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THE INFLUENCE OF SENSORS MOUNTED CONDITION DURING GROUND BORNE VIBRATION MEASUREMENT

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Abstract: During the measurement processes on mechanical vibration, the sensors should normally be installed as rigid and firm as possible and the installation surface should be as clean and flat as possible. But in practice, the installation condition always hardly satisfies the requirement. Especially, during the measurement on ground borne vibration caused by metro railway system, the surface condition are always uncertain, altered with concrete road surface, sandy ground , soft soil ground etc. In order to analyse the influence on the measurement result caused by sensors mounted condition, a special designed comparison test was conducted on a free ground nearby Beijing metro L4. VLZmax and 1/3 octave spectrum for five types of different condition were compared in this presented paper , involving asphalt road surface, brick surface, compacted soil layer and two special designed mounts. The results indicated that: (1) almost 10 dB difference in VLZmax were observed from different condition, and (2) The maximal value of VLZmax occurred on brick surface, while the minimal value of VLZmax occurred on asphalt road surface.

Keywords: Urban subway, ground vibration test, piezoelectric transducer, transducer mount

1. Introduction

Field test is one of the important methods to study the vibration of the subway. The test results can provide the basis for the theoretical analysis of the subway vibration, verify the correctness of the theoretical model and evaluate the environmental vibration level of the ground and buildings cause by the city subway [1].

During the measurement process, the sensor should, in principle, be mounted on flat and solid floor, and be protected from soft surfaces such as carpets, grasslands, sandy land or snow, thus minimizing the effects of coupling effects [2]. However, in the actual situation, due to the limits of the measurement conditions, Surface sampling points often encounter sand, fields and other unfavourable conditions. For the above conditions, we usually use the mount to arrange the sensor. When the sensor is placed on mount, the sensor and the mount form a resonant system, and the measurement vibration of the sensor is affected by the system. In the study of the past, G.N.Bycroft indicated the values of magnification and phase shift arising in a ground vibration detector due to partial resonance of the instrument on the ground [3]. G.Gutowski found that short stake-type mounts provided good agreement for vertical motion [4]. Fukuhara Bodu studied changes in the resonant frequency of the sensor in clay and sand [5]. Sadao Omata examined the characteristics of the frequency response of the vibration transducer placed on the ground and provided the optimum relationships between the base area and the weight of the transducer for decreasing the effect of ground coupling under all condition [6]. GUO Haven analysed the effect of temperature, humidity and installation on the performance of piezoelectric sensor [7].

However, in the urban orbital system, there is no study of the impact of different sensor installation environments such as asphalt pavement, sidewalk pavement (brick), soil surface and the mount on the test results. Therefore, this paper uses the subway vibration as the signal source, when the sensor is installed on the asphalt pavement, the sidewalk (brick), the soil surface and the mount, the test was carried out to study the influence of the different sensor placement environment on the vibration test result.

2. Experiment settings and measurements

According to the sensor installation method specified in the standard, the vibration sensor were respectively installed on the concrete floor, the sidewalk brick surface, the aluminium-made and iron sensor mounting bracket and the dense soil layer to test ground vibration caused by Beijing Metro L4.

2.1 Test instruments and parameters

This experiment used the Brüel & Kjær DeltaTron Accelerometer Type 8344 (shown in Figure 1 (a)).its quality is 0.176kg and the other specific parameters are shown in Table 1 (a). Data acquisition using INV3062 T-type 24-bit high-precision distributed acquisition device (shown in Figure 1 (b)), the specific parameters are shown in Table 1 (b) below.

(a) DeltaTron Accelerometer Type 8344

(b) Data acquisition instrument INV3062

Figure1 Test instrument diagram

Table1 (a) Piezoelectricity acceleration sensor parameters

Voltage Sensitivity	2500mV/g
Frequency Range	0.2Hz~3kHz
Measuring Range	±2.6g
Input Coupling	ICP

Table1 (b) Data-acquisition instrument parameters

Sampling Frequency	0~51.2k
Input Range	±10v
Total Harmonic Distortion	-70dB
Input Mode	DC\AC\ICP

2.2 Measuring-point arrangement

Five sensors that respectively installed on the concrete floor, the sidewalk brick surface, the aluminium-made and iron sensor mounting brackets and the dense soil layer were far away as the subway line. The relative position of each measuring point and subway is shown in Figure 2.

