Characteristics of Earthquake Ground Motion during the Aftershocks of the Mid Niigata Prefecture Earthquake in 2004

by

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ABSTRACT

This paper presents the characteristics of earthquake ground motion recorded at two building in Ojiya city by the aftershocks of mid Niigata Prefecture Earthquake in 2004. At the earthquake observation sites near by these two buildings, excessive acceleration records were observed by main shock and principal aftershocks. However, the earthquake damages of these two buildings were minor and not compatible with observed high accelerations. The earthquake records of rather small acceleration by aftershocks show that the maximum accelerations and Fourier amplitudes in 2 to 7 Hz frequency range observed at base of building are smaller than those at adjacent ground surface. These decreases may be caused by input loss of earthquake motions as a result of kinematic interaction. The further big accelerations by aftershocks should be observed with adequately installed many seismometers and investigated to evaluate the actual input or effective input motions during main shock.

KEYWORDS: 2004 The Mid Niigata Prefecture Earthquake, Aftershocks observation, Input loss, Spectral Ratio

1. INTRODUCTION

On Oct. 23, 2004, the Mid Niigata Prefecture Earthquake, magnitude in Japan Meteorological Agency (hereafter as JMA) scale Mjma 6.8 was occurred. According to the JMA prompt report, totally over 800 aftershocks had occurred by December 28th [1]. Fig. 1 and 2 show distribution of JMA Seismic Intensity and PGA for the mainshock. The highest JMA seismic intensity (hereafter as Ijma) for main shock was scale 7 registered at Kawaguchi station. The peak ground accelerations of this station were 1675cm/s^2, 1141cm/s^2 and 869cm/s^2 for East-West, North-South and Up-Down components, respectively. The Ijma 6+, next to Ijma 7, was observed at Yamakoshi village, Oguni town and Ojiya city.

At JMA532, JMA strong motion observation site in Ojiya city, 897.6 cm/s2 of peak ground acceleration was observed. At NIG019, belonging to one of nationwide strong motion observation network (K-NET) organized by the National Institute for Earth Science and Disaster Prevention (hereafter as NIED) in Ojiya city, approximately 700m apart from JMA532, the peak ground acceleration 1313.5 cm/s2 was recorded [2]. The seismic intensity value calculated with the same scheme for the JMA seismic intensity at this site was Ijma 7. While the reinforced concrete buildings by these two observation sites, Ojiya primary school (OJP) and Ojiya city hall (OJC) respectively, were minor & slightly damaged as shown in photo 1 and 2 for example [3]. Those damages were not compatible considering observed high lever ground motion records.

In order to examine the actual input motions or effective input motions characteristics and caused response of these two buildings, aftershock observation was conducted during Nov. 12 to Dec. 27.

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2. AFTERSHOCKS OBSERVATION

The earthquake records simultaneously observed at base of building and adjacent ground surface level could be used to recognize input loss by kinematic interaction effects. The plane of OJP looks like "E" shape as shown in Fig. 3. The main building is three stories reinforced concrete structure. The strong motion seismometers for aftershock observation were put base (1st floor) and top (corresponding 4th floor) of staircase that is located southeast end of building as depicted in Photo 2. The two horizontal components were set N230E and N320E along building. However NIG019 is about 200 m away from this site, it is used as reference site for observation in this study. The building of OJC is four stories reinforced concrete structure. As depicted in Photo 3, the strong motion seismometers for aftershock observation were put 1st floor as base, 5th floor level as top and warehouse under approaching staircase in front of entrance as ground level (GL) that is considered reference site. The two horizontal components were set N210E and N300 E along building. Because of electrical power cut and machine trouble, the records on GL were available till Nov. 19. The JMA532 is located about 300 m to the southwest from OJC.

As shown in Fig. 4, the seismic activity was getting calm down gradually, the magnitude of observed aftershocks are lower than Mj4.7. The maximum acceleration values for one of horizontal components and magnitude about observed several rather big earthquakes are shown in Table1 with those observed at NIG019 and JMA532 respectively as reference. Two horizontal directions considered about OJP, OJC, NIG019 and JMA532 are N210N/N300E, N230E/N320E, N000E/N090E and N000E/N090E respectively. The observed maximum acceleration at 01F level is at most 34 cm/s2.

