Ground Vibration Measurement at TPS Site

For the future TPS project in the NSRRC, ground vibration is an important issue for the new machine. We have measured ground vibration under various locations and conditions at NSRRC site. Sensors were installed in three sites, on the ground and underground in different level down to 40 meters below the surface. From the measurement, we compare the effect of day and night, peak traffic effect, and the propagation of internal machine vibration. Specific vibration sources and their propagations are also discussed.

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I. Introduction

In the TPS project, this synchrotron is designed to have features of low emittance, high brightness, high stability etc. The mentioned parameters are sensitive to the vibration. In the planning phase, we performed the measurement of ground vibration at different locations of TPS site in different underground levels to identify the vibration source and distribution. The measured data provides valuable information to civil engineer and accelerator physicist in their design consideration and simulation.

II. Measurement method and process

The measurement were made using seisometers of Guralp CMG 6TD and Tokyosokushin VSE-15D for the ground measurement; Tokyosokushin VSE-355D for the underground measurement. The mentioned sensors were velocity types in three axes with flat response from 0.1 Hz and upwards. A chart recorder or build-in hard disk was programmed to record the ground vibration with sampling rate of 200Hz. The sensors were calibrated with laser interferometer and the error bars of the reading were within 10%. We selected three measurement points around the planed site of TPS as shown in Figure 1. For the underground measurement, we prepared three down holes in different depth and measured underground 5 meters for BH10, 15 meters for BH11, and 40 meters for BH8. To study the peak traffic effect, we selected the measuring point of vibration which is about five meters from the road.

The measurements were taken once or twice per hour. After reading time domain data from recorder, we set the time interval of 2048 data points to perform Fast Fourier Transform (FFT) and using 10 times averaging to calculate Power Spectrum Density (PSD). The integrated Root Mean Square (RMS) displacement was defined as the integrated PSD from specific frequency up to 100Hz and takes square root.

III. Measurement Result

1. Power spectrum density

Figure 2 shows typical results of PSD on the site surface in vertical directions. We can find a peak around 3 Hz, which can be found in the

