GROUND MOTION STUDIES NEAR THE DAM SITE

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Abstract

The power spectrum density and coherence function on the ground motions have been reported by many authors aiming at the construction of the large future electron-positron linear colliders and next generation accelerators. The transfer function of the ground motion, however, is not exactly clear by these present data. We are developing the study to obtain the transfer function using the distinct ground motion source. In the beginning, our studies started in the granite tunnel which is near the dam site, since the wide frequency band source of the ground motion is available and the geological character is simple.

1 INTRODUCTION

Many measurements on the ground motion were made for several accelerator sites and their related sites, because of the special interest of accelerator physicists. Any alignment errors cause an orbit distortion and which lead to reduction of the dynamic aperture of the machine. An extreme situation is emittance growth of the accelerating beam. Slow ground motion which frequency components are less than characteristic frequencies of the accelerator has been usually considered as not having serious effect on the machine operation, assuming complete space and time coherence of the ground motion. This assumption, however, not exactly works out for the weak geological structure as shown by relatively large A value of the ATL model [1, 2]. The ground motion caused by daily or seasonal variation of the ground temperature, groundwater level variation, atmospheric pressure variation and earth tides have a large correlation length. The residual part of these variations, however, becomes inelastic component of the ground motion and looses the correlation since the source of the motion is removed. The ground motion spectrum excluded characteristic spectra is empirically given as,

$$P(f) = \frac{K}{f^2 (f_0^2 + f^2)}, \qquad (1)$$

where $P(f)$ is a power spectrum in m^2/Hz, K is constant and f is frequency in Hz [3]. A constant f_0 depends on geological structure and changes from 0.1 Hz to 0.01 Hz.

2 EXPERIMENTAL SETUP AND RESULTS

Several sensors are arranging together in order to get complimentarily the broadband spectrum of the ground motion in the granite tunnel. Measuring devices are:

- STS-2 (Streckeisen); force balance broadband seismometer; 3 sets.
- VSE-15D (Tokyo Sokushin); force balance broadband seismometer; 1 set.
- Broadband Tiltmeter (Pinnacle); bubble level tilt meter; 5 sets.
- HLS (Fogal Nanotech); Half Filled Water Tube Tiltmeter; 2 sensers.

These devices are set in the tunnel as shown in Fig. 1.

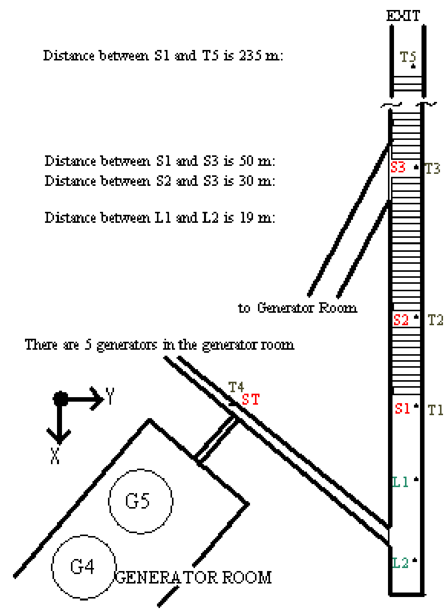

Figure 1: Schematic description of the related tunnel and the position of measuring devices. S1, S2 and S3 correspond to the STS-2, T1 through T5 to Pinnacle's tiltmeter, L1 and L2 to HLS respectively. ST to VSE-15D.

The depth of setting place (for S1, L1 and L2) from the surface is 60 meters, which corresponds to 208 meters in elevation. A slant height from S1 to T5 is 50m then S2/T2 and S3/T3 are setting on the stair. The distance between the exit of the tunnel and centre of the dam is 130m.

2.1 Geological Description

The dam was made using the Tenryu-river in Shizuoka Prefecture. This river runs along the ancient fault and the geological structure of the right bank side is granite. The left bank side is complex metamorphic rock (blackschist, greenschist and sandstone) in the geological structure. Under the mountain of the right bank, the Shintoyone electric power plant is constructed as underground facility. The plant has five generators, shown partly in Fig. 1, and works as the pumped storage. The present experimental place is an adjacent ventilation tunnel. The vibrating noises induced by the generator system and the slow ground motion as a result of the change of altitude of the dam are expected as definitely observable ground motions.

We set four kinds of devices to get the information of transfer function parameters on the simple granite tunnel. The following experimental results and discussions are about extractive information from the macroscopic point of view for existing data.

2.2 Experimental Results

A typical data for slow ground motion is shown in Fig. 2. This figure shows the tilt observed by L1 and L2 (red line) and variations in altitude of the dam (blue line).

