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FIELD MEASUREMENT AND ANALYSIS OF VIBRATION REDUCTION EFFECT OF STEEL SPRING FLOATING PLATE AND VIBRATION RESPONSE STUDY ON SURROUNDING BUILDING

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ABSTRACT

In order to realize the vibration reduction effect of steel-spring floating slab to surrounding buildings, by taking the rail transit underground of a city as the research object, three sites, with the ordinary track bed on the line, with the steel-spring floating slab on the line and the curve, were picked out. At the former two sides, a series of field measurements of vibration characters of the rail, the bed and the tunnel wall induced by the train passing by were carried out to explore the vibration reduction effect of steel-spring floating slab on the line. Meanwhile, the vibration response of surrounding buildings around the line were also tested and analyzed. The experimental results showed that: (1) With the steel-spring floating slab on the line and the curve, the vertical vibration acceleration level of the tunnel wall was both lower than that on the line with the ordinary track bed in the frequency range of 20- 200 Hz. Therefore, the steel-spring floating slab on the line had a good vibration isolation performance. (2) At the sites with the steel-spring floating slab on the line and the curve, the acceleration level of the measurement points on the ground were mainly concentrated on the frequency range of 0-160 Hz, with the significant peaks around 40-80 Hz. With the increase of the distance away from the central line of the tunnel, the levels decreased first, then increased and decreased again. Specifically, the increase of the acceleration level appeared mainly at the distance 5.5-10 meters away from the line. (3) At the site on the curve, the acceleration levels of all the measurement points on the ground were higher considerably than that at the site on the line. As a consequence, the vibration reduction effect of the steel-spring floating slab on the curve had a relative bad performance on the response of the surrounding buildings, which might be caused by rail corrugation or track irregularity. This cause would be studied in the further study.

1. Introduction

With the property of large volume, fast speed and safety, the subway has become an effective measure to mitigate urban traffic congestion. However, the subway vibration caused in the running process will do harm to inhabitants and buildings along the line [1,2]. Therefore, controlling the vibration caused by the subway circulation has become urgent. In order to solve problem in urban rail transit construction and the process of operation. The steel spring floating slab track is one of the main vibration reduction measures adopted in urban rail transit in China, and it is very important to analyze its damping effect and the vibration effect of the surrounding buildings [3,4]. This article mainly analyzes the field measurement about the damping effect of steel spring floating slab track and vibration response alone the line on the ground, and the vibration effects and characteristics of the steel spring floating slab track as well as the vibration transmission rules of the surrounding buildings are obtained. The research results provide reference for vibration prediction and control of rail transit.

2. FIELD TEST OVERVIEW

This paper selected a certain rail transit underground line and the ground along the line as well as the observation point of the exterior wall of the sensitive building as the research object, carrying out the vibration response field test.

2.1 Test working conditions

The three sections are selected to compare. The specific features of the sections are shown in table 1 below.

Table 1: Test section characteristics

	Vibration reduction measures	Line type
Section I	Overall track bed with DTIII2 fastener steel spring floating plate	Transition curve
Section II	Overall track bed with DTIII2 fastener and long pillow	Straight line
Section III	Overall track bed with DTIII2 fastener steel spring floating plat	Straight line

2.2 Arrangement of measuring points

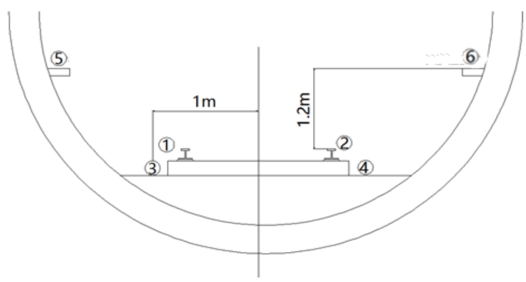


Figure 1 shows the arrangement of underground test measuring points, and the test collects vertical acceleration signal of the rail (measuring point 1-2), the track bed (measuring point 3-4) and tunnel wall (measuring point 5-6) of section I - III.

