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Array observation system for aseismic design of Akashi Kaikyo bridge

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ABSTRACT: Long period ground motions were observed near the long suspension bridge called Akashi Kaikyo bridge which is under construction in Japan. This papaer introduces the 3 site array observation system of long-period ground motions to examine multi-support input for a long-span bridge. Several ground motions were recorded using this system since 1989. Some of them had a predominant period of 20 to 25 seconds, which is almost the same as the first natural period of Akashi Kaikyo bridge. The earthquake records observed in Awajishima island usually showed larger values than the mainland Honshu. From the records of the 1991 Myanmar earthquake, the propagation velocity was estimated to be 4.8 km/sec between 2 sites in the mainland Honshu.

1 INTRODUCTION

Akashi Kaikyo bridge in Japan which is under construction and expected to be completed in 2000 will be the world longest suspension bridge (Figure 1). It will have a center span of 1990 m long, and the fundamental natural period is about 16 seconds. Three sets of servo velocity meters, whose reliable frequency ranges are 0.025 to 70 Hz, have been set near the both ends of this bridge to record long-period ground motions. To measure the phase difference between them, accurate digital clocks have been installed.

New observation system consisting of the latest digital equipment around the real bridge will improve seismic investigation of large scale flexible structures.

2 ARRAY OBSERVATION SYSTEM

The locations of our observation stations near Akashi Kaikyo bridge are shown in Figure 2. Site A has been active since 19 July 1989 while the other 2 sites have been active since 21 November 1990. Sites A and B are on the same side of the bridge (Mainland Honshu side) and site C is on the other side (Awajishima Island). The stations are between 4.8 and 6.0 km apart from each other.

The observation system at each site is shown in Figure 3. The pick-ups are reliable from 0.0025 to 70 Hz, and have resolution of 0.00005 kine (Tokyo Sokushin Co. 1988). Time code generator corrects its clock automatically every hour using NHK medium wave radio's clock signal, and send time signals to the data recorder which enables the exact time to be clocked in the accuracy of 0.1 sec. As the duration of a long period ground motion is long, the low sampling rate of 10 Hz was used because of the limited memory. Because of the low seismicity of this region, the velocity range of ±1 kine was selected among 6 ranges: ±100, ±30, ±10, ±3, ±1 and ±0.3 kine. For the same reason, the trigger level is set low to catch even small earthquakes: 20 mkine for site A, 15 mkine for site B and 40 mkine for site C. Trigger signal is filtered to pass the high frequency waves to avoid very long period noise more than 100 seconds. This machine also has a pre-trigger recording system for 10 seconds. The velocity meter is connected to the digital data recorder, and it saves velocity data and the time signals into a floppy disk of the personal computer automatically.

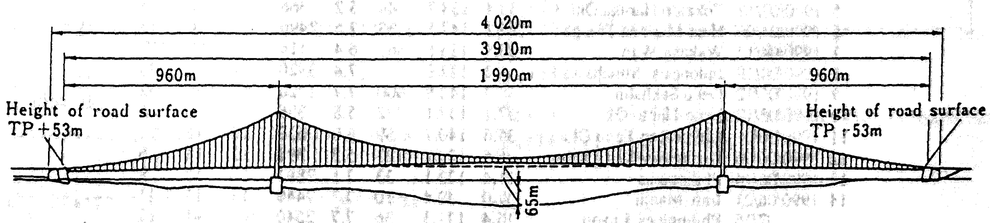


Figure 1. General view of Akashi Kaikyo bridge.

