GROUND MOTION AT VARIOUS SITES IN JAPAN

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Abstract

Ground motion at various sites were measured and analyzed in Japan in order to have knowledge on characteristics of ground motion in various geologies. Frequency spectra are compared, and effect of the traffic is studied. Ground motion of various grounds at the time of an earthquake is also presented.

1. INTRODUCTION

The beam size at the interaction point is very small in a future very high energy electron-positron linear collider. For example, the vertical beam size is designed to be about 6nm at the interaction point (IP) in the ILC (International Linear Collider) [1]. Relative stability of the vertical position between final focusing quadrupole magnets installed at both sides of IP is required to be higher than 1nm. And in the frequency region higher than 10Hz, the stability of about 10nm is also required in the BDS (Beam Delivery System) area and 30nm in the Main Linac area. So the stability of the ground is one of important issues for the construction of a future very high energy electron-positron linear collider.

The ground motion at various sites were measured and analyzed in Japan in order to have knowledge on characteristics of ground motion in various geologies.

2. MEASURED SITES AND INSTRUMENTS

Measurements were performed at 6 points in 5 sites as listed in Table 1. Points 1 and 2 are located in a soft ground area and points 3 to 6 are hard rock area. Measurements at point 5 were made in a refuge of a road tunnel. This tunnel penetrates Sefuri Mountain whose geology is granite. Measurement point is just 11m far from the edge of the road. Detailed description of the site and its traffic environment is described in Section 4. Points 5 and 6 are one of site candidate areas for the future very high energy electron-position linear collider [1].

Velocity sensors were used in these measurements. Model VSE355G2 of Tokyo Sokushin Co., Ltd. was used at points 1 to 3, and STS-2 of Streckeisen at points 4 to 6. Frequency range and sensitivity of these sensors are 0.012 - 70 Hz and 2.5 V/kine for VSE355G2 respectively, and 0.00833 - 50 Hz and 15 V/kine for STS-2 respectively, where the unit kine is cm/sec.

3. GROUND MOTION AT VARIOUS SITES

Results of measurements and analysis are presented in detail in the reference [2] for points 1, 2 and 4, and reference [4] for points 5 and 6. Figure 1 shows power spectrum density for horizontal component of ground motion (a) in the daytime and (b) in the nighttime. Figure 2 shows square root of the integrated power spectrum of horizontal component. Spectra in the daytime are the average of those for the period 9:00 to 17:00, and spectra in the nighttime the average of those for the period 19:00 to 3:00 for points 1 to 3 and 19:00 to 5:00 for points 4 to 6. Figures 3 and 4 show power spectrum density and square root of the integrated power spectrum respectively for the vertical component of the ground motion. Figures (a) and (b) are plots in the daytime and nighttime respectively.

Table 1: Measured sites and instruments

No.	Site	Geology	Sensor
1	At D9 electric power station, surface over the KEKB ring, KEK [2]	Kanto diluvium formation	VSE355G2 of Tokyo Sokushin (velocity sensor)
2	At D9 electric power station, in the KEKB ring tunnel, 10m deep underground, KEK [2]		
3	At the bottom of the access tunnel, Shintoyone Hydroelectric Power Plant, Electric Power Development Co., Ltd. [3]	Granite layer	
4	On the bedrock in the west area, SPring-8, JASRI [2]	Kamigori metagabbro layer	STS-2 of Streckeisen (velocity sensor)
5	Refuge of Mitsuse road tunnel, Sefuri Mountain, Saga [4]	Granite layer	
6	Esashi Earth Tide Observatory, NAOJ, Mizusawa, Iwate [4]	Granite layer	

Characteristics of these spectra are listed in the following.

- Amplitude of spectrum density and the integrated spectra for KEK are larger by 2-4 orders of magnitude and 1-2 orders of magnitude respectively than those for the hard rock area in the frequency region higher than 1Hz. This is because the KEK site is located in the soft ground area and close to a main road.

- Peak is observed clearly in the KEK site around 3Hz, which is said to be caused by manmade vibrational noises such as traffic, motors, etc. This peak around 3Hz is not observed or quite small in the hard rock sites.

- It is interesting that the amplitude of the spectra for Mitsuse road tunnel is as small as those for SPring-8 in spite of frequent traffic near by in the frequency region higher than 1Hz.

- Amplitude of spectra for Esashi site is the smallest in the frequency region higher than 1Hz. This is because the Esashi site is located in the hard bedrock area and the environment is very quiet.

- Amplitude of spectra for sites of hard rock area (points 3 - 6) is almost the same in the frequency region lower than 1Hz. This is because the vibrational source around 0.3Hz is natural phenomena such as ocean swells, wind, etc.