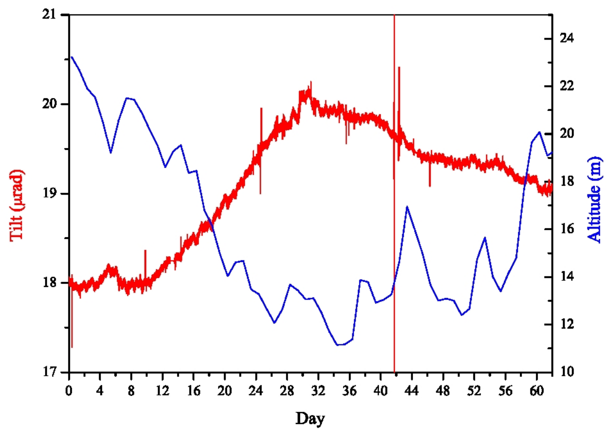

Figure 2: Typical tilts and variations in altitude.

A fine structure of the tilt thickening the red line corresponds to the earth-tide as shown in Fig. 3.

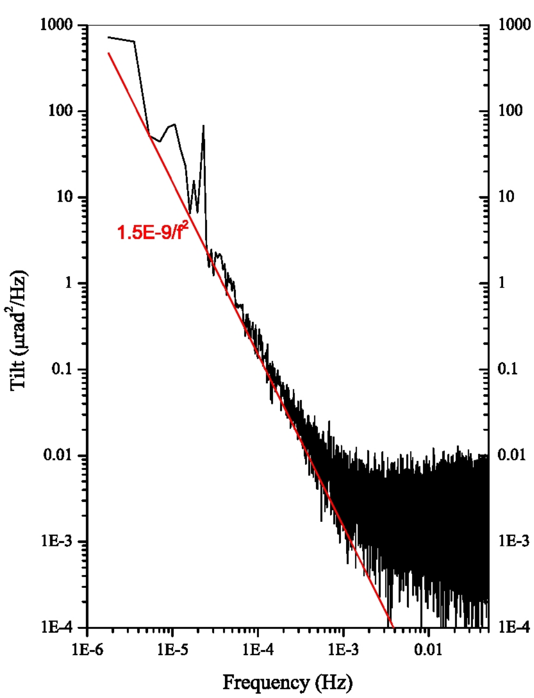

Figure 3: Earth-tide spectrum at Shintoyone. A red line corresponds to the equation (1)

We are now progressing to analyse the data of tilt and to separate out the irregular component from the data using BAYTAP-G [4]. In order to get an approximate relation between the tilt and the altitude, we have adopted the least square fitting between them. We got the tilt versus the altitude being 0.18 $\mu rad / m$. Detailed discussion is in the section 3.

The observed vibrations, when the No. 1 generator is operated only, are shown in Figs. 4, 5, 6 and 7. In each figure, X and Y directions are corresponding to X and Y in Fig. 1 respectively, Z direction to perpendicularly upward.

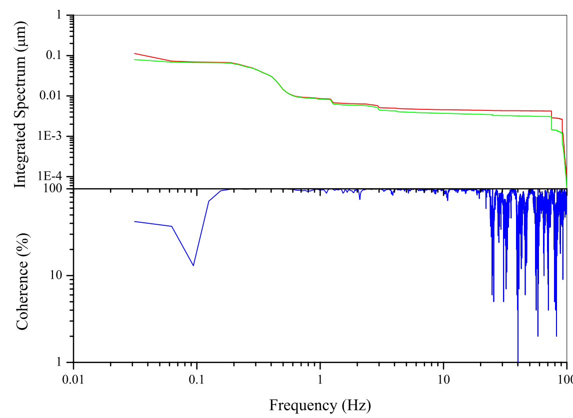

Figure 4: Integrated power spectrum and coherence between S1 and S2 for X direction. Red line corresponds to S1 and green line to S2.

The spectra of S1 and S2 for X direction show same amplitudes in the observed frequency range. Although the absolute spectrum amplitudes are different for each data set, similar phenomena are observed on the spectra of S1 and S2, for both Y and Z directions.

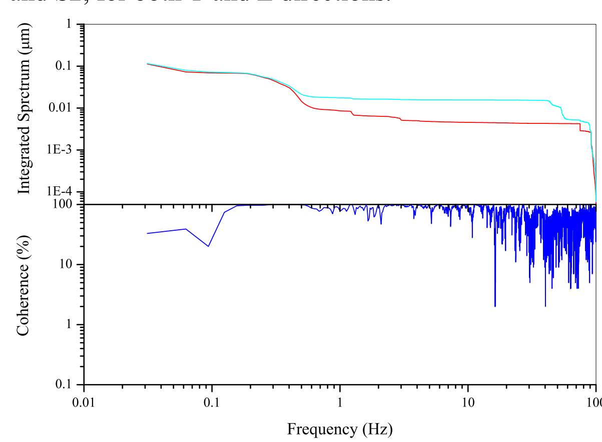

Figure 5: Integrated power spectrum and coherence between S1 and S3 for X direction. Red line corresponds to S1 and light blue line to S3.

Fig. 5 shows distinctive differences in amplitude between S1 and S3 on the frequency range from 0.4 to 60Hz, though their coherence is good. Figs. 6 and 7 show also distinctive differences between the observing points. These results indicate that the observing point S3 is singular point on the vibration. Similar phenomena were observed at 40m point from the S1 instead of S3 (50m point). An observed result at 30m point, however, gives mostly the same results as S1 and S2.