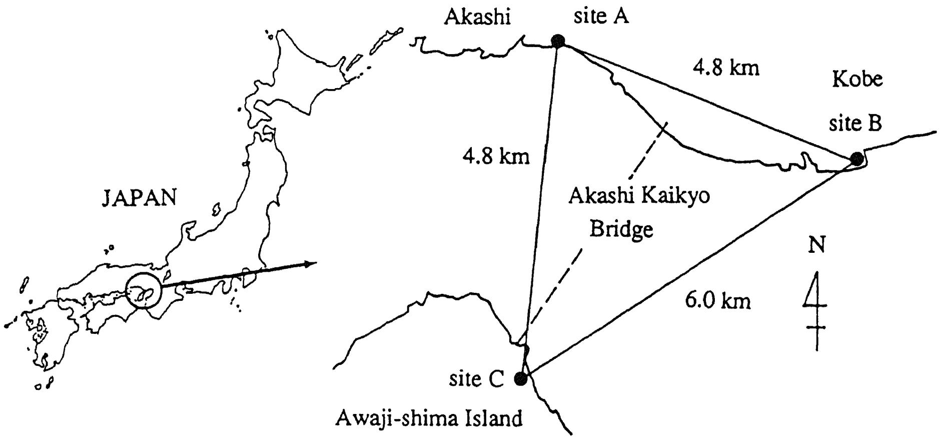


Figure 2. Locations of Akashi Kaikyo bridge and array observation system.

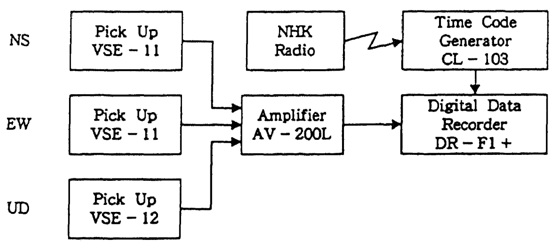


Figure 3. Equipment for array observation system.

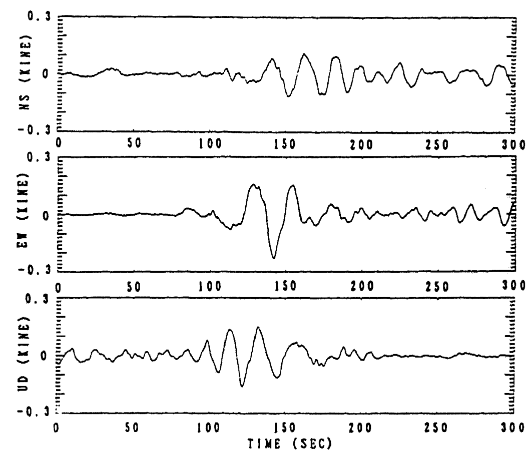


Figure 4. Velocity time histories of No. 2 Iwate-Ken Oki earthquake.

Table 1. Observed earthquakes at site A.

No.	Date	Hypocenter	Epicenter °N	Epicenter °E	Depth (km)	M	Dis-tance (km)	Max. Vel. (mkine) NS	EW	UD
1	1989/08/10	Wakayama-Ken Hokubu	34.2	135.6	65	4.6	71	71	40	18
2	1989/11/02	Iwate-Ken Oki	39.8	142.8	38	7.3	921	121	207	173
3	1989/11/02	Tottori-Ken Seibu	35.3	133.4	16	5.4	165	149	66	44
4	1990/02/20	Izu Ohshima Kinkai	34.7	139.3	17	6.5	393	118	98	55
5	1990/03/12	Tokaido Haruka Oki	33.4	138.7	44	5.2	366	6	6	3
6	1990/04/06	Near Mariana Trough	15.2	147.5	33	7.5	2490	39	40	43
7	1990/04/12	Wakasa-Wan	35.5	135.6	367	6.4	114	92	80	152
8	1990/04/18	Indonesia, Minahassa Pen.	1.2	122.9		7.4	3920	21	11	25
9	1990/05/12	Deep Sakhalin	48.9	142.9	600	7.7	1720	52	28	32
10	1990/05/17	Noto-Hanto Oki	37.1	137.1	272	5.8	336	12	10	5
11	1990/06/01	Chiba-Ken Toho Oki	35.6	140.7	59	6.0	530	16	15	21
12	1990/06/05	Kanagawa-Ken Chubu	35.6	139.2	123	5.5	398	13	11	5
13	1990/06/14	Philippines	11.4	122.1	33	7.1	2890	10	12	8
14	1990/06/21	Iran, Manjil	37.0	49.4	10	7.7	7440	11	11	11
15	1990/07/16	Philippines, Luzon	15.4	121.3	36	7.7	2540	104	145	62
16	1990/09/05	Akashi Kaikyo	34.6	135.0	8	3.3	0	88	51	39

Table 2. Observed earthquakes by array observation system.