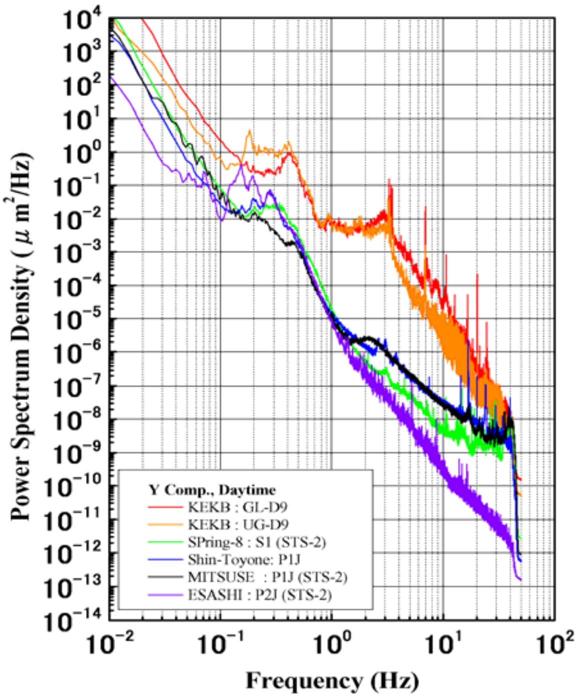

Figure 1(a): Power spectrum density for horizontal component in the daytime.

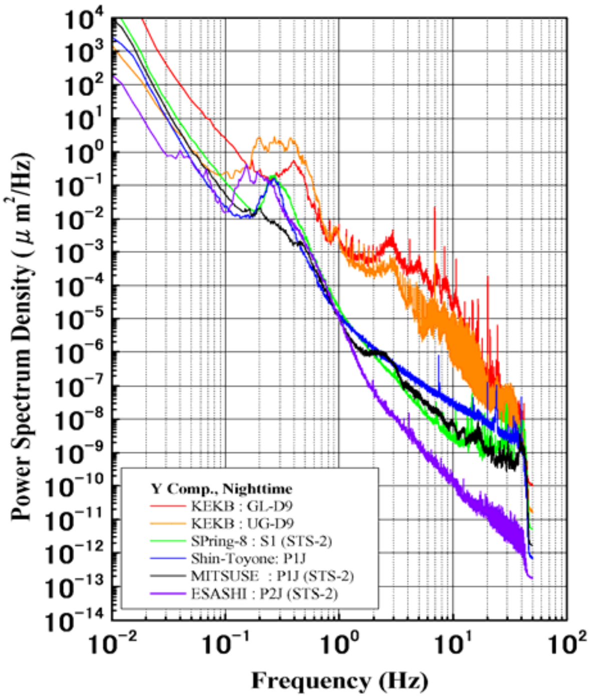

Figure 1(b): Power spectrum density for horizontal component in the nighttime.

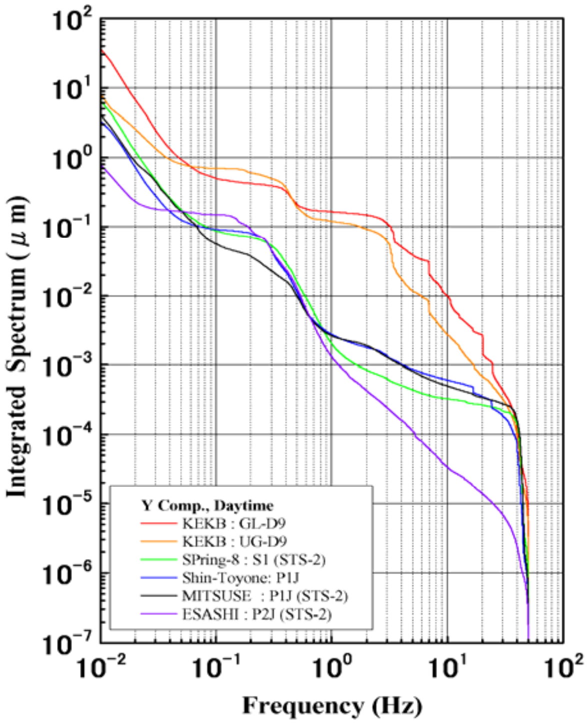

Figure 2(a): Integrated spectrum for horizontal component in the daytime.

