Research on vibration isolation and noise reduction technology for the metro depot

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Abstract. Under the situation of increasingly tight land resources, the development of depot superstructures has been applied in many cities. The noise generated by the passage of subway vehicles and the vibration of buildings are problems that need to be solved urgently. The use of vibration and noise reduction measures for the track is an important solution. In order to study the vibration reduction effect of the depot vibration reduction measures, taking the Guangzhou Metro Chentougang Depot as an example, the vibration and noise reduction technology of the depot is studied. The research results show that: (1) It can be seen from Table 1 and Table 2 that after the vehicle speed is corrected to the same speed, the Z vibration level of the trapezoidal sleeper section at the foot of the ballast slope is lower than that of the ordinary transverse sleeper section, and the train speed is 10km/h (low speed). The insertion loss VLZ is 8.24dB, and the insertion loss VLZ is 8.53dB under the train speed of 35km/h (high speed). (2) At the measuring point 7.5m away from the centerline of the track, the Z vibration level of the trapezoidal sleeper section is smaller than that of the ordinary transverse sleeper. The insertion loss VLZ under low-speed conditions is 8.60dB, and the insertion loss VLZ under high-speed conditions is 8.93dB.

1. Introduction
The development of urban rail transit has greatly increased the transportation volume of urban public transportation, facilitated people's travel, and promoted the development of the city. Metro depot is an indispensable part of rail transit construction, which requires a large amount of land area and high
investment and construction costs. With the continuous increase in the scale of my country's subway construction, how to make good use of the land area of the depot has become an urgent problem to be solved[1-4]. In recent years, the development of superstructures of depots has been implemented in Beijing and Guangzhou and other places with good results. Therefore, in some cities in China, the development of superstructures has become a trend, and the development of superstructures of depots has become a trend, normal. The properties above the subway depot are mostly small and high-rise buildings with low floor area ratios. However, due to the impact of vibration and noise generated by the operation of the depot, the quality of the properties is low. Therefore, it is very important to solve the problem of vibration and noise reduction in the depot on the superstructure, which will improve the quality of the superstructure and increase the economic efficiency.

In recent years, domestic and foreign scholars have obtained a certain breakthrough in the research of vibration induced by rail transit. Foreign countries have studied this problem earlier, among which Fujikake[5] has studied the generation principle, propagation law of building vibration caused by running vehicles and its impact on the surrounding environment. Anderso[6] chose to conduct actual vibration measurements inside two buildings affected by subway vibration, and found that the larger vibrations are mainly distributed in the frequency domain of 5-50 Hz. Based on numerical simulation, Metrikine[7] generalized the subway tunnel and the soil layer into Euler Bernoulli beams and elastic layered media respectively, focusing on the propagation law of vibration waves inside the building. Different from the train running on the underground track, when the subway train enters and exits the depot, the superstructure is located above it. The vibration wave caused by the subway operation lacks the attenuation process that propagates in the soil layer, and it propagates directly to the top through the track bed, column and platform. Construction, the vibration characteristics of the superstructure at this time and the vibration characteristics of the surrounding buildings caused by subway trains running on the underground track are very different. This paper takes the Guangzhou Metro Chentougang Depot as the research object to test the vibration damping effect of the trapezoidal sleeper of the gravel track bed in the subway depot.

1.1. Project Background

Guangzhou Rail Transit Line 18 and 22 and the simultaneous implementation of the station complex design and construction general contracting project after the station project (Panyu Square Station-Chentougang parking lot track project) Chentougang parking lot The tasks of parking and overhauling vehicles on Guangzhou Metro Line 22, and overhauling vehicles on this line will be undertaken by Wanqingsha Depot. The Chentougang parking lot is located on the north side of Shibi Village, close to Chentougang Station, with an area of about 29.0 hectares. The track bed of the test track of Chentougang parking lot is a gravel track bed, the track structure is 0.84m high, and there are 2 ladder-shaped sleepers. The mileage is SDK0+025.000～SDK0+616.690 (591.690m long) and SDK0+820.175～SDK1+070.593 (long 250.418m), the rest are ordinary horizontal sleepers.

2. Test plan

In this test, the test line of the Chentougang parking lot of Guangzhou Metro Line 22 selected 2 sections of trapezoidal sleeper track beds and 2 sections of ordinary transverse sleepers, a total of 4 test sections, and each test section set a total of 3 measuring points. The location of the points is shown in the figure 5. According to the site conditions, the measuring points of the gravel track bed and soil roadbed need to be fixed with steel drills (steel drills with a diameter of 2cm and a length of 1m).
3. Test results and analysis

3.1. Vibration acceleration time history curve

The typical vertical acceleration time-history curves of the rails, the toe of the ballast and the ground at 7.5m from the track centerline under the driving conditions of each test section are shown in figure 2 and figure 3. The left picture shows the trapezoidal sleeper, and the right picture shows the ordinary sleeper.

3.2. Vibration level $VLZ$ and insertion loss

Based on the requirements in Reference [8], the vertical (Z-direction) weighting method (1–80Hz) in Reference [9] 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\(^{[10]}\) 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.

Take the data measured when 3 trains pass through the test section, read the maximum number of each train passing through, analyze and calculate the VLZ value and the vibration difference of the vibration acceleration measurement points of each test section under the two types of track beds. VLZ, see Table 1 and Table 2.