3. THE CHARACTERISTICS OF OBSERVED EARTHQUAKE RECORDS

The characteristics of aftershock records by the earthquake occurred 9:39am, Nov 15, Mj4.7, bold and italic one in Table 1, that is maximum one during aftershock observation period were examined.

Fig. 5 shows observed time history at OJC. About horizontal components, the maximum acceleration at base (01F) is half amplitude of ground level (GL) and top (05F) is double to double-half amplitude of base level. While UD components, the maximum acceleration at base (01F) is comparable amplitude to ground level (GL) and top (05F) is slightly amplified to base level. Fig. 6 shows Fourier spectral ratios, 01F/GL, in horizontal directions. This figure represents differences between ground earthquake motion and input motion. In the low frequency range up to 2 Hz, spectral ratio is approximately 1.0. In the frequency range from 2.5 to 7.0, the values of spectral ratio are lower than 1.0 that are considered to affect difference of peak acceleration in time domain. These phenomena may be caused by input loss of earthquake motions as a result of kinematic interaction.

In order to consider this effects on vibration characteristics of building, Stewart and Fenves introduced system parameters for various conditions of base fixity [4]. Taking Fourier spectral ratios about Top/Base and Top/GL as shown in Fig. 7, the effects of the "flexible base" system and the "pseudo flexible base" system could be considered. The spectral ratios of the system with flexible base and pseudo-flexible show predominance at 2.39Hz and 2.52Hz respectively, namely, the effect of swaying motion slightly shorten predominance frequency about 5%. This means that influence of swaying is not large. While predominant frequency in two horizontal components, N210E and N300E, perpendicular and parallel to the building, are coincident. Fig. 8 and 9 show time history of three components and Fourier spectral ratios of 01F/NIG019 (considered as GL component) in horizontal directions observed at OJP. The maximum acceleration at base (01F) is half amplitude of ground level (NIG019) and top (04F) is largely amplified into double-half to triple of base level. While UD components, as same as OJC, the maximum acceleration at base (01F) is comparable amplitude to ground level (NIG019) and top (04F) is slightly amplified to base level. Fig. 9 represents the differences between ground earthquake motion and input motion. The values of spectral ratio are lower than 1.0 in wide frequency range, 0.6 to 6.0 Hz, partially different depending on directions. Those differences are considered to affect the difference of decrease about peak acceleration of two horizontal components in time domain. Fig. 10 shows spectral ratios about Top/Base and Top/GL. In this figure, the predominant frequency by pseudo-flexible base system is 4.91 to 5.66 Hz but the one by flexible base system is not recognized clear.

During aftershocks observation, the number of earthquake waves data simultaneously observed on adjacent ground surface level and base of building at OJC and OJP were six and five respectively. At OJC, the maximum acceleration values for one of horizontal components on base are smaller than those on ground level and take 0.43 to 0.61 (0.53 mean) ratios using these six earthquakes. At OJP, the same maximum acceleration values take 0.46 to 0.74 (0.56 mean) ratios toward those on NIG019 using these five earthquakes. Comparing results of previous studies [5 and 6], these maximum acceleration ratios, 0.53 mean and 0.56 mean, are rather small. Using these six and five earthquakes records, Fourier spectral ratios 01F/GL in horizontal directions were calculated. The shape of Fourier spectral ratio about OJC as shown in Fig. 11, the trend of Fourier spectral rations in both N210E and N300E directions are similar. In the low frequency range up to 3 Hz, the values of spectral ratio are approximately 1.0 and gradually decrease to 0.3 to 0.5 in frequency range from 3 Hz to 7 Hz. After taking minimum values, they increase up to 1.0 in 7 Hz to 9 Hz frequency range and decrease lower than 1.0 again in frequency range higher than 9 Hz. Higher than 3 Hz, the values in N300E direction are slightly lower than those in N210E direction. About OJP as shown in Fig. 12, the values of spectral ratio are approximately 1.0 in the low frequency range up to 1 Hz and decreasing in 1 to 3 Hz range. In N230E direction, the values of ratio take 0.3 to 0.4 at around 3 Hz and 5 Hz, 0.7 at 4 Hz, then increase till 2.0 from 5 Hz to 7 Hz. After taking 2.0 in 7 Hz to 9 Hz, they decrease again to 1.0. In N320E direction, they take rather simple shape. They decrease till 0.1 from 1 Hz to 3 Hz, increase till 2.0 from 3 Hz to 9 Hz and decrease again toward 1.0.

