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INVESTIGATION OF VIBRATIONS ATTENUATION WITH DIFFERENT FREQUENCY ALONG HEPS GROUND

Yuning Yang[1], Fang Yan†, Zihao Wang, Xiangyu Tan
The Institute of High Energy Physics of the Chinese Academy of Sciences, Beijing, China
Xiangrong Fu, Wenjie Wu, Lan Yan, China Agricultural University, Beijing, China
Jun Lei, Peking University, Beijing, China
[1]also at China Agricultural University Beijing, China

Abstract

High Energy Photon Source (HEPS) has a strict restriction on vibration instabilities. To fulfil the stability specification, vibration levels on HEPS site must be controlled. The control standards are highly related with the vibration amplitude of the sources and the distance between sources and the critical positions. To establish reasonable regulations for new-built vibration sources, the decay patterns are investigated on HEPS site for different frequency noises. A series of experiments were conducted using shaker to generate vibrations with frequency from 1 Hz up to 100 Hz. The vibration attenuation on ground and slab were measured using seismometers and the attenuation law were analysed. Details will be presented in this paper.

INTRODUCTION

With the usage and development of high precision equipment, the impact of vibrations on large scientific facility is becoming increasingly prominent. Depending on source of the vibrations, the noises can be classified into artificial vibrations and natural vibrations [1]. Natural vibration include ground motions, wind-induced vibrations, water wave vibrations et al., while artificial vibration include vibrations generated by vehicles, light rail, building facilities, large machinery et al.. The random noise generated by these vibration sources can have a significant impact on the resolution and sampling efficiency of equipment. In severe cases, it can even cause expensive equipment or system unworkable. Therefore, controlling the internal and outside vibrations are necessary [2].

Due to the non-uniformity of the ground medium and the uncontrollability of random noise (frequency, amplitude), it is difficult to accurately predict the vibrations generated by external vibration sources using widely used Bornitz model [3]. Therefore, it is necessary to propose more reasonable prediction formulas based on the measured attenuation data on HEPS.

To ensure the validity of the measurement data, the self-noise measurement of the employed instrumentation was conducted, and compared with the environmental noise level on the foundation of HEPS storage ring and the vibration amplitude transmitted over a distance of 170 m from the shaker. Subsequently, vibrations with frequency of 1 Hz up to 100 Hz were generated using the shaker, and the ground and floor vibrations along the propagation line were measured using a seismometer. The attenuation of these vibrations was analysed and presented in this paper.

Instrumentation

The seismometers and velocimeters used in this experiment include five Gaia Code Alpha and three Guralp 3espcde all-in-one seismometers and the detailed parameters of these equipment are listed in Table 1:

Table 1: Margin Specifications

Seismometer	Frequency Ranges	Sensitivity
Alpha	0.0083~150 Hz	6000 V/m/s
3espcde	0.017~100 Hz	2000 V/m/s

ANALYSIS AND CALCULATION OF DEVICE SELF-NOISE

Seismometer Self-noise Measurement

The three-sensor coherence analysis method is a seismic instrument self-noise analysis method based on correlation analysis. Its basic principle is that when three seismometers observe the same input signal, the correlated parts of the signal are removed, and the remaining parts are considered as the device's self-noise. This analysis method requires two assumptions [4]:

1. The internal noise of the data acquisition channels is uncorrelated.
2. The internal noise of the seismometer and the environmental noise signal are uncorrelated.

The basic model is shown in Fig. 1. The calculation formula is shown in Eq. (1):

$$N_{ii} = P_{ii} - P_{ji} \cdot \frac{P_{ik}}{P_{jk}} \tag{1}$$

The experimental site for the self-noise testing of the 8 devices used in this study was located in an observation cave at the Beijing National Seismic Observatory. Each device was shielded using a simple shielding cover as shown in Fig. 2.

All the seismometers have low self-noise levels. Due to limited space, the result of one Guralp's 3espcde plotted in Fig. 3.