When the measuring points were arranged by means of mounting, we made two different materials mounts. The top of the mount disc radius is 4cm (shown in Figure 3) and the sizes of mounts are shown in Table 2. The surface of the concrete floor, the sidewalk brick surface and the sensor mounting support were kept clean and flat, In the process of embedding the mount to the soil to maintain the top of the disc surface level, Before laying the measuring points on the surface, use the hammer to smash the soil to ensure that the sensor is perpendicular to the ground. Test site is shown in figure 4.

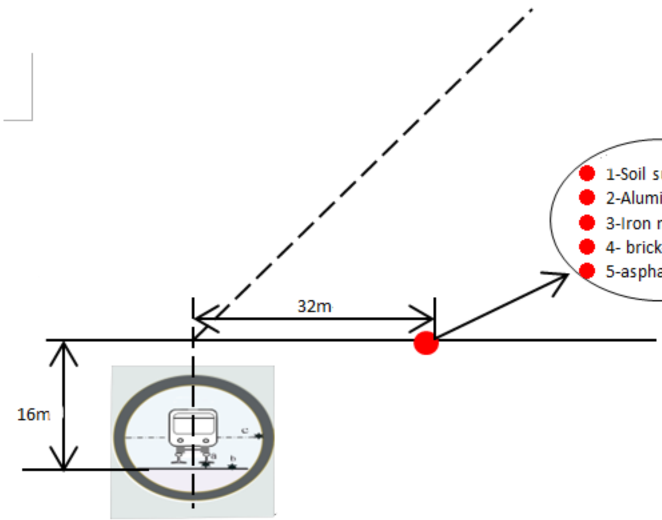

Figure2 the relative position of the measuring point and the subway

(a) Aluminium-made Mount (b) Iron-made mount

Figure 3 Pictures of Mounts

Table2 mount size

NO.	Material	the radius of the disk/mm	the length of the nail/mm	weight/g
1	Aluminum	40	150	205
2	Iron	40	150	540

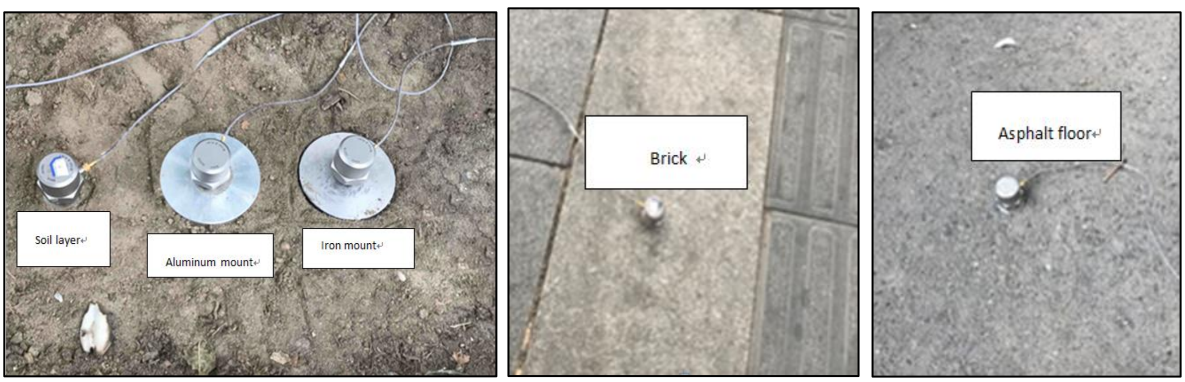

Figure 4 Test Site

2.3 Data processing

Select the waveform without a complete distortion and no obvious passers-by and road traffic interference effective data, the time-domain figure and frequency spectrogram of the vertical vibration acceleration when the single train passes is shown in Fig5.