4. CONCLUSIONS

The aftershock observation about 2004 the Mid Niigata Prefecture Earthquake was conducted at two reinforced concrete buildings in Ojiya city during Nov. 12 to Dec. 27. At the earthquake observation sites near by these two buildings, excessive acceleration records were observed by main shock and principal aftershocks. However, the earthquake damages of these two buildings were minor and not compatible with high accelerations. As the seismic activity had got down in this period, the observed maximum acceleration at 01F level is at most 34 cm/s2. The maximum accelerations at base of building were always smaller than those at ground surface level. In frequency domain, the Fourier amplitude values at base of building are always smaller than those at ground surface level in the frequency range of 2 Hz to 7 Hz. These decreases may be caused by input loss of earthquake motions as a result of kinematic interaction. The further big accelerations by principal aftershocks should be observed with adequately installed many seismometers and investigated to evaluate the actual input or effective input motions during main shock.

5. ACKNOWLEDGMENT

The earthquake records used in this study are observed at seismic intensity observation point by JMA and K-NET by NIED, downloaded through web sites. The authors wish to express their sincere thanks to JMA & NIED for their works.

6. REFERENCES

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Table1 observed aftershocks and their bigger max accelerations about two horizontal components

Date & time	*H*	*Mjma*	OJP		OJC			NIG 019	JMA 532
			01F	04F	GL	01F	05F		
11/13 10:01	9	4.1	18	55	-	10	14	39	32
11/13 14:41	8	3.4	13	24	15	9	11		
11/14 06:36	5	2.7	20	39	14	6	8		
11/14 09:28	8	3.1	4	14	-	-	5		
11/15 09:39	***0***	***4.7***	***11***	***31***	***26***	***12***	***25***	***23***	***30***
11/15 12:40	10	2.8	6	12	-	-	-		
11/16 08:35	13	3.1	14	29	25	16	17		
11/16 12:09	5	3.5	25	44	13	8	8		
11/19 06:03	10	3.2	16	-	20	9	13	27	44
11/24 15:50	6	2.9	8	16	-	-	5		
11/25 20:45	9	2.9	18	35	-	-	11		
11/28 14:03	13	3.8	9	21	-	-	14	16	36
11/30 08:26	14	3.3	5	11	-	-	-		
12/06 07:38	8	3.2	7	16	-	-	5		
12/10 16:22	12	3.5	34	51	-	25	30	46	61
12/23 21:03	11	4.5	-	-	-	15	25	23	24
12/25 10:23	11	4.4	-	-	-	23	32	33	32

h: hypocentral depth(km), *M*: JMA magnitude

Two horizontal directions considered at OJP, OJC, NIG019 and JMA532 are N210N/N300E, N230E/N320E, N000E/N090E and N000E/N090E respectively

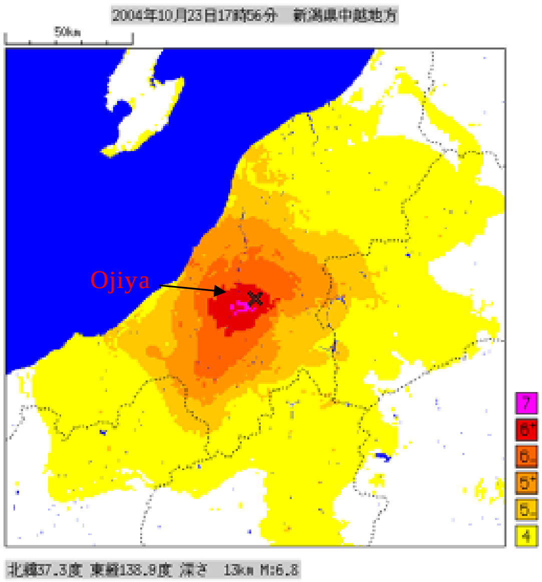

Fig. 1 JMA seismic intensity distribution map for the mainshock [1] (with some retouch)