### Table 1. Trapezoidal sleeper section and ordinary transverse sleeper section VLZ and its vibration difference VLZ at 10km/h

| Measuring point location | Track bed form          | Average VLZ (dB) | Average Insert loss VLZ (dB) |
|--------------------------|-------------------------|-----------------|-----------------------------|
| The foot of the ballast  | Ordinary track bed      | 78.44           | /                           |
|                          | Trapezoidal sleepers    | 70.20           | 8.24                        |
| 7.5m from track center line | Ordinary track bed      | 62.35           | /                           |
|                          | Trapezoidal sleepers    | 70.95           | 8.60                        |

### Table 2. Trapezoidal sleeper section and ordinary transverse sleeper section VLZ and its vibration difference VLZ at 35km/h

| Measuring point location | Track bed form          | Average VLZ (dB) | Average Insert loss VLZ (dB) |
|--------------------------|-------------------------|-----------------|-----------------------------|
| The foot of the ballast  | Ordinary track bed      | 79.97           | /                           |
|                          | Trapezoidal sleepers    | 71.44           | 8.53                        |
| 7.5m from track center line | Ordinary track bed      | 73.23           | /                           |
|                          | Trapezoidal sleepers    | 64.30           | 8.93                        |

It can be seen from Table 1 and Table 2 that after the vehicle speed is corrected to the same speed, the Z vibration level of the trapezoidal sleeper section at the foot of the ballast slope is lower than that of the ordinary transverse sleeper section, and the train speed is 10km/h (low speed). The insertion loss VLZ is 8.24dB, and the insertion loss VLZ is 8.53dB under the train speed of 35km/h (high speed).

At the measuring point 7.5m away from the centerline of the track, the Z vibration level of the trapezoidal sleeper section is smaller than that of the ordinary transverse sleeper. The insertion loss VLZ under low-speed conditions is 8.60dB, and the insertion loss VLZ under high-speed conditions is 8.93dB.

### 3.3. 1/3 octave band vibration acceleration level

When the subway train of each section passes, the vertical vibration acceleration at the foot of the ballast slope and 7.5m away from the track centerline is linearly averaged with 1/3 octave frequency spectrum (3 times), according to JGJ/T 170-2009 frequency The frequency division vibration level in the range of 4–200Hz obtained by weighting is shown in figure 4 and figure 5. The left picture is a low speed, the right picture is a high speed comparison chart.
It can be seen from the comparative analysis of the figure 4 that when the train speed is 10km/h (low speed), the trapezoidal sleeper at the foot of the ballast slope has a better vibration reduction effect at 10~200Hz than ordinary transverse sleepers, and the vibration reduction effect is most obvious at 125Hz. It is 22.0dB. When the train speed is 35km/h (high speed), the trapezoidal sleepers at the foot of the ballast slope have a better vibration reduction effect at 10~200Hz than ordinary transverse sleepers. The vibration reduction effect is the most obvious at 125Hz, which is 10.3dB.

From the comparison and analysis of the figure 5, it can be seen that when the train speed is 10km/h (low speed), at a distance of 7.5m from the track centerline, the trapezoidal sleeper has a better vibration reduction effect at 10~160Hz than the ordinary transverse sleeper, and the vibration is reduced at 31.5Hz. The effect is the most obvious, at 14.9dB. When the train speed is 35km/h (high speed), at a distance of 7.5m from the centerline of the track, the trapezoidal sleeper has a better vibration reduction effect at 10~125Hz than ordinary transverse sleepers, and the vibration reduction effect is the most obvious at 40Hz, which is 16.8dB.

![Figure 4. Comparison of 1/3 octave acceleration levels at the foot of the ballast slope](image)

![Figure 5. Comparison of acceleration levels in 1/3 octave band at 7.5m from the track centerline](image)
4. Conclusion

4.1. Vibration level VLZ and insertion loss

After the vehicle speed is corrected to the same speed, at the measurement point at the foot of the ballast, the Z vibration level of the trapezoidal sleeper section is smaller than that of the ordinary transverse sleeper section. The insertion loss VLZ is 8.2dB under the train speed of 10km/h (low speed), and the train speed is The insertion loss VLZ is 8.5dB under 35km/h (high speed) conditions. At the measuring point 7.5m away from the track centerline, the Z vibration level of the trapezoidal sleeper section is smaller than that of the ordinary transverse sleeper. The insertion loss VLZ is 8.6dB under the train speed of 10km/h (low speed), and the train speed is 35km/h (high speed). The insertion loss VLZ under working conditions is 8.9dB.

4.2. 1/3 octave analysis

Through comparative analysis, it can be seen that when the train speed is 10km/h (low speed), the trapezoidal sleeper at the foot of the ballast slope has a better vibration reduction effect at 10~200Hz than ordinary transverse sleepers, and the vibration reduction effect is the most obvious at 125Hz. 22.0dB. When the train speed is 35km/h (high speed), the trapezoidal sleeper at the foot of the ballast slope has a better vibration reduction effect at 10~200Hz than ordinary transverse sleepers. The vibration reduction effect is the most obvious at 125Hz, which is 10.3dB.

Through comparative analysis, it can be seen that when the train speed is 10km/h (low speed), at a distance of 7.5m from the centerline of the track, the trapezoidal sleeper has a better vibration reduction effect at 10~160Hz than ordinary transverse sleepers, and the vibration reduction effect is 31.5Hz. The most obvious is 14.9dB. When the train speed is 35km/h (high speed), at a distance of 7.5m from the centerline of the track, the trapezoidal sleeper has a better vibration reduction effect at 10~125Hz compared with ordinary transverse sleepers, and the vibration reduction effect is the most obvious at 40Hz, which is 16.8dB.

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