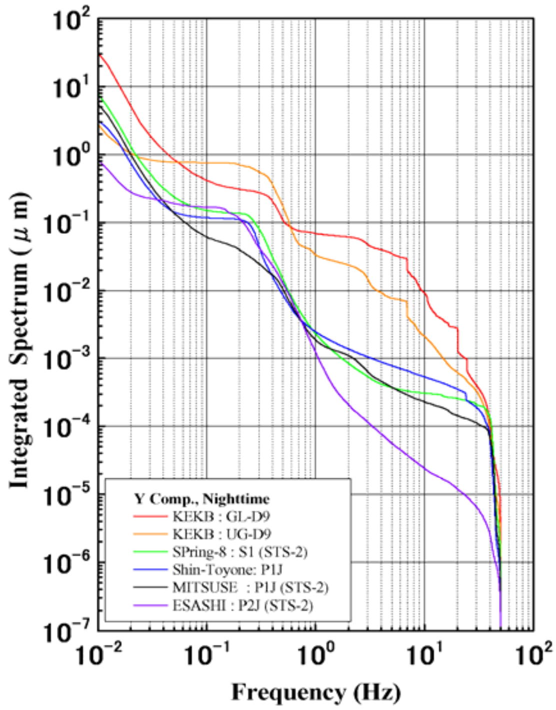

Figure 2(b): Integrated spectrum for horizontal component in the nighttime.

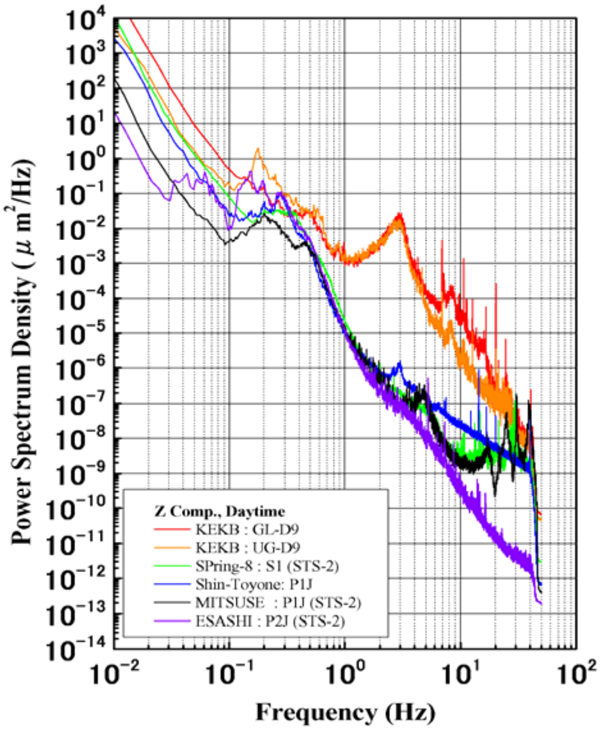

Figure 3(a): Power spectrum density for vertical component in the daytime.

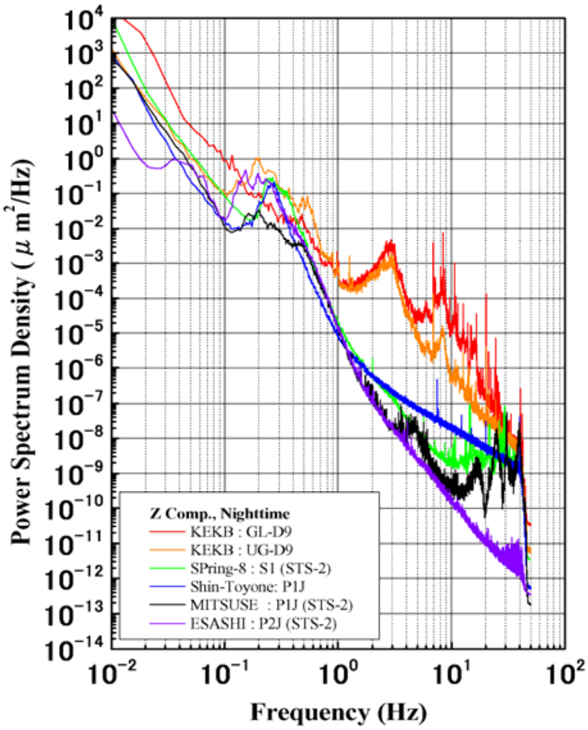

Figure 3(b): Power spectrum density for vertical component in the nighttime.

