Experimental Study on Vibration Absorption Performance of Floating Slabs of Vibration Isolation Pads in Metro Shield Tunnels

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Abstract. The monolithic track bed with isolated damping pad and floating slab is a common design of urban subways in recent years. The type of track bed, urban subway lines usually pass through densely populated areas of the city, and subway trains. In the course of driving, it is inevitable that large track vibration noise will be produced. In order to reduce the impact of track vibration noise on the daily life of surrounding residents, noise reduction measures must be considered during design. Isolated shock absorber floating board The monolithic track bed is one of them. Compared with the steel spring floating slab monolithic track bed, it has the technical characteristics of "low engineering cost, more convenient construction, and good noise reduction effect". In order to study its damping effect, we selected two working conditions of straight line and curve for comparison. It can be seen from the comparison results with the ordinary track bed: (1) The acceleration level of the shock-absorbing cushion tunnel wall in the straight section is greater than the ordinary track bed section within 1~10Hz, and is close to the ordinary track bed section within 12.5~20Hz, at 25 it is smaller than the section of ordinary track bed within ~1000Hz. (2) The maximum Z-vibration level measured from the tunnel wall is most suitable for evaluating the seismic source intensity of the subway, and the seismic source intensity of the subway line is 65.69 dB.

1. Introduction
In order to overcome the problems caused by subway vibration, civil engineers around the world have discovered a variety of methods to achieve subway vibration absorption, mainly including steel spring floating plates, vibration isolation pad floating plates, ladder sleepers, etc. [1-2]. The monolithic track bed with isolated damping pad and floating slab is a common design of urban subways in recent years[3]. The type of track bed, urban subway lines usually pass through densely populated areas of the
city, and subway trains. In the course of driving, it is inevitable that large track vibration noise will be produced. In order to reduce the impact of track vibration noise on the daily life of surrounding residents, noise reduction measures must be considered during track design. Isolated shock absorber floating board, the monolithic track bed is one of them. Compared with the steel spring floating slab monolithic track bed, it has the technical characteristics of “low engineering cost, more convenient construction, and good noise reduction effect”.

2. Test Condition

2.1 Metro Line Information
In order to study the track displacement and vibration effects of the damping fasteners in the driving environment, field tests were carried out on the cross-section of the damping pad and the ordinary cross-section of a subway. Select the test section of the laying cushion and the test section of the ordinary section. In the curved section, the cross section with a radius of 450 m is selected for the two types of track beds.

2.2 Arrangement of the Measuring Points
(1) Track vibration is measured by acceleration sensors. Each measurement section uses two acceleration sensors, one is used to measure the vertical acceleration of the rail (figure 1), and the other is used to measure the vertical acceleration of the floating plate (figure 2).

![Figure 1](image1)

**Figure 1.** Layout of measuring points for rail acceleration test.

![Figure 2](image2)

**Figure 2.** Layout drawing of measuring points for track bed acceleration test.

The tunnel wall vibration is measured by acceleration sensors. Each measurement section uses an acceleration sensor to measure the vertical acceleration of the tunnel wall (figure 3). The field test is shown in figure 4.

![Figure 3](image3)

**Figure 3.** Layout of the measuring points of the tunnel wall acceleration test.
3. Data Analysis

Based on the requirements in Reference [4], the vertical (Z-direction) weighting method (1~80Hz) in Reference [5] was used to analyze data related to the tunnel wall vibration. In which, the Z-vibration level (VLZ), which is currently the most commonly used evaluation index, refers to the Z-vibration level measured when a train passes through the measurement section.

Vehicle speed has a certain influence on environmental vibration. Reference [6] gives the correction formula for environmental vibration caused by different speeds:

\[ C_v = 20 \log \frac{v}{v_0} \]

In which

- \( v_0 \) — Reference speed of a source, in km/h;
- \( v \) — Running speed of a train, in km/h.