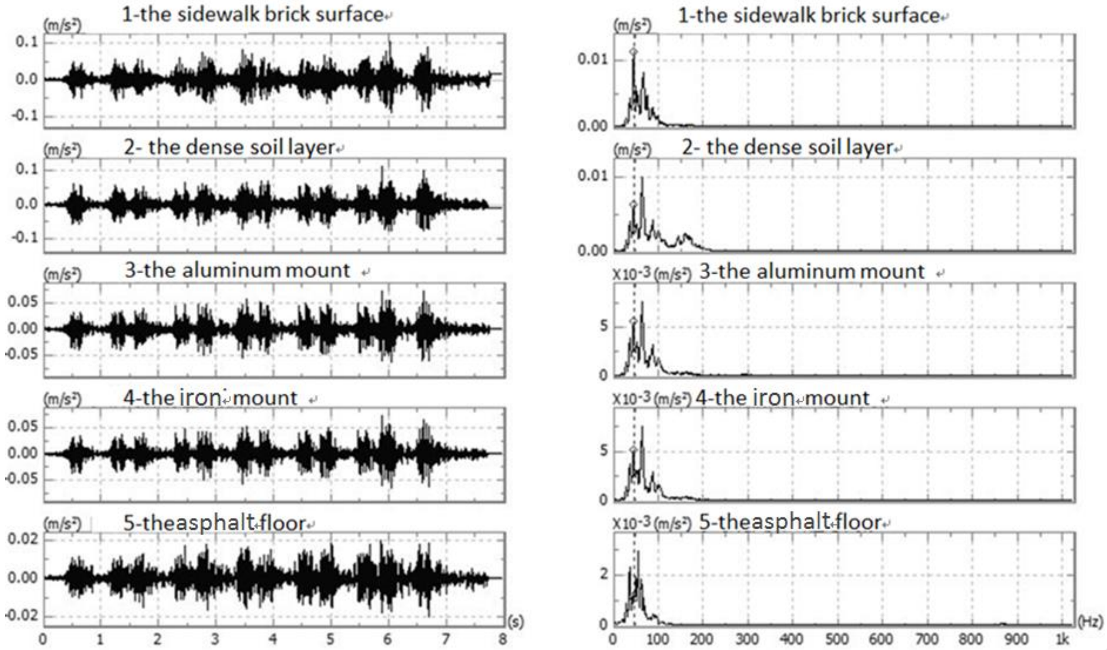

Figure5 the time-domain figure and frequency spectrogram

3. Results analysis

When the sensor is arranged on the mount to measure the vibration, the sensor and mount will produce resonance, in order to ensure the accuracy of the measurement results, the modal analysis of the system composed of sensor and mount is carried out to solve the first 5 order modes. The results are shown in Table 3.

Table 3(a) Natural frequency of first five orders of aluminium-made mount

modality	f/Hz
1	584.81
2	584.96
3	3480.1
4	3481.1
5	6068.1

Table 3(b) Natural frequency of first five orders of iron-made mount

modality	f/Hz
1	424.21
2	424.24
3	2530.3
4	2530.6
5	4629.4

The resonant frequency of the system is much larger than the frequency of the vibration signal, so there is no significant effect on the measurement of ground vibration. Therefore, the value obtained by arranging the sensor on the mount is the effective.

Get the VLZmax of ground vibration measured when subway vehicles passing through. The results of the different sensor installation modes, as shown in Figure 6:

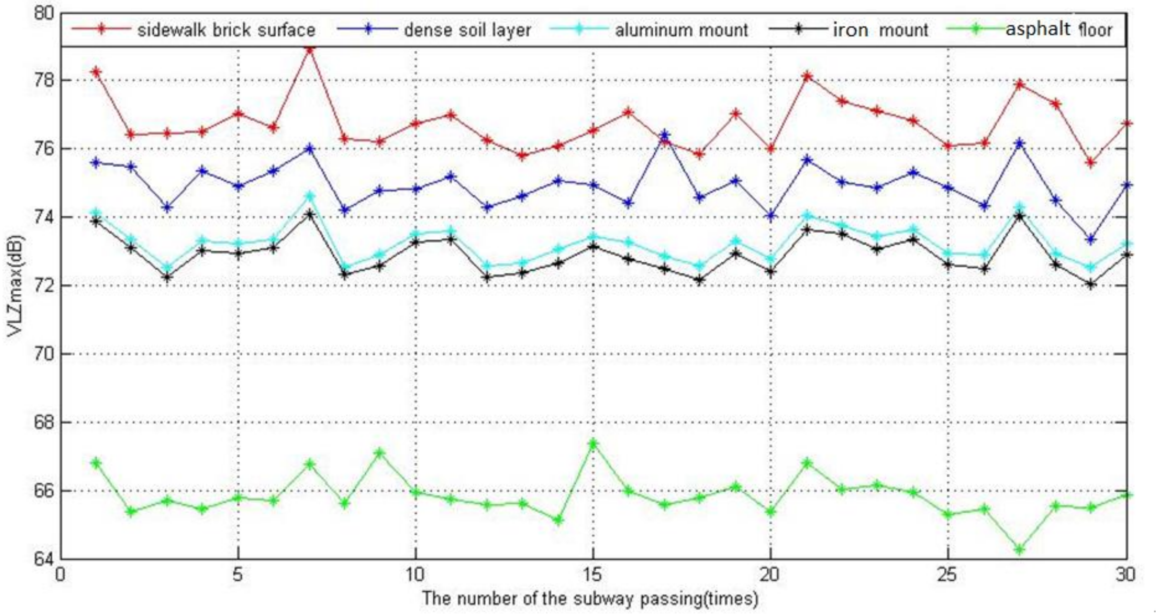

Figure 6 VLZmax measured when the trains passes through the different sensor settings