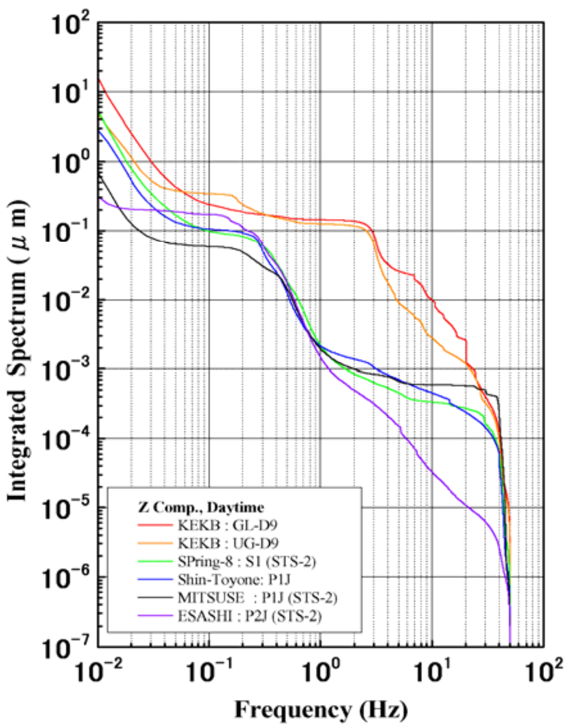

Figure 4(a): Integrated spectrum for vertical component in the daytime.

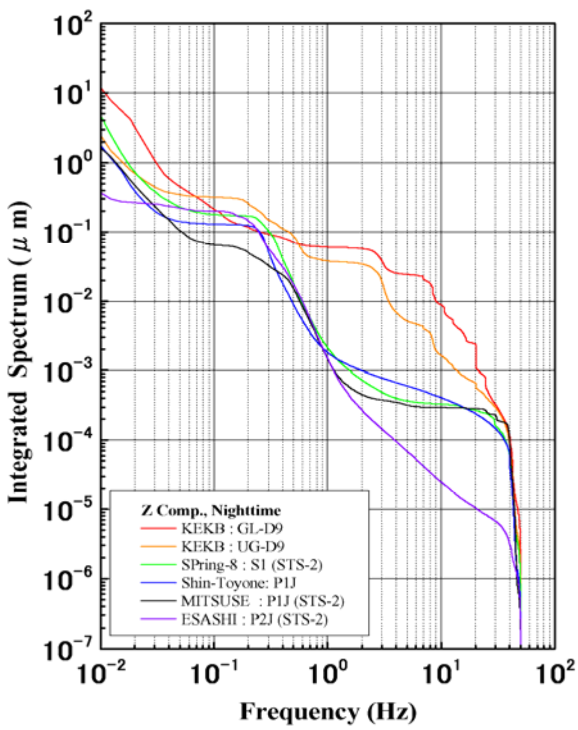

Figure 4(b): Integrated spectrum for vertical component in the nighttime.

4. INFLUENCE OF TRAFFIC

Influence of traffic on the ground motion was studied in the Mitsuse road tunnel, which penetrates Sefuri Mountain located in granite area and the KEK site located in soft ground area. At KEK site, a main road runs nearby. Figure 5 shows the time distribution of the traffic in the Mitsuse road tunnel. Figure 6 shows the route mean square (RMS) of the vertical component of the signal from seismometers placed at P1J (shown by red color) and P2J (blue color) together with the number of trucks passing through the tunnel for each time slot. P1J is the point 11m far and P2J 6m far from the edge of the road on the concrete floor in a refuge in the tunnel. Figure 7 and 8 show the same plots in case of the KEK site. Figure 7 shows the time distribution of traffic, and Figure 8 shows the RMS of the vertical component of the vibrational signal. P1 (shown by red color) is a point 30m far from the edge of the road in the 10m deep KEKB tunnel, and P2 (blue color) is 30m far, P3 (green color) 19m far and P4 (orange color) 4m far on the surface.

At the Mitsuse road tunnel, it is hard to distinguish which is the main source for vibration between passenger cars and trucks because passenger cars and trucks have almost the same distribution. But it is quite interesting that the amplitude of the vibration is degraded very much at P1J, which is only 5m further from the edge of the road than P2J. It should be mentioned here that the bump in the plot for P1J around the time slot 19:00 - 20:30 is not a real signal but a drift of the sensor. At the KEK site, it is clear that the main source of the vibration around 3Hz is the passage of trucks [2] although it is not shown here. Good correlation between the RMS of the vibrational signal and the frequency of the passage of trucks is observed clearly at P2J in the KEK site.