No.	Date	Hypocenter	Site	Epicenter °N	Epicenter °E	Depth (km)	M	Distance (km)	Max. Vel. (mkine) NS	Max. Vel. (mkine) EW	Max. Vel. (mkine) UD
17	1991/01/06	Myanmar	A	23.5	96.3		7.2	3930	27	30	28
			B						38	24	21
18	1991/03/10	Kii Suido	B	33.8	134.9	20		89	7	6	3
19	1991/05/03	Torishima Kinkai	A	28.2	140.2	460	6.5	866	17	14	6
			B						21	29	10
20	1991/05/13	Kyoto Osaka Fuzakai	A	34.9	135.6	10		64	5	8	6
21	1991/06/16	Nara-Ken Nanbu	A	36.0	135.6	68	4.3	84	18	13	7
			B						23	26	7
			C						13	9	9
22	1991/07/30	Kii Suido	A	33.8	134.8	52	4.1	91	18	15	7
23	1991/08/09	Wakayama-Ken Hokubu	A	34.1	135.2	14	3.7	59	6	7	10
24	1991/08/20	Kii Suido	A	33.8	135.0	7	4.0	89	10	5	4
25	1991/08/28	Shimane-Ken Tobu	A	35.3	133.2	15	5.9	182	106	84	49
26	1991/08/31	Kyoto Shiga Kenzakai	A	35.3	135.8	13	4.2	107	15	10	6
27	1991/09/03	Tokaido Haruka Oki	A	33.7	138.8	33	6.3	364	26	28	15
28	1991/10/20	Kii Hnto Oki	B	33.4	135.3	52	5.1	136	134	57	33
29	1991/10/27	Wakayama-Ken Chubu	A	33.8	135.3	59	4.3	93	16	10	6
			C						18	8	5
30	1991/10/28	Suou Nada	A	33.9	131.2	19	5.9	358	38	24	15
			C						60	35	19
31	1991/11/02	Kyoto-Fu Chubu	A	35.0	135.6	14	4.3	71	8	11	7
			C						12	8	7

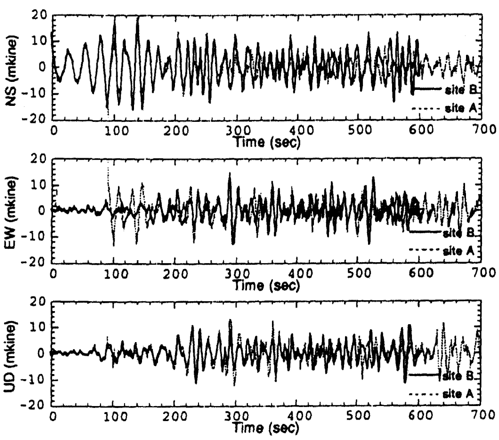


Figure 5. Velocity time histories of No. 17 Myanmar earthquake.

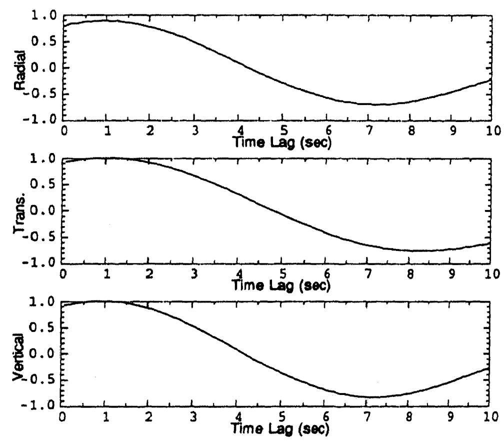
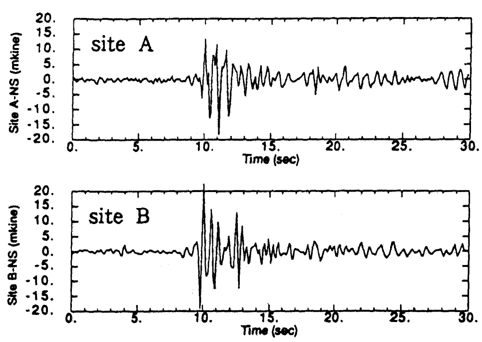


Figure 6. Cross correlation function for No. 17 Myanmar earthquake.