†yanfang@ihep.ac.cn

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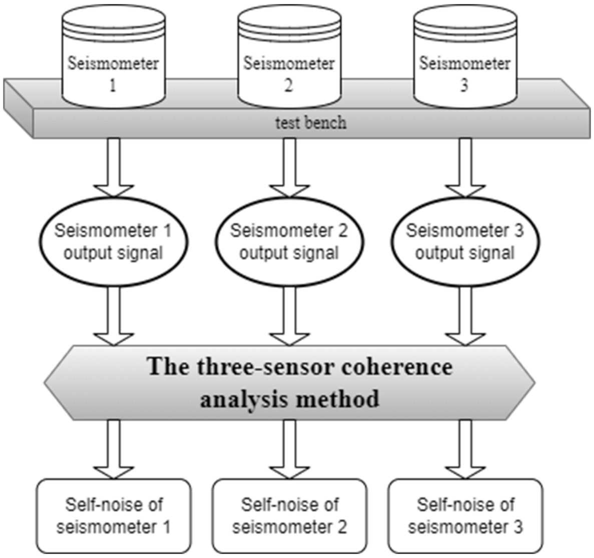

Figure 1: The three-sensor coherence analysis method.

Figure 2: Self-noise test site.

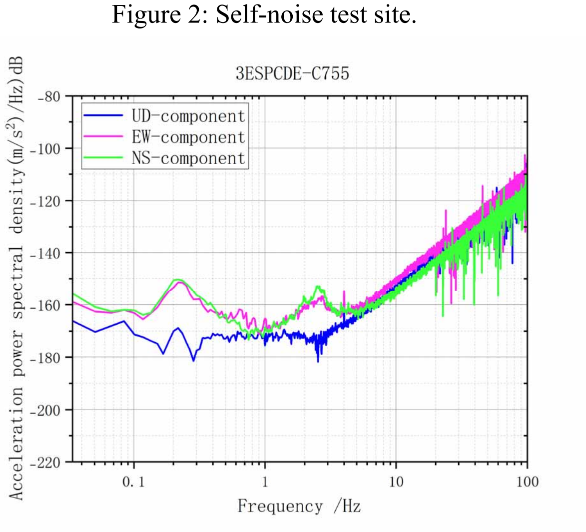

Figure 3: Self-noise curve of C755.

ATTENUATION EXPERIMENTS AND ANALYSIS OF EXPERIMENTAL DATA

Experimental Arrangement

HEPS has implemented special treatment for the foundations of storage ring and experimental hall. Four meters underground layer has been dug out and refilled with 3 m of plain concrete and 1 m of reinforced concrete. The measurement point for the decay experiment is located in the experimental hall of HEPS (6 points on the floor of the experimental hall and 1 point outside the raft: Fig. 4). The shaker was positioned approximately 170 m away from the experimental hall, on a paved road as shown in Fig. 5.

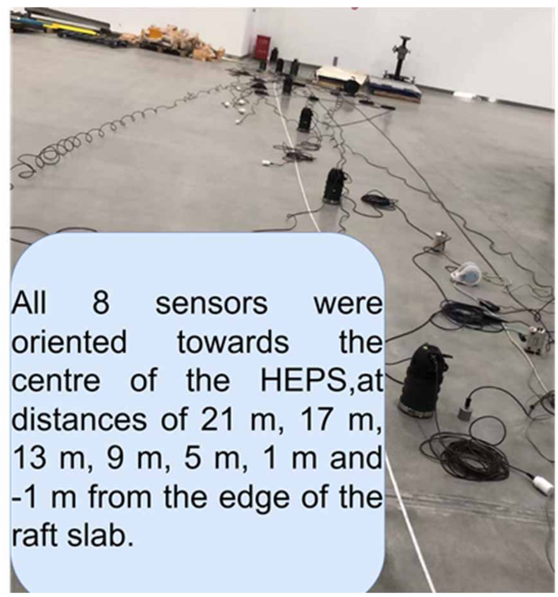

Figure 4: Attenuation test site.

Figure 5: Shaker position.

To investigate the attenuation characteristics of external vibrations on a raft foundation, a vertical sinusoidal wave with frequency of 1 Hz up to 100 Hz was applied to the shaker. The excitation of each frequency lasted for 40 s, and the first 5 s and last 5 s of data were discarded to eliminate the frequency changing part. The remaining 30 s

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data were used to calculate the root mean square (RMS) displacement of the vibration for each frequency.