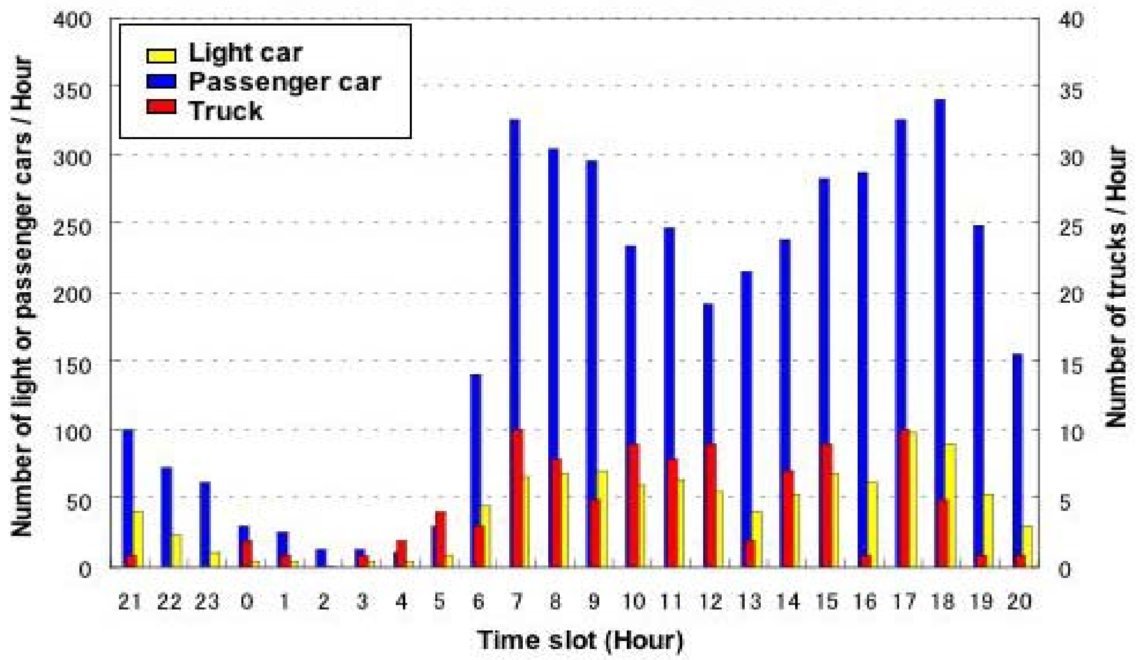

Figure 5: Number of cars passing through the Mitsuse road tunnel

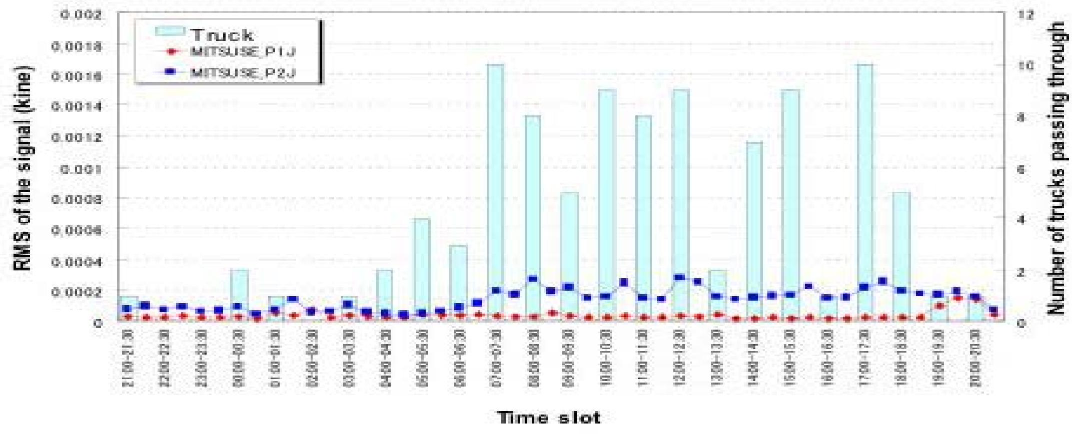

Figure 6: RMS of the vertical component of the signal (shown by red and blue colors) and the number of trucks passing through (shown by thin blue color) in the Mitsuse road tunnel. Measurement points P1J (red color) and P2J (blue color) are described in the text.

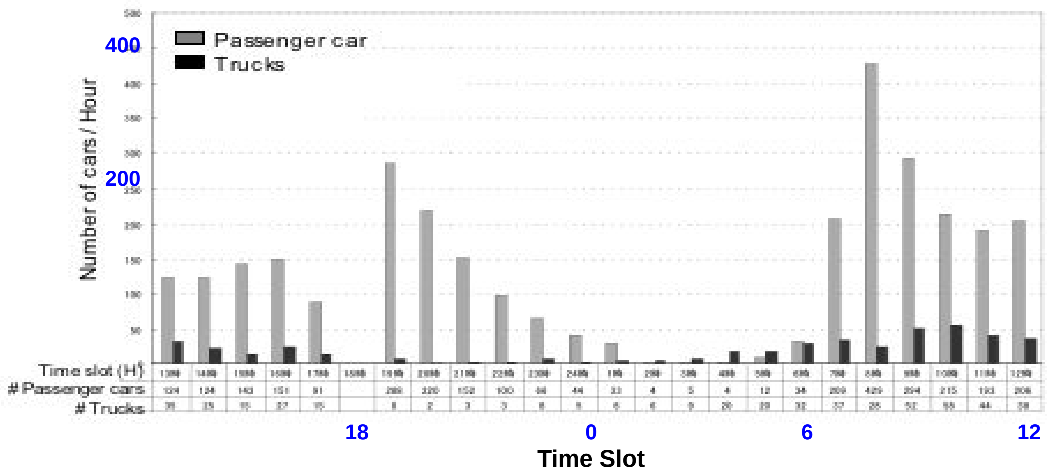

Figure 7: Number of cars passing by on the nearby main road, Higashi-Odori, at KEK site.