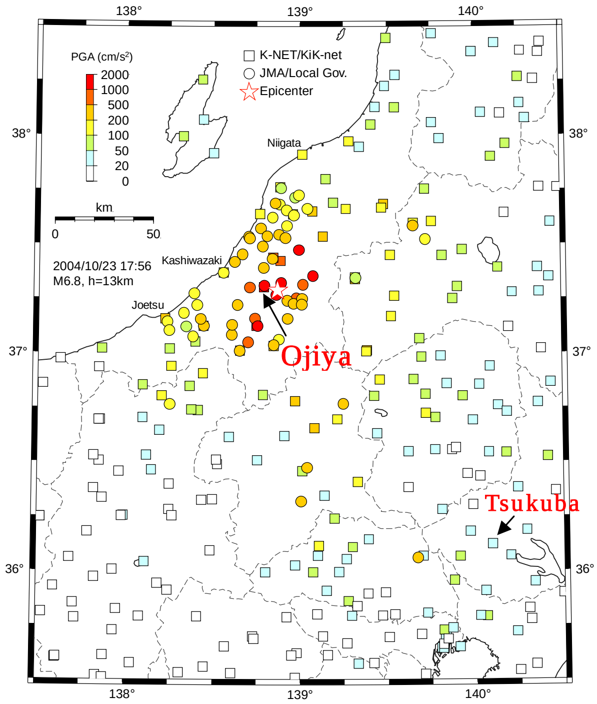

Fig. 2 PGA distribution map for the mainshock

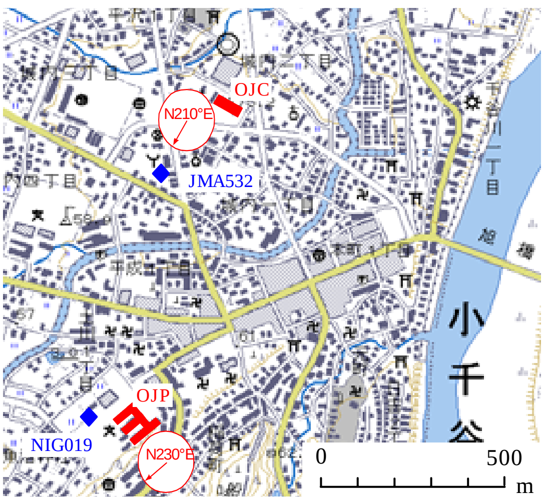

Fig. 3 The earthquake observation sites used this study

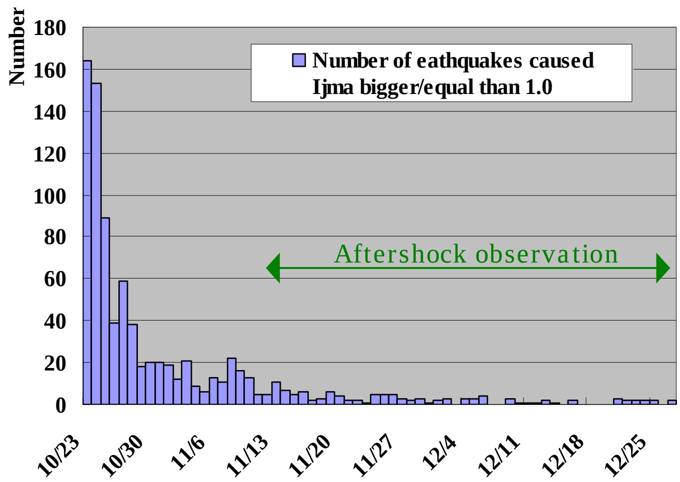

Fig. 4 The numbers of aftershocks by December 28 [1]