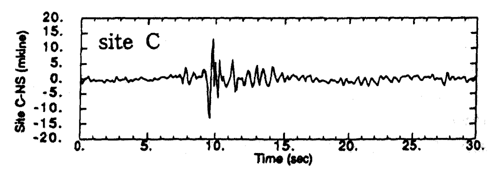


Figure 7. Velocity time histories of No. 18 Nara-Ken Nanbu earthquake.

3 OBTAINED EARTHQUAKE RECORDS BY ONE SITE OBSERVATION SYSTEM

Until 1990, only site A had been active and got 16 records shown in Table 1. No. 14 the Manjil earthquake in Iran and No. 15 the Luzon earthquake in the Philippines caused serious disaster in these countries. No. 16 Akashi Kaikyo earthquake occurred just under the construnction site. The large earthquakes larger than Magnitude 7 can be recorded even if the hypocentral distance is longer than 1500 km.

No. 2 Iwate-Ken Oki earthquake record in Figure 4 has small amplitudes, but continued for more than 40 minutes. The spectrum for the first 5 minutes shows a dominant period around 20 to 25 seconds, which is almost as the same as the first natural period of Akashi Kaikyo bridge.

4 OBSERVED EARTHQUAKE RECORDS BY ARRAY OBSERVATION SYSTEM

Array observation using 3 stations started in 1990. Until January of 1992, site A has 14 records, site B has 8 and site C has 7 records. The number of the observed records varies among the sites, because these were triggered independently of each other. The noise level at site C, which is located in Awajishima Island, is much higher than those of the other 2 sites; nevertheless, several records were obtained simultaneously at more than 2 stations.

For No. 17 Myanmar earthquake, records were obtained at site A and site B. This earthquake occurred about 4000 km away from the stations. Figure 5 shows 2 time histories of both sites together according to their time signal. The seismometer at site A triggered this event 91.4 sec after site B. They are quite similar except the earlier part of EW components. Figure 6 shows the cross correlation function of these 2 records normalized to have the maximum value of 1.0; given in radial, transverse and vertical direction, respectively. They have sinusoidal wave form due to high correlation between 2 records. From these figures, the phase lag of these records calculated to have the maximum cross correlation results in 1.0 second. As the distance between site A and site B is 4.8 km, the propagation velocity is estimated to be 4.8 km/sec.

Next, an example of a small and near-field earthquake is presented. Figure 7 shows No. 18 Nara-Ken Nanbu earthquake which occurred near the stations. Its magnitude was only 4.3, however, the epicentral distance is near enough to be recorded at all the 3 stations. The NS components of 3 sites in Figure 7 show quite different movements to have the low correlation for each other. The piers and anchorages of Akashi Kaikyo bridge might be excited independently by small near-field earthquakes. Furthermore, the earthquake records at site C of Awajishima island usually showed larger values than the mainland Honshu.

5 CONCLUSIONS

Observation system of earthquakes near a real long suspension bridge with the application of the obtained records is introduced. The observation stations have been installed and activated to measure long-period earthquakes and their phase lag between the both ends of the bridge, which is important for providing multi-support inputs of long-span bridges. Main conclusions obtained in this study are as follows:

1. Thirty-three earthquake records were obtained from the array observation system near Akashi Kaikyo bridge whose center span will be about 2 km long. Some of them had a dominant period of 20 seconds, which is almost the same as the first natural period of Akashi Kaikyo bridge.
2. The noise level of Awajishima island was higher than the mainland Honshu. Furthermore, the earthquake records at this island usually showed larger values than the mainland.
3. The 1991 Myanmar earthquake was observed by 2 sites of the array observation system. As their phase lags were 1.0 second, the propagation velocity is estimated to be 4.8 km/sec. More array observation data is expected to study multi-support input motion of a long-span bridge.
4. The 1991 Nara-Ken Nanbu earthquake observed by all sites showed low correlation between each record. The piers and anchorages of Akashi Kaikyo bridge might be excited independently by small near-field earthquakes.

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