Figure 1: The diagram of the arrangement of underground test measuring points

Figure 2 shows the arrangement of the ground vibration measurement points, the test collects vertical vibration acceleration signal in the center of the test tunnel (point 1), the top of the upward tunnel boundary (point 2) and the building base within 0.5m of the outer wall of the building (point 3). Because this test does not have the indoor test condition, to predict the vibration transfer characteristics from outdoors to indoors, the test has vertical vibration acceleration signal on the road of neighborhood (point 4 to 6, points 4 and 5 are 4.5 m apart, while the measuring point 6 is 4 m away from point 5). In addition, the vertical distance between the measurement point 4 and external wall of the building is consistent with the measuring point 3.

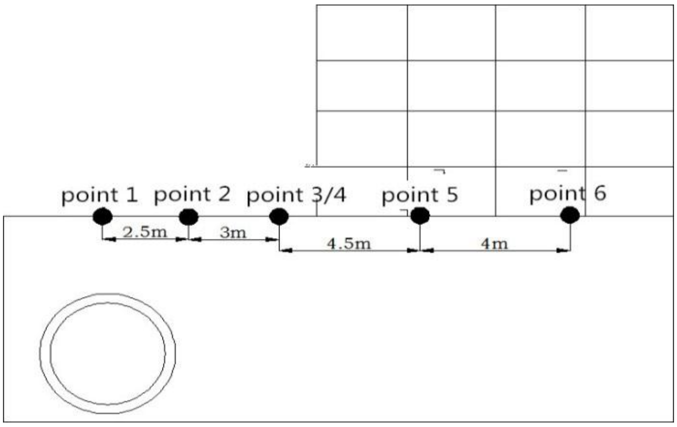


Figure 2: Layout of test points on the ground

3 AN ANALYSIS OF TEST RESULTS

3.1 Analysis of vibration reduction effect of steel spring floating plate

To analyze the vibration reduction effect of steel spring floating plate, the acceleration signal is measured by Fourier transform, and 1/3 octave acceleration of the measuring points is obtained. According to the requirements of *CJJT 191-2012 Floating Slab Track Technology Specification*, the frequency range of the vibration reduction effect is 1-200 Hz, and use Z-weighted vibration level as evaluation.

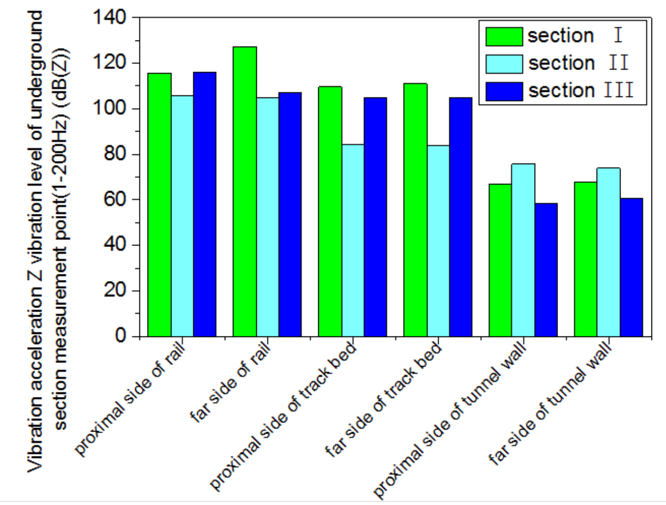


Figure 3: Z-weighted vibration level of measurement points in underground section (1-200 Hz)

Figure 3 and figure 4 give Z-weighted vibration level of each measuring point in the underground section and 1/3 octave characteristic of the tunnel wall respectively. Through the analysis of figure 3, it shows that the rule of the track bed Z-weighted vertical vibration level is the maximum in section I, and then the section II, while section III the smallest. The law of Z-weighted vibration level of tunnel wall is the maximum in section II, then section I, the minimum section is III. The reason is that in the vibration reduction mechanism of steel spring floating slab is vibration isolation [6]. The structure of steel spring floating slab track is using the fasteners to fasten rail on the concrete floating slab, and floating slab on both sides are fixed with elastic material, forming a kind of mass - spring vibration isolation system. Its vibration isolation element causes the less vibration of the upper rail to pass to the structure of the below rail, which is more concentrated in the track bed. Therefore, the vibration of the track bed is larger and passing to the tunnel wall, it becomes smaller.