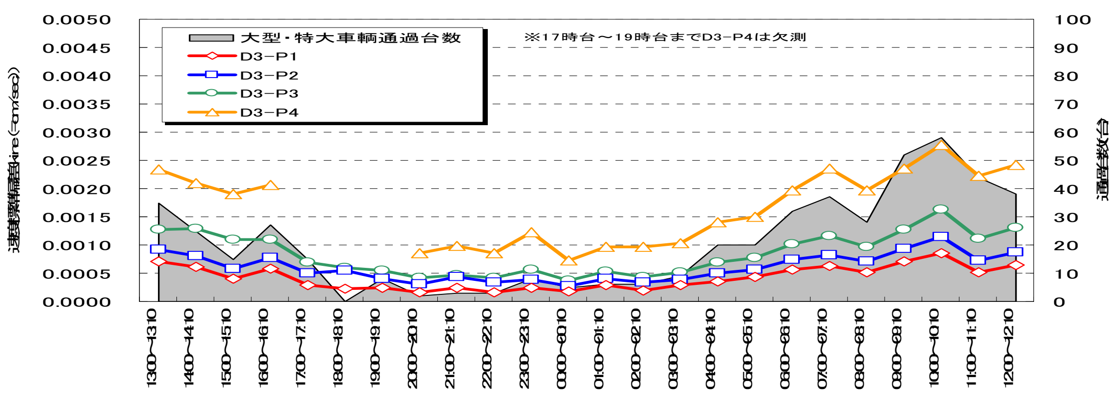

Figure 8: RMS of the vertical component of the signal (shown by 4 colors) and the number of trucks passing by (shown by grey color). Measurement points P1 (red color), P2 (blue color), P3 (green color) and P4 (orange color) are described in the text.

5. GROUND MOTION AT THE TIME OF AN EARTHQUAKE

When the ground motion was remeasured at the SPring-8 site, vibration caused by an earthquake was observed. The seismic center was located in Osaka (about 100km east of SPring-8) and 9km deep underground. Magnitude was 3.1.

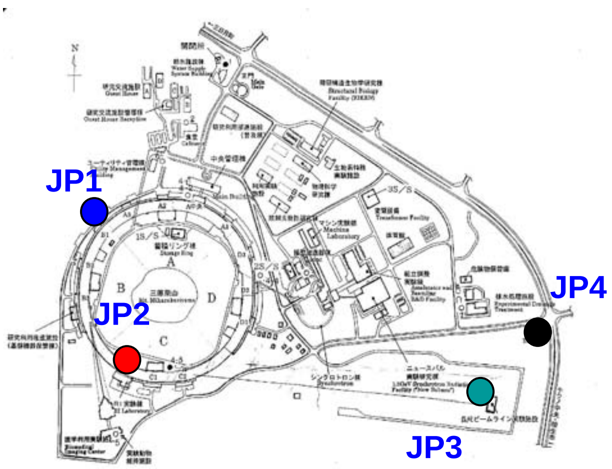

Figure 9: Measurement points in the SPring-8 site.

Remeasurement was performed during the period 9-11 July 2007 at 4 points as shown in Figure 9. Point JP1 is on an outcrop of the bedrock, JP2 on a granite base block in a room, JP3 a mound covering about 600m long XFEL beam line, and JP4 ground at the east gate. JP1 and JP2 are hard rock area, and JP3 and JP4 soft ground area. The ground motion was measured with velocity sensors, STS-2 of Streckeisen.