Taking the measured data collected when 20 trains pass through this section as the actual measured data, the collected data is analyzed, and the VLZ and the vibration difference DVLZ of the two types of track bed tunnel wall measurement points are obtained, as shown in table 1.

| Line type     | Track bed form            | VLZ (dB) | Insert loss VLZ (dB) | Average value (dB) |
|---------------|---------------------------|----------|----------------------|-------------------|
| Straight line | Ordinary track bed        | 65.69    | /                    |                   |
|               | Vibration isolation pad floating board 1 | 51.04    | 14.65                | 14.35             |
|               | Vibration isolation pad floating board 2 | 52.31    | 13.38                |                   |
| Curve         | Ordinary track bed        | 63.05    | /                    |                   |
|               | Vibration isolation pad floating board 3 | 48.02    | 15.03                |                   |

It can be seen from Table 1 that after the vehicle speed is corrected to the same speed, for the straight section, the Z-vibration level of the vibration isolation pad floating plate section 1 is smaller than that of the ordinary track bed section, and the insertion loss VLZ is 14.65dB; for the straight section, the vibration isolation pad floats The Z-vibration level of the slab section 2 is smaller than that
of the ordinary track bed, and the insertion loss VL_{Z} is 13.38dB; for the curve section, the Z-vibration level of the vibration isolation cushion floating plate section 3 is less than the ordinary track bed section, and the insertion loss VL_{Z} is 15.03dB. Therefore, it can be found that the Z-vibration level of the section of the floating plate of the vibration isolation pad is smaller than that of the ordinary track bed section, and the average insertion loss VL_{Z} is 14.35dB.

3.1. 1/3 Octave Analysis Comparative Analysis

1/3 octave analysis was performed on the measuring points of the vibration damping pad, and the acceleration level in the range of 1~1000 Hz was obtained. The same treatment was also done for the ordinary track bed. Compare the 1/3 octave acceleration levels on the tunnel wall of the two types of track beds respectively, as shown in figures 5 and 6.

![Figure 5](image)

**Figure 5.** Comparison of acceleration levels of vertical 1/3 octave bands on the straight tunnel wall (without weighting).

It can be seen from figure 5 that the vertical acceleration level of the tunnel wall for the section 1 of the linear section of the vibration isolation cushion floating plate and section 2 of the linear section of the vibration isolation cushion floating plate is greater than that of the ordinary track bed section within 1~10Hz. It is close to the section of the ordinary track bed within 12.5~20 Hz, and is smaller than the section of the ordinary track bed within 25~1000 Hz.

![Figure 6](image)

**Figure 6.** Comparison of acceleration levels of vertical 1/3 octave band of the tunnel wall on the curve section (without weighting).

It can be seen from figure 6 that the vertical acceleration level of the tunnel wall of the cross-section of the floating slab of the vibration isolation cushion in the curve section is greater than that of the ordinary track bed section within 1~16Hz, and is significantly smaller than that of the ordinary track bed within 20~1000Hz.
3.2. Vibration Acceleration Time History Curve (as shown in figure 7-11)

Figure 7. Vibration isolation pad floating board 1.

Figure 8. Vibration isolation pad floating board 2.

Figure 9. Vibration isolation pad floating board 3.

Figure 10. Ordinary linear track bed.

Figure 11. Ordinary curve track bed.

Note: 1 is the vertical acceleration of the rail; 2 is the vertical acceleration of the track bed; 3 is the vertical acceleration of the tunnel wall.
4. Conclusion

(1) After the vehicle speed is corrected to the same speed, for the straight section, the $Z$-vibration level of the vibration isolation pad floating plate section 1 is smaller than that of the ordinary track bed section, and the insertion loss $VL_Z$ is 14.65 dB; for the straight section, the $Z$-vibration level of the vibration isolation cushion floating plate section 2 Class is smaller than the section of ordinary track bed, and the insertion loss $VL_Z$ is 13.38 dB.

(2) After the vehicle speed is corrected to the same speed, for the curve section, the $Z$-vibration level of section 3 of the vibration isolation pad floating plate is smaller than that of the ordinary track bed, and the insertion loss $VL_Z$ is 15.03 dB. Therefore, the $Z$-vibration level of the section of the floating plate of the vibration isolation pad is smaller than that of the ordinary track bed section, and the average insertion loss $VL_Z$ is 14.35 dB.

(3) For the vertical acceleration level of the tunnel wall of the straight section of the vibration isolation cushion floating slab section 1 and the straight section of the vibration isolation cushion floating slab section 2, the vertical acceleration level of the tunnel wall is greater than the section of the ordinary track bed within 1~10 Hz, and is close to the section of the ordinary track bed within 12.5~20 Hz, less than the section of ordinary track bed within 25~1000 Hz.

(4) The vertical acceleration level of the tunnel wall of the section 3 of the floating slab of the vibration isolation cushion in the curved section is greater than the section of the ordinary track bed within 1~16 Hz, and is significantly smaller than the section of the ordinary track bed within 20~1000 Hz.

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