In the different sensor installation modes, the average of the 30 sets of measurement data is shown in the following table 4:

Table 4 the average of VLZmax under different sensor installation mode

Installation	Brick surface	Soil layer	Aluminium mount	Steel mount	Cement floor
AVE.	76.8	74.9	73.2	72.9	65.8

It can be seen from Figure 6, different sensor installation method has great impact on the results. When the sensor is mounted on the brick surface, the vibration level is significantly larger than the other four ways, the test results on the brick surface are 11 dB higher than test results obtained on the asphalt averagely. When the sensor is mounted on aluminium and iron steel brackets, the results are almost equal, only a difference of 0.3 dB, are slightly smaller than the results measured directly on the soil. The result obtained on the concrete floor is most minimal.

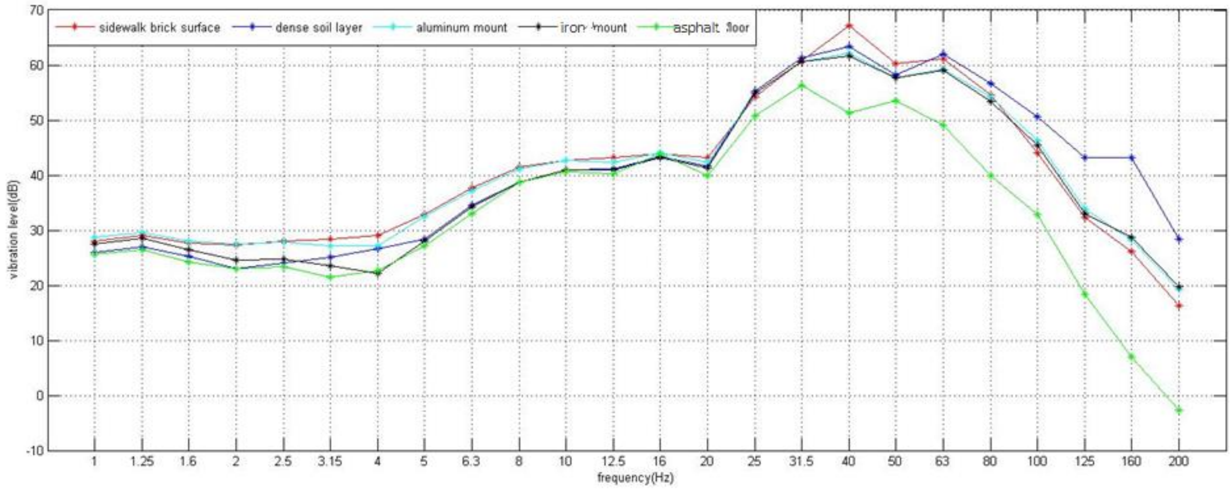

Figure7 1/3 octave spectrum measured when the train passes through the different sensor settings

It can be seen from the figure 7, under 20Hz frequency, The effect of different sensor mounting modes on Z-direction vertical vibration acceleration level is not obvious. The value that measured on the brick and aluminium mount on is slightly higher than other ways. At frequencies above 20 Hz, especially in the range of the main frequency of subway vibration, with the change of frequency, the difference between the measured values obtained by different installation methods is gradually increasing. The vibration level obtained on the asphalt surface is significantly lower than other methods; the measured values on the brick surface are the largest; the values obtained on the soil and the iron mount is almost equal.

4. Conclusion

In the measurement of ground trains caused by the ground vibration, different sensor installation ways will get different test results. Through the above data analysis and summary we get the following conclusions: (1) when the sensor is arranged on the brick surface, the measured vibration value is the largest, the values measured on the soil, aluminium-made mount, iron mount are reduced in turn. When the sensor is arranged on the asphalt surface, the measured value is the smallest; almost 10 dB differences in VL_{Zmax} were observed from different condition. (2) The vibration values of the vibration sensors installed on aluminium mount and iron mount are almost equal to the difference of 0.3 dB, so the material of the mount is considered to have no effect on the measurement results.

In the subsequent measurement process, Whether it is to use the field test results to verify the correctness of the theoretical model, or to assess environmental vibration level of the ground and buildings cause by the city subway, the tester should as much as possible to explain the actual installation of the sensor environment and manner In the report to ensure the accuracy and applicability of the results.

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