It can be seen from figure 4 that the low frequency vibration of the steel spring floating slab is not attenuated in the low frequency vibration below 20Hz. The vibration energy of the tunnel wall is mainly distributed in the 40-80 Hz frequency band, and the vibration damping effect of the steel spring floating slab is the best in this frequency band. For steel spring floating slab track line, the straight line and transition curve section of the tunnel-wall vertical vibration acceleration level within 20-200 Hz are less than ordinary monolithic bed. But in centered of 10 Hz frequency band, it is amplified within 5 dB (Z). And the damping effect of straight is better than transition curve .

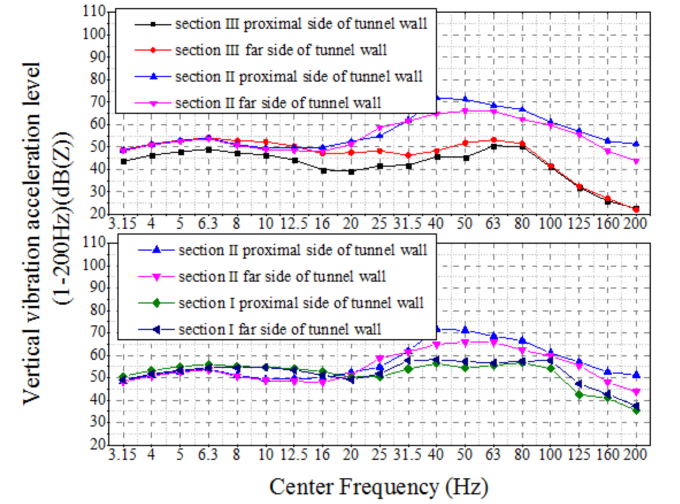


Figure 4: 1/3 octave vibration acceleration level chart of the underground section measuring points

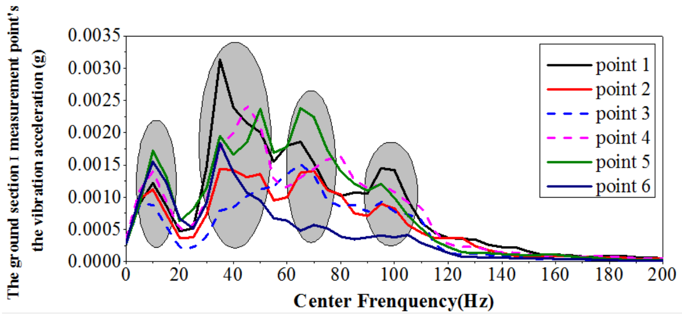
According to appendix 1.4 in the requirements of *CJJT 191-2012 Floating Slab Track Technology Specification*, the evaluation calculated amount of damping effect is the deference value of frequency vibration level root-mean-square ΔLa (namely,damping effect) and the maximum deference value of frequency vibration level $\Delta Lmax$. According to the calculation, the damping effect of the floating slab is shown in table 2. According to the table, the damping effect of the steel spring floating slab is better than that of the ordinary monolithic bed, and its vibration reduction effect of the line segment is better than that of the transition curve.