Figure 10 shows the horizontal component of output from sensors placed at (a) JP1, (b) JP2, (c) JP3 and (d) JP4. Figure 11 shows vertical component of the signal. Beat signal is seen in the vertical component at JP3 (Figure 11 (c)). This is thought to be caused by some motors working nearby. A primary wave started at about 0 o'clock and 330 second on July 11, and a secondary wave reached about 10 seconds later. Figure 12 shows Power Spectrum Density (PSD) at the time of the earthquake of (a) horizontal and (b) vertical component. Blue, red, green and black lines in Figures from 12 to 14 show results for measurement points JP1, JP2, JP3 and

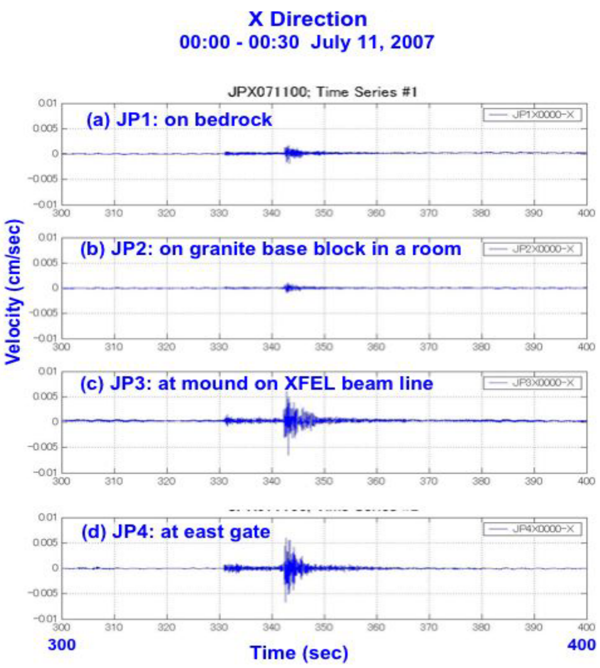

Figure 10: Horizontal component of the output from sensors placed at (a) JP1 (b) JP2, (c) JP3 and (d) JP4. Measurement points JP1-JP4 are described in the text.

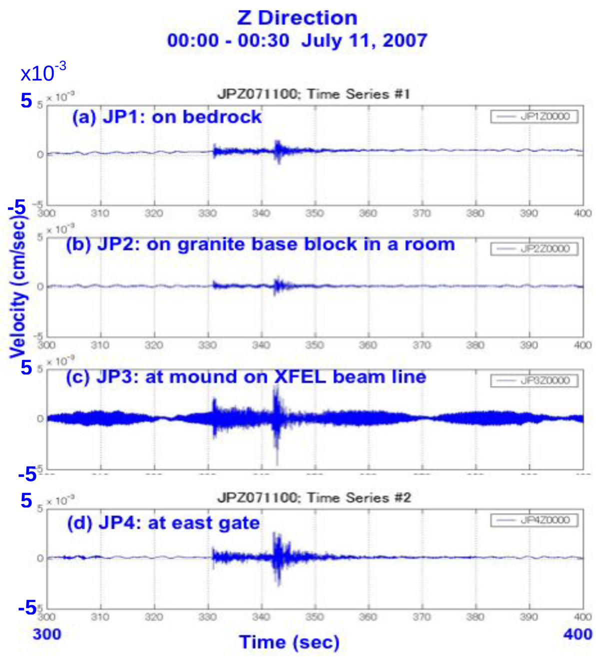

Figure 11: Vertical component of the output from from sensors.

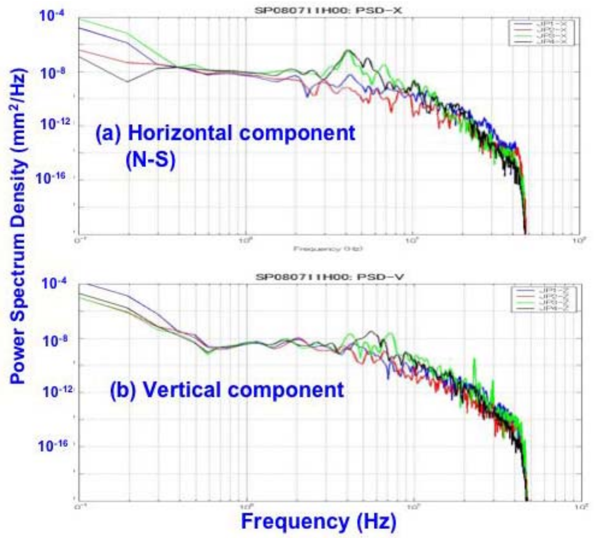

Figure 12: Power Spectrum Density (PSD) of (a) horizontal component and (b) vertical component at the time of an earthquake. Blue, red, green and black lines show data at JP1, JP2, JP3 and JP4 respectively in this Figure and in Figures 13, 14 and 15 as well.