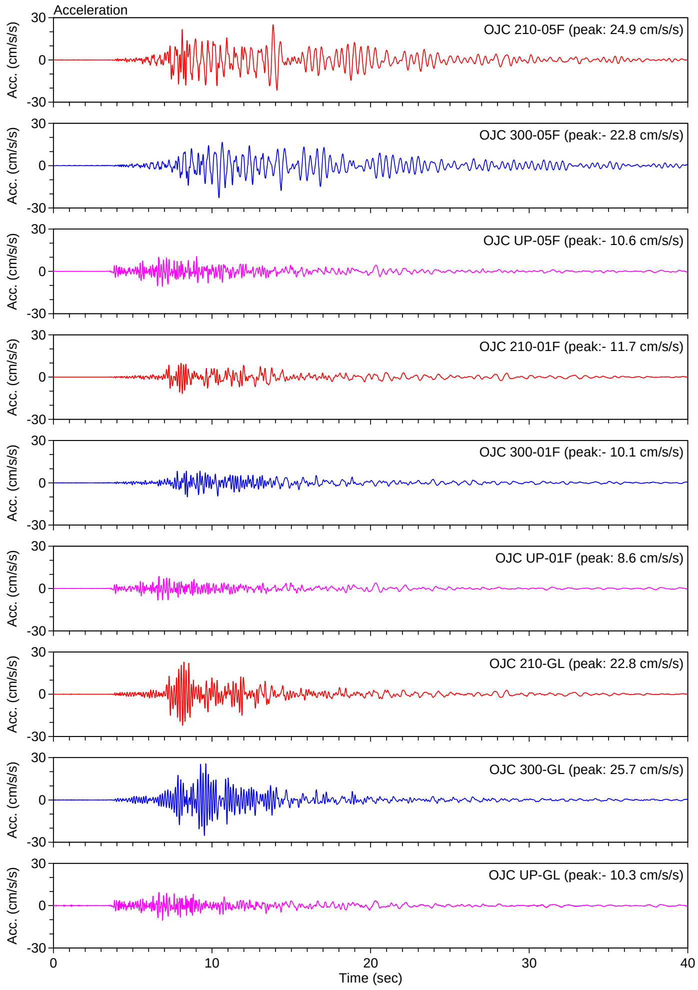

Fig. 5 Observed time history at OJC by the earthquake occurred 9:39am, Nov 15, Mj4.7

