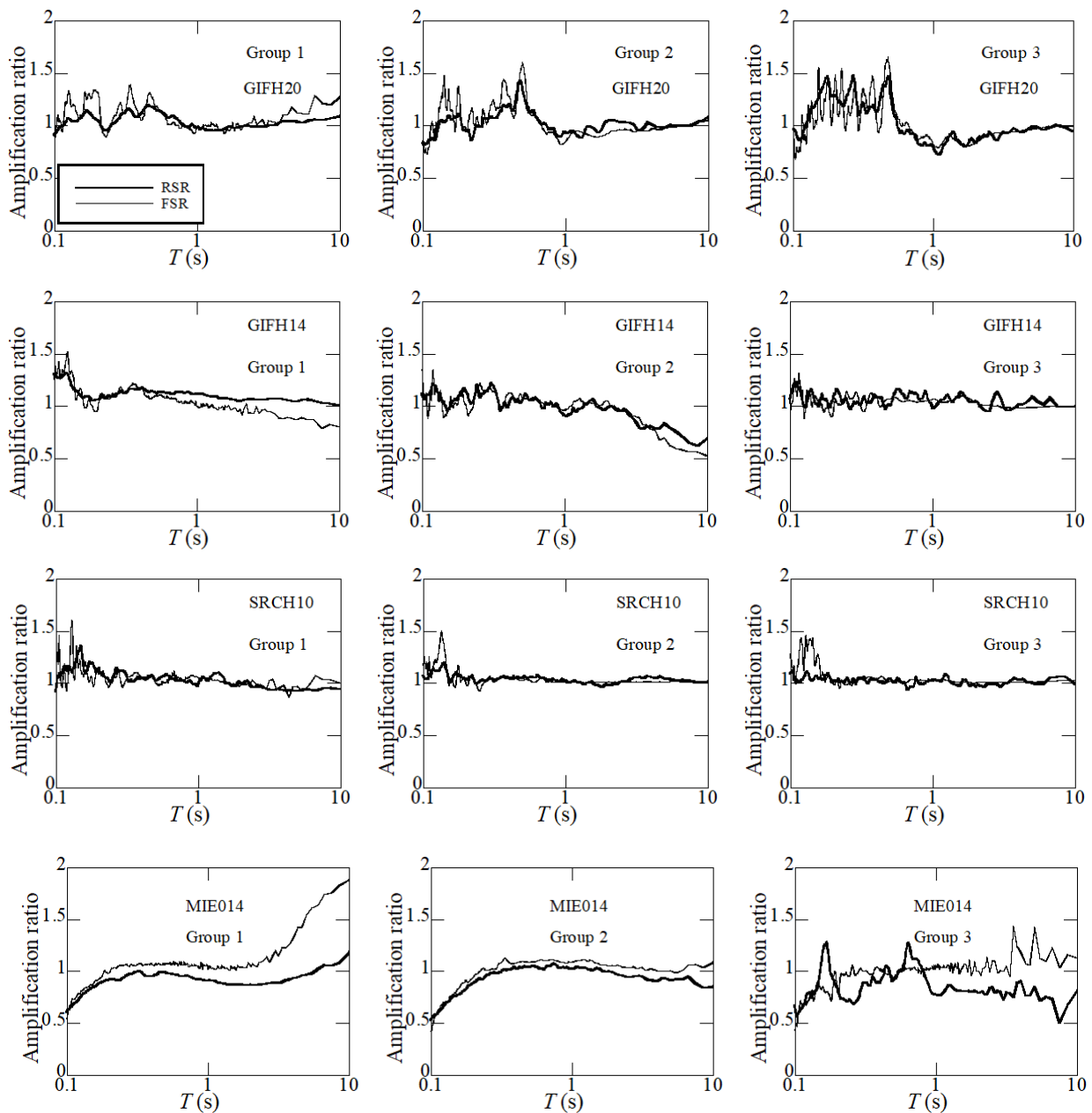


Fig. 5 Comparison of RSR and FSR for each group of the 5 pairs of soil and rock sites on which the spectral ratios have no obvious peaks

4.3. Effect of the oscillator damping ratio

As response spectral ratio is dependent of the oscillator damping ratio, it can be easily known that the RSR-FSR relationship should also be dependent on the oscillator damping ratio. To investigate the effect of the oscillator damping ratio, three values of oscillator damping ratio, named 1%, 5% and 10%, are considered in the calculation of RSR. The averaged values of RSR with different damping ratios are compared with those of FSR for each pair of soil and rock sites, in Fig. 6.