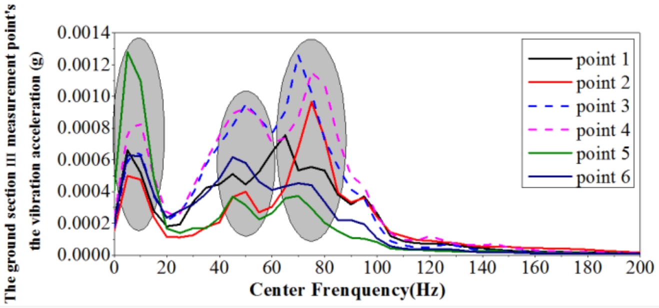
Table 2: Damping effect of steel spring floating slab

the curve segment		The line segment	
proximal side	far side	proximal side	far side
10.08dB(Z)	5.11 dB(Z)	18.19dB(Z)	9.80 dB(Z)

3.2 Study of ground vibration response along the line

In order to obtain the transmission characteristics and frequency characteristics of the vibration, this paper analyzes the vibration acceleration of the ground section through spectral and 1/3 octave characteristic. According to *the CJJT 191-2012 urban rail transit causing buildings vibration and secondary radiation noise limit and measurement standard (CJJ/T 170-2009)*, the vibration of ground along urban rail line from underground is mainly within the 200 Hz frequency band. Here only the vibration of ground measuring point within 0-200 Hz frequency band is analyzed, , as shown in figure 5 and figure 6 respectively.

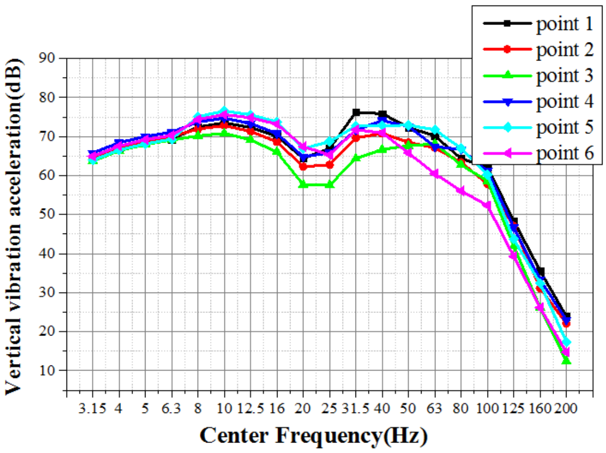




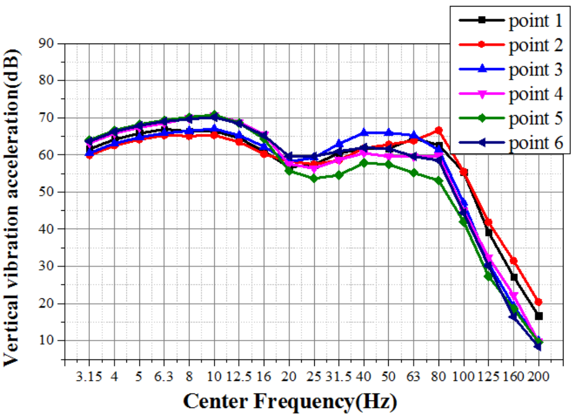
(a) The vibration acceleration spectral diagram of the ground section I measurement points

(b) The vibration acceleration spectral diagram of the ground section III measurement points

Figure 5: The vibration acceleration spectral diagram of ground measurement pointsse



(a)The 1/3 octave vibration acceleration level diagram of ground section I



(b) The 1/3 octave vibration acceleration level diagram of ground section III

Figure 6: The 1/3 octave vibration acceleration level diagram of ground sections

It shows that the vibration of ground section mainly concentrates on frequency band between 0-160 Hz, and it reaches frequency peak basically in 40 -80 Hz. And it can be seen that the vibration frequency characteristic from the tunnel to the ground mainly appears in 40- 80 Hz frequency band. The global peak of the section I is in the 40-50 Hz frequency band, and there are local peaks in the 5-10 Hz, 70Hz and 100Hz. The global peak of the ground section III is in the 70-80 Hz frequency band, and local peaks are also presented in the 5-10 Hz and 50Hz. Thus, it can be seen that compared with the straight-line segment, the steel spring floating slab track in the curve peak period of vibration energy is relatively increased concentrated number, presented multi-peak spectrum curve phenomenon, which increase the dangers of the ground measurement point. The vibration response frequency of ground point is mainly low frequency, and the peak is below 160Hz.