Experimental Data and Analysis

To ensure accurately and reliablely observation of the excitation signal and the tunnel ambient noise, the self-noise of the equipment farthest away from the shaker is compared to the vibration amplitude and ambient tunnel noise generated by the shaker propagating through 170 m distance, and the displacement power spectral density (PSD) on the ground in the vicinity of the shaker. (see Fig. 6). It was found that the self-noise of the C755 device is significantly lower than the noise from the excitation signal and tunnel environment, this indicates that the signals observed by this device are valid, and the vibrations generated by the shaker are at the same level within the frequency range of 10 Hz to 70 Hz.

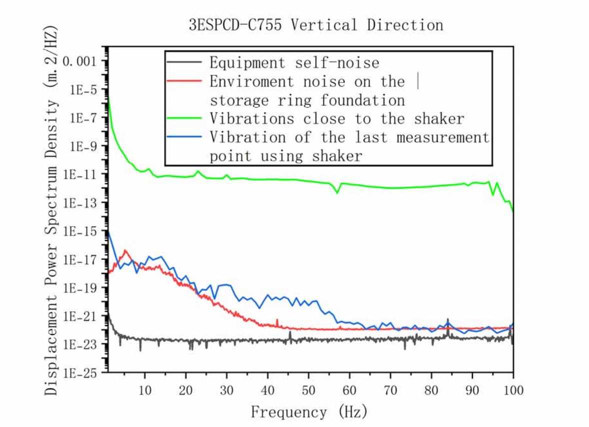

Figure 6: Displacement PSD comparison.

A comparison was made using the displacement responses at frequencies of 10 Hz, 20 Hz, 30 Hz, 40 Hz, 50 Hz, 60 Hz, and 70 Hz (see Fig. 7). In Fig. 7, the x-axis represents the distance from the edge of the raft foundation in the experimental hall, the shaker was located 170 m away from the foundation raft edge in the other direction.

The result shows that:

1. When the frequency exceeds 70 Hz, the vibration generated by the shaker has already overlapped with the ambient noise of the tunnel itself, indicating that vibrations above 70 Hz have become equivalent to the environmental noise after attenuation by the ground at a distance 170 m.
2. High-frequency vibrations decay faster than low-frequency vibrations, vibrations with frequency of 10-30 Hz still exhibiting high amplitudes after propagating 170 m, while the decay curve for vibrations above 40 Hz is relatively flat.
3. Some frequency points may experience amplification of vibrations when entering or propagating through a raft foundation, possibly due to the phenomenon of reflection superposition occurring during the process of wave propagation between different materials.

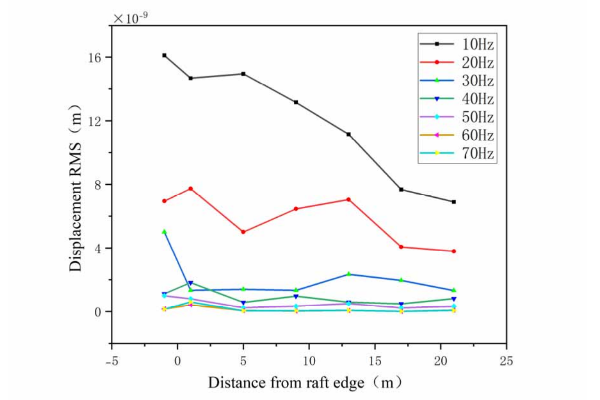

Figure 7: Attenuation of displacement response at different frequencies.

CONCLUSION

The test was conducted on the foundation of HEPS experimental hallusing a shaker for generating vibrations with frequency of 1 Hz to 100 Hz. The attenuation pattern of vibrations in the tunnel and the experimental hall was summarized.

In this test, measurement points were arranged radially within one period. Subsequent plans involve conducting the same experiment in multiple periods of the tunnel to analyze the attenuation pattern of different frequencies at different locations. This analysis will be used to develop a predictive formula for vibration attenuation, which will be validated by applying traffic loads on the road close by. The aim is to provide engineering strategies for controlling vibrations.

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