It can be obviously found from Fig. 6 that the RSR is dependent on oscillator

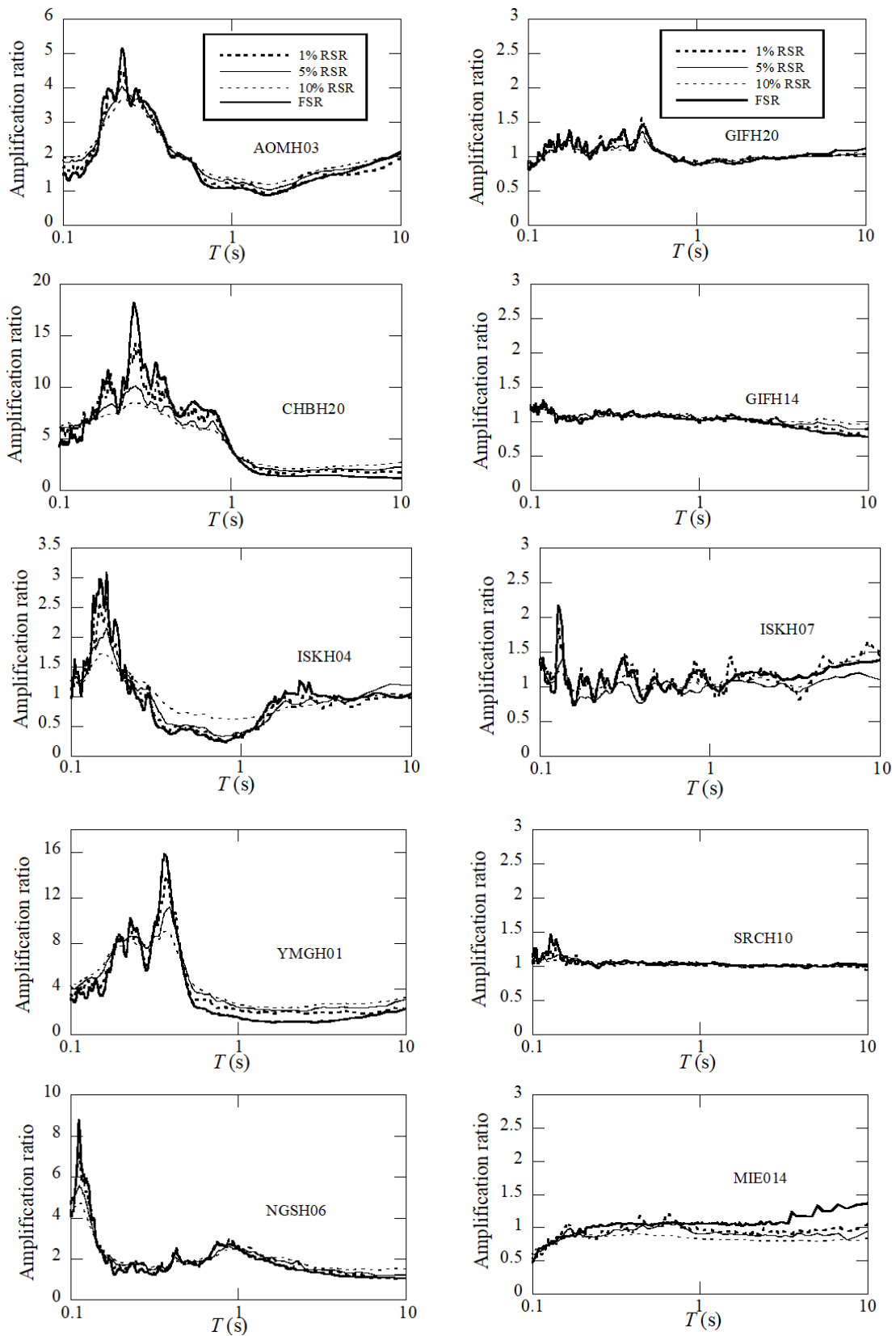


Fig. 6 Comparisons of FSR and RSR with different oscillator damping ratio

damping ratio. Values of RSR approach those of FSR with decreasing oscillator damping, and this trend is most prominent near the maximum peak. Three representative values of the RSR - FSR ratio at 0.1s, the maximum peak, and 2s are selected to further investigate the dependence of the RSR – FSR relationship on oscillator damping ratio. Values of RSR and FSR at 0.1s and 2s as well as the calculated ratios of RSR and FSR at these periods are listed in Table 2. Most of these ratios are found to approach 1 with decreasing oscillator damping ratio, which supports that the values of RSR approach those of FSR with decreasing oscillator damping ratio.