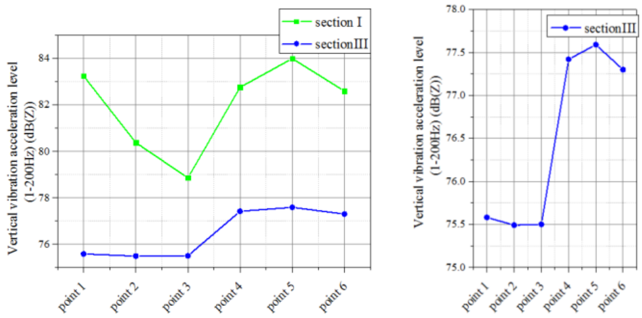


Figure 7: Comparison diagrams of global values of the measured points in the ground sections (1-200 Hz)

In order to analyze the vibration response rules of the measured points on the ground section, the comparison diagram of the Z-weighted vibration acceleration level of the ground section I and III points is shown in figure 7. The analysis shows that the global value of the vertical vibration of the ground displays a tendency to decrease before increasing and then decrease from the point of the center line of the tunnel to one side. The ground vibrations in in the process of rendering firstly decrease and then increase, while reaching the maximum at the measuring point 5, it reduces. The rule is not monotone decrease with distance. Its reason is that when the subway through the tunnel, there is a vibration amplification area of the ground vibration response in a certain distance from the tunnel centerline. A lot of literatures and tests have confirmed the amplification area [5]. It can be seen from figure 6 that the amplification area is located between the measuring point 3 and the measurement point 5, which is located 5.5 m-10m away from the center line of the tunnel. In order to control and reduce the vibration of surrounding buildings caused by subway operation, the sensitive buildings along the subway can be considered to avoid the vibration amplification zone.

By contrast, it can be found in the ground section I , vertical vibration acceleration level of all points are larger than the ground section III, and the biggest difference in point 1, namely the center line of the tunnel, the difference value is 7.67 dB (Z), and difference of point 3 namely 0.5 m away building exterior wall in two differential section is 3.36 dB (Z). The vibration acceleration level of section I measuring point 4 is 5.34 dB (Z) larger compared with section III. Thus, it can be seen that the steel spring floating slab curve segment compared with straight line, leads to a amplification for the vertical vibration response of the buildings along the tunnel centerline. The biggest difference is directly above the tunnel axis.

3.3 Study on vibration transmission rule

To deeply and directly analyze the tunnel vibration transmission rule, the global extreme value and the liner weighing1/3 octave of the rail, track bed, tunnel wall in section I and section III and the all ground measurement points , are shown in figure 8 and figure 9.

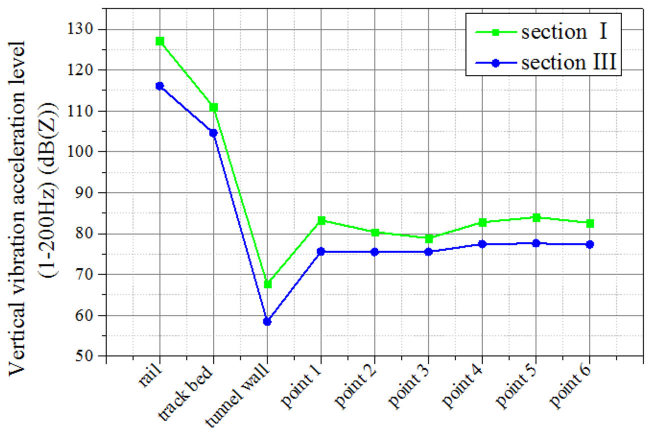


Figure 8: Compassion diagram of measurement points' vibration acceleration level from the underground to the ground(1-200Hz)