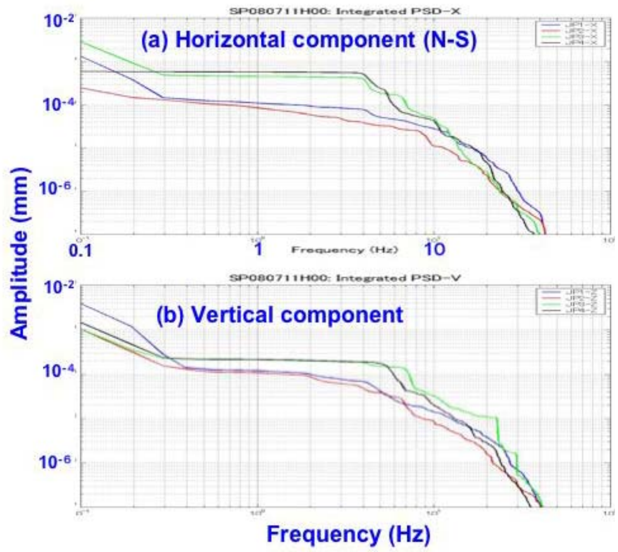

Figure 13: Square root of integrated PSD of (a) horizontal component and (b) vertical component at the time of an earthquake.

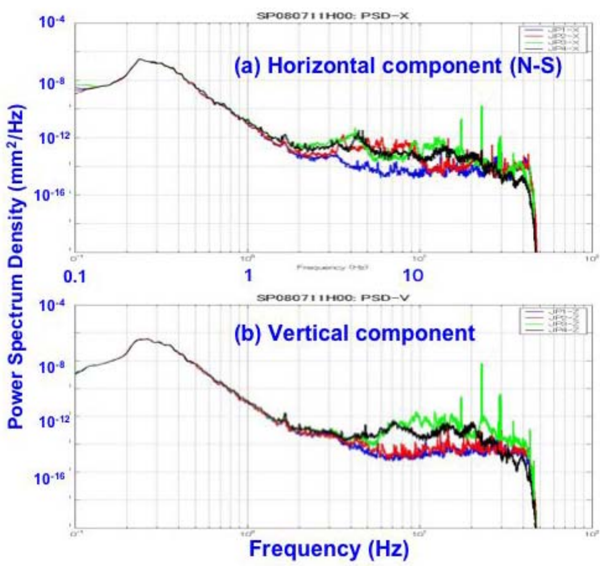

Figure 14: Power Spectrum Density (PSD) of (a) horizontal component and (b) vertical component in the usual midnight.

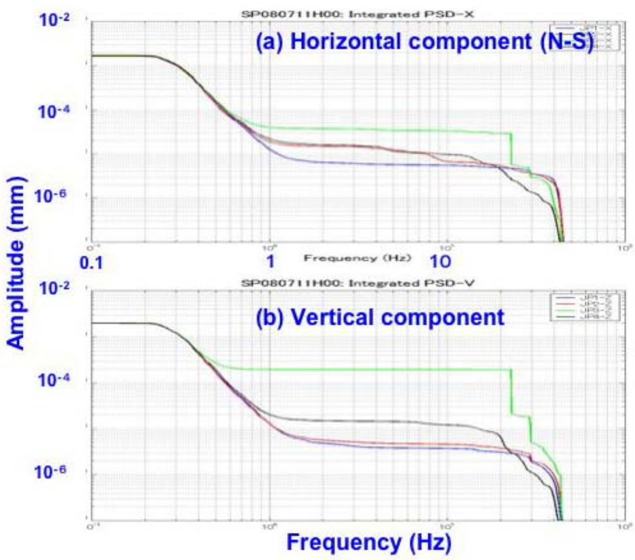

Figure 15: Square root of integrated PSD of (a) horizontal component and (b) vertical component in the usual midnight.

JP4 respectively. Figure 13 shows square root of integrated PSD at the time of the earthquake. Figures 14 and 15 show PSD and square root of PSD in the usual midnight (01:00 - 01:30 on July 11th). The frequency spectra were enhanced broadly in the frequency region from 1Hz to 10Hz. The amplitude of the vibration is quite different depending on the measurement points. In general, the amplitude of the vibration is much less in the hard rock area (JP1 and JP2) than that in the soft ground area (JP3 and JP4). The integrated spectra show that the amplitude of horizontal component at JP1 and JP2 is about 1/5 of that at JP3 and JP4 in the frequency region 1-10Hz. The amplitude of vertical component at JP1 and JP2 is about a half of that at JP3 and JP4 in the frequency region 1-10Hz.

6. COCLUSION

Ground motion at various sites were measured and analyzed in Japan. Frequency spectra are compared, and effect of the traffic is studied. Ground motion of various grounds at the time of an earthquake is also presented.

In general, the amplitude of the ground motion is much smaller in the hard rock area than that in the soft ground area. In the hard rock area, the amplitude of the ground motion does not depend on the geology, but depends on the conditions of some natural phenomena such as ocean swells and wind in the frequency region lower than 1Hz. An earthquake looks good tool to study the characteristics of various geologies because the source of vibration is the same and results can be compared directly.

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