Table 4 Results for the 5 pairs of soil and rock sites on which the spectral ratios have no obvious peaks

Name		Period (s)	Period ratio	Maximum peak value	Maximum peak value ratio	Value at 0.1s	0.1s-value ratio	Value at 2s	2s-value ratio
1	1% RSR	0.22	1.00	4.52	0.88	1.67	1.13	0.99	1.01
	5% RSR	0.22	1.00	4.03	0.78	1.88	1.27	1.14	1.16
	10% RSR	0.23	1.05	3.67	0.71	1.98	1.34	1.27	1.30
	FSR	0.22	--	5.14	--	1.48	--	0.98	--
2	1% RSR	0.28	1.04	14.26	0.78	5.62	1.32	1.60	1.19
	5% RSR	0.28	1.04	10.09	0.55	6.10	1.44	1.89	1.40
	10% RSR	0.27	1.00	8.48	0.47	6.17	1.45	2.11	1.56
	FSR	0.27	--	18.19	--	4.25	--	1.35	--
3	1% RSR	0.16	1.00	2.67	0.87	1.06	1.07	0.82	0.78
	5% RSR	0.16	1.00	2.15	0.70	1.27	1.28	0.87	0.83
	10% RSR	0.15	0.94	1.72	0.56	1.27	1.28	0.83	0.79
	FSR	0.16	--	3.08	--	0.99	--	1.05	--
4	1% RSR	0.37	1.03	13.66	0.86	3.71	1.17	1.95	1.74
	5% RSR	0.39	1.08	11.17	0.71	4.25	1.34	2.06	1.84
	10% RSR	0.37	1.03	9.07	0.57	4.32	1.36	2.36	2.11
	FSR	0.36	--	15.83	--	3.18	--	1.12	--
5	1% RSR	0.11	1.00	7.19	0.82	4.78	1.10	1.50	0.99
	5% RSR	0.11	1.00	5.58	0.64	4.68	1.08	1.81	1.20
	10% RSR	0.12	1.09	4.70	0.54	4.43	1.02	1.98	1.31
	FSR	0.11	--	8.77	--	4.33	--	1.51	--

For the 5 pairs of soil rock sites on which the spectral ratios have no obvious peaks, the values of RSR are nearly identical to those of FSR and equal about unity for all values of oscillator damping ratio. Nevertheless, the values of RSR vary slightly and also approach those of FSR with decreasing oscillator damping.

In addition, it can be seen from Fig. 6 that, for all values of oscillator damping ratio, the two spectral ratios have very similar overall shapes, and the shape of RSR is relatively flatter. In addition, the maximum peak of RSR and FSR occur at about the same period with the FSR one consistently exceeding the RSR one. To further investigate the relationship between the maximum peaks of RSR and FSR, their maximum peak values and corresponding periods are obtained and listed in Table 4. Then the ratio of the maximum peak values as well as the ratio of the periods between the two spectral ratios are computed and listed the table. It is found that all the period ratios are very near 1, and all the maximum-peak-value ratios are smaller than 1. This indicates that the maximum peak values of the two spectral ratios occur at nearly the same period with the FSR one consistently exceeding the RSR one for any damping.

5. CONCLUSIONS

This study investigates statistically the relationship between the RSR and FSR. By analyses of a lot of seismic ground motions recorded on 10 pairs of nearby soil and rock sites in Japan, following systemic relationships between the two spectral ratios are derived.

(1) The shape of RSR is very similar with that of FSR. When the two spectral ratios have obvious peaks, the maximum peak values of RSR and FSR occur at about the same period with the FSR one consistently exceeding the RSR one.

(2) The relationship between RSR and FSR is dependent on oscillator damping ratio, values of RSR generally approach those of FSR with decreasing oscillator damping ratio. This trend is particularly prominent for the spectral ratios having obvious peaks.

(3) The relationship between RSR and FSR is dependent on input rock motion and ultimately magnitude and epicentral distance. At long periods the difference between RSR and FSR decreases with increasing magnitude and epicentral distance. This trend is also particularly prominent for the spectral ratios having obvious peaks.

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