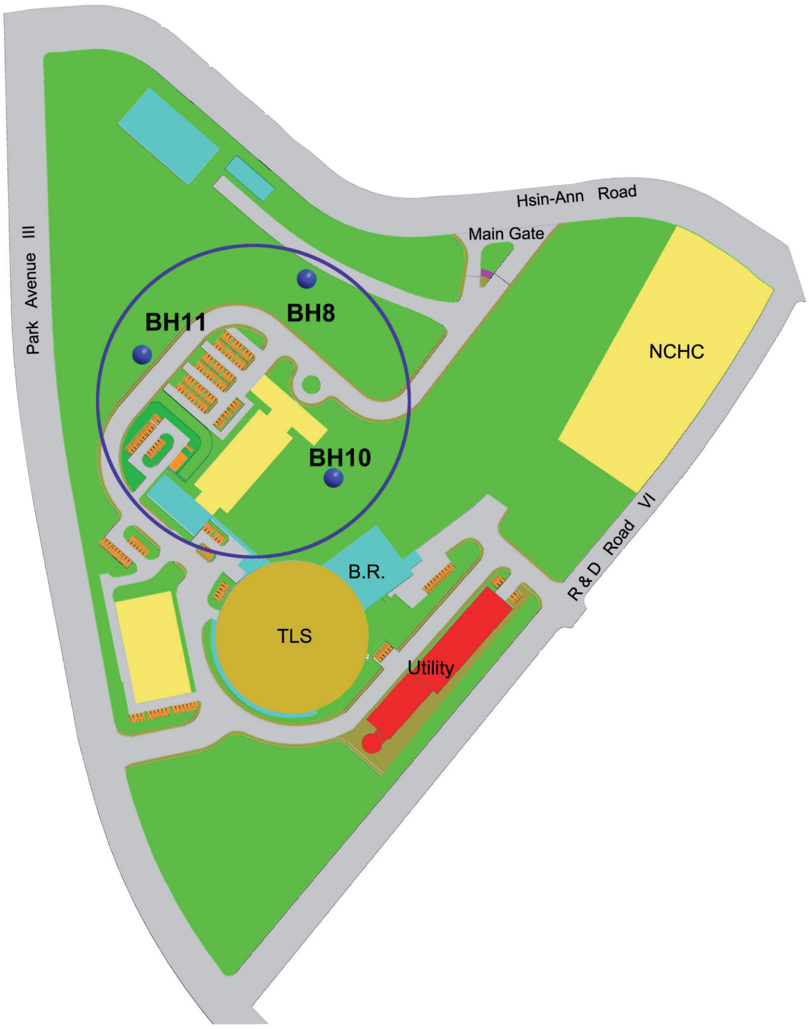

Fig. 1: Layout of TPS site and measurement points of ground vibration

island of Taiwan, easily. The mechanism and source is not clear yet. Integrated displacements from 1 Hz to 100 Hz and from 2 Hz to 5 Hz were 108 nm and 56 nm in vertical direction, respectively. For this strong 3 Hz peak, it is difficult to suppress by civil or mechanical methods. However, from the simulation of the beam dynamics, the amplification factor, with girder's constrained, through the ground vibration was less below 4 Hz comparing to that at higher frequency.

2. Integration displacement of ground motion at different locations.

The selected 3 measurement points are BH8, near the public road, BH10 near the staff and utility building, and BH11 close to the NSRRC campus road. Table 1 shows the average of a 24 hours measurement at different locations between 19:00, Oct. 19 and 18:30, Oct. 20 2005. Data was taken twice per hour during this period.

We can find the displacement of transverse vibration (N-S, E-W) was sometimes higher than that in vertical direction from 1.12 Hz upwards. However, same as vertical from 3.5 Hz upwards. It seemed the 3 Hz peak was not so isotropic in three directions. For

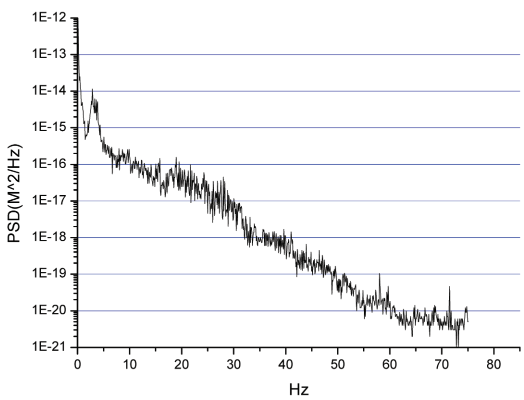

Fig. 2: A typical power spectrum density of ground vibration in vertical direction.

Table 1: Average of ground vibration measurement in nm at different locations

	1.12 Hz upwards			3.55 Hz upwards		
	BH8	BH10	BH11	BH8	BH10	BH11
N-S	139	97	223	42	51	54
E-W	146	110	166	47	58	48
V	113	105	101	46	53	46

Table 2: Summary of vertical vibration at different latitude from surface.

	1.12 Hz upwards	3.55 Hz upwards
0 m (BH8)	113 nm	46 nm
-5 m (BH10)	101 nm	50 nm
-15 m (BH11)	87 nm	28 nm
-40 m (BH8)	81 nm	20 nm

the vertical vibration displacement from 1.1Hz upward, BH8 was highest about 10% above average; BH10 was highest from 3.5 Hz upwards. It suggested the internal noise contribute to the vibration amplitude.

3. Vibration at different latitudes of underground

Before comparing the vibration at differentg depth, the level of BH8, BH10, and BH11 were 109, 118, and 119 meters above the sea level, respectively. Table 2 shows the summary of one day's measurement at different level of underground. We can compare the displacement from 3.5 Hz upwards at different depth. There was a decaying trend as the down hole going deeper and deeper. But there was no significant attenuation in vibration amplitude between 1.1 Hz to 3.5 Hz. It seemed that the high frequency part generated from the ground surface attenuated as it propagated deeper and deeper. It could reduce to half that amount as it propagated 40 meter in depth. Comparing with Table 1, on the ground with different sea level, the vibration was not so big different, it suggested the vibration propagating is surface wave dominant.

4. Culture and traffic induce vibration effect

In order to study the traffic effect, we measured a point which is about five meters away from the public road. Figure 3 shows the measurement result in vertical direction for one day. During rush hour, vibration increased by a factor of two comparing to averaged value. Vibration amplitude was reduced significantly during mid-night. From Fig. 3, we can conclude that the traffic effect increased the vibration amplitude not only the low frequency part (1 Hz upwards) but also high frequency (4 Hz upwards) part. Fig. 4 shows the vibration amplitude in 4-100Hz at different distance from the public road. Vibration peak in the rush hour time at nine o'clock drops significantly as distance 20 meters away from the road. It is attributed to the damping effect of distance.