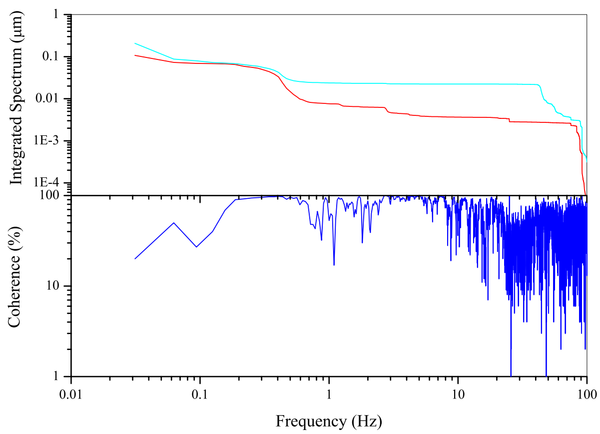

Figure 6: Integrated power spectrum and coherence between S1 and S3 for Y direction. Red line corresponds to S1 and light blue line to S3.

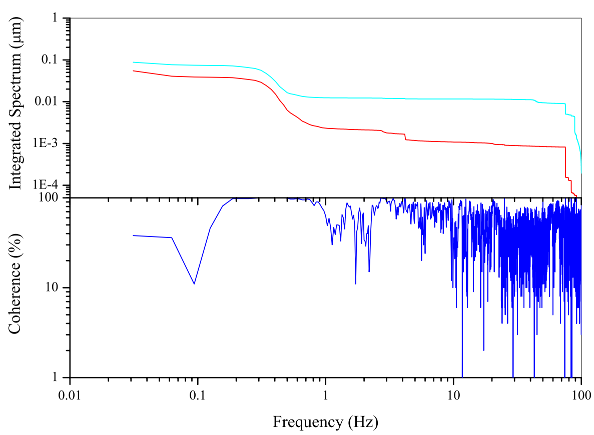

Figure 7: Integrated power spectrum and coherence between S1 and S3 for Z direction. Red line corresponds to S1 and light blue line to S3.

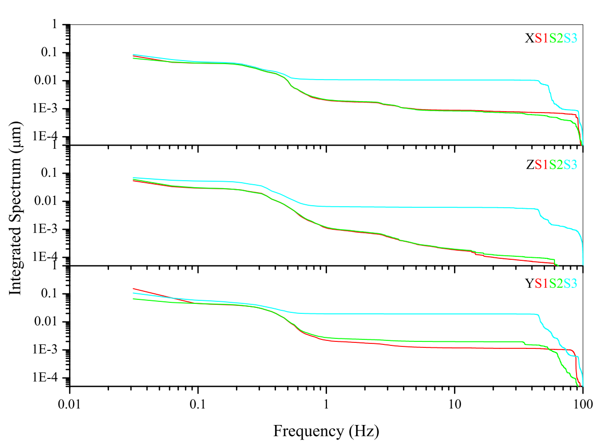

Figure 8: Spectra for each position, when any generators are not operated.

Fig. 8 shows all integrated spectra in the quiet tunnel except being the ventilation system operated continuously. The light blue lines (S3) for all directions show very large amplitudes in comparison with other spectra. It seems this noise source coming from the ventilation systems through the connected tunnel to the generator room as shown in Fig. 1. The surface wave generated by the large ventilation system seems to transmit on the tunnel flower and to be detected by the seismometer near the open hole of the tunnel.

3 DISCUSSIONS

We made a simple assumption to explain the strong correlation between the tilt and the altitude as shown in Fig. 2. The geological features of the left bank side are very different from the right bank, as mentioned above, then we apply a model of the cantilever formed by the granite rock to the tunnel of Fig. 1. A deflection angle at the point of L1 becomes

$$\vartheta = \tan^{-1}\left[\frac{f_0(L-a)}{2EI}(Lx_0 + ax_0 - x_0^2)\right], \quad (2)$$

where, f_0 is distributed load by the water, L is the length of the granite beam, *a* is the length of the related tunnel and EI is the modulus of section. Considering actual data about the tunnel, we assign the following values to variables of equation (2); f_0=1.18E5N/m, *L*=435m, *a* =235m, x_0=23m and *EI*=7.8E16Nm^2. The calculated deflection angle is $2.24\mu rad$, which is consistent with $2.1\mu rad$ obtained by the experiment. We have a plan to analyse the present data using the finite-element method in order to get more detailed information.

In contrast with the simple speculation for the tilting effect, the observed vibration phenomena mentioned above are not so easy to speculate their mechanism. The followings, however, are clear information as looking the data of Figs. 4 to 8:

- The differences on amplitude between each spectrum are less distinct in the frequency ranging smaller than 0.4Hz.
- Clear differences are there around the S3 point, in the frequency range 0.6Hz<f<90Hz, and we may get transfer function parameters of the granite tunnel by detailed analysis for these data.
- Good coherency is observed over a wide frequency range higher than 0.2Hz, though the amplitudes largely changes.

The ATL value in this related tunnel is about 1nm^2/m/sec, which is calculated by the present data.

4 REFERENCES

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