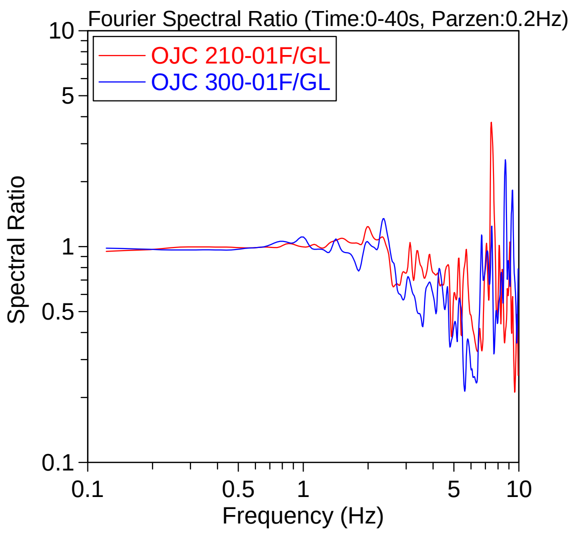

Fig. 6 Fourier spectral ratios, 01F/GL, in horizontal directions at OJC

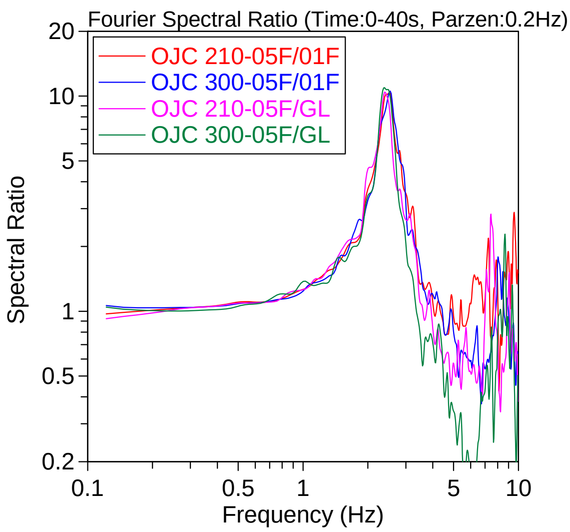

Fig. 7 Fourier spectral ratios about Top/Base and Top/GL at OJC

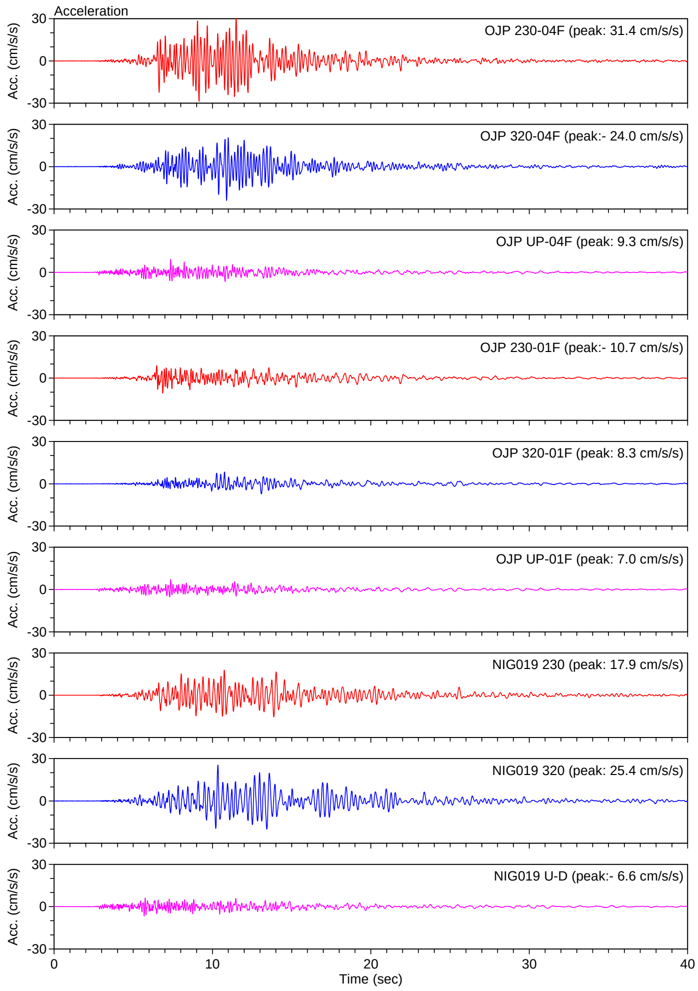

Fig. 8 Observed time history at OJP by the earthquake occurred 9:39am, Nov 15, Mj4.7