5. Internal vibration source

There was internal source such as utility vibration and some pumps etc. BH8 stands for the outside traffic contribution. Comparing the lowest background, the vibration amplitude of Fig. 3 or Fig. 4 was about 20nm from 4 Hz and above during the midnight. Figure 5 shows the vertical displacement in a point

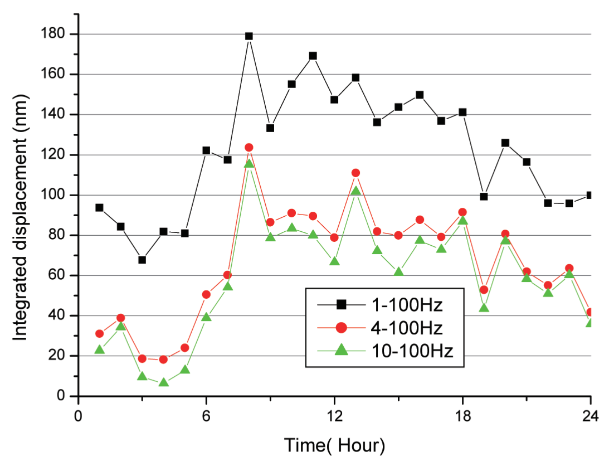

Fig. 3: Ground vibration at 5 meters away from the public road.

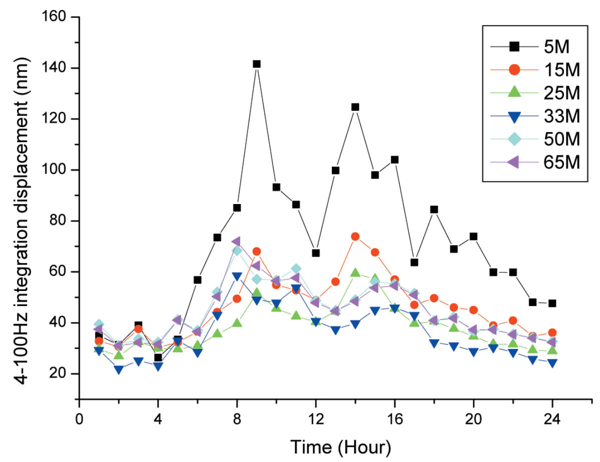

Fig. 4: Vertical vibration at different distance from the Park Avenue III public road.

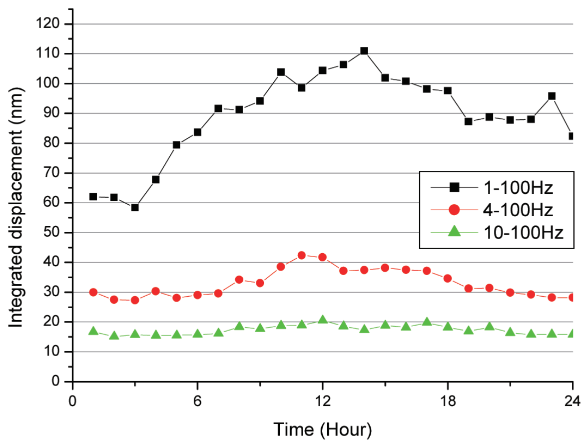

Fig. 5: Vertical vibrations near the TLS tunnel.

near the TLS tunnel. The vibration amplitude was about 30nm from 4 Hz and above. It seemed that 10nm of vibration amplitude came from the internal source such as utility, water or air-condition flow. Comparing the vibration amplitude of Fig. 3 and Fig. 5, we can conclude that the vibration amplitude of frequency higher than 10 Hz was about 8nm for the different site and tunnel during midnight. One of internal vibration source, induced by water, has been analyzed and reported.

IV. Summary

The measurement of vibration at TPS site is summarized as following.

1. Vibration amplitude in vertical direction was about 50nm from 4 Hz and above at three measurement points in different latitude above sea level.
2. Vibration amplitude in vertical direction decreased as the underground measuring going deeper and deeper. The amplitude of vibration is only 20nm from 4 Hz upwards in the depth of 40 m below surface.
3. The internal noise was estimated to be about 10nm from 4 Hz upwards in the TLS tunnel.

References

- C. C. Kuo, "*Beam Dynamics*", TPS Design report, (2006).
- CECI report, March (2006).
- D. J. Wang *et al.*, "*Water Induced Vibration in the NSRRC*", PAC, (2005).
- S. Redaelli *et al.*, EPAC, 2275 (2004).
- J. S. Bendat *et al.*, "*Engineering Applications of Correlation and Spectral Analysis*", John Wiley & Sons Inc., New York (1993).

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