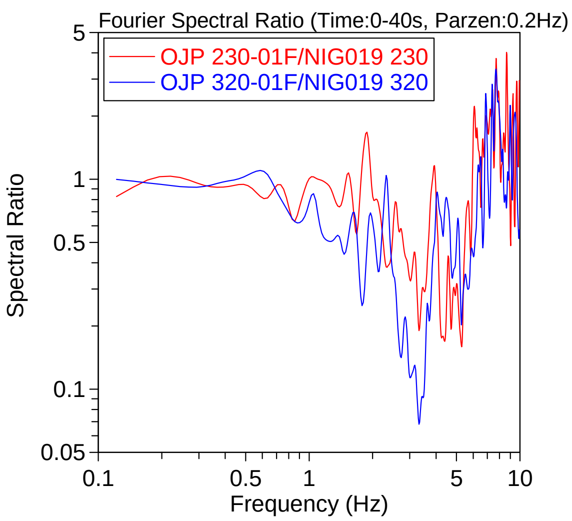

Fig. 9 Fourier spectral ratios, 01F/GL, in horizontal directions at OJC

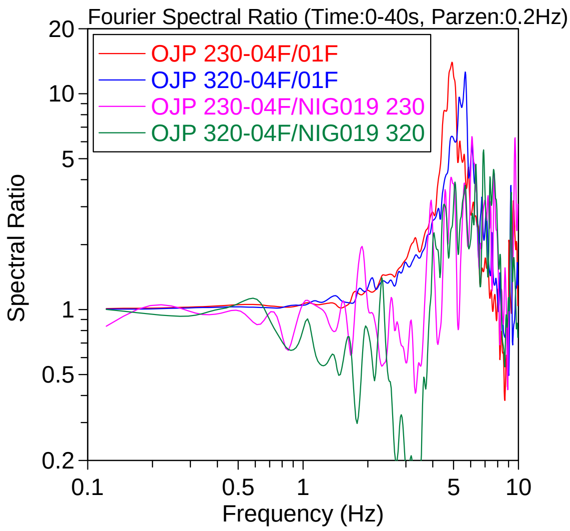

Fig. 10 Fourier spectral ratios about Top/Base and Top/GL at OJP

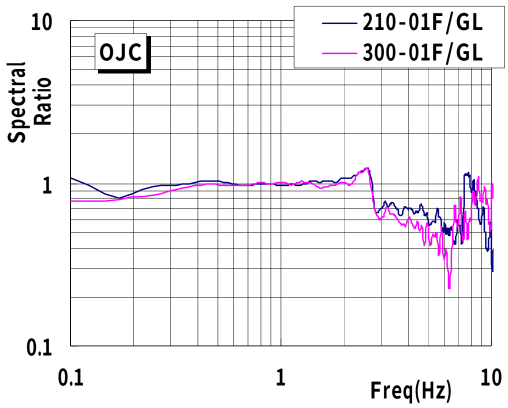

Fig. 11 Fourier spectral ratios 01F/GL in horizontal directions about OJC

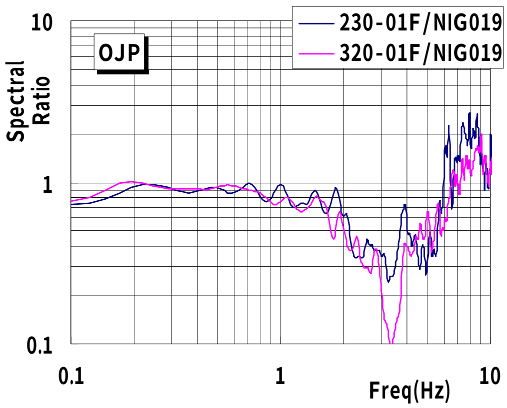

Fig. 12 Fourier spectral ratios 01F/GL in horizontal directions about OJP

Photo 1 Shear crack on column (OJP) [3]

Photo 2 The ground deformation by subsidence (OJC)

Photo 3 Locations of seismometer at OJP

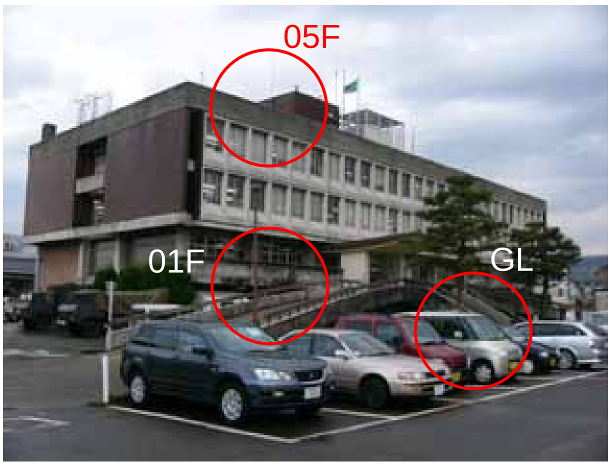

Photo 4 Locations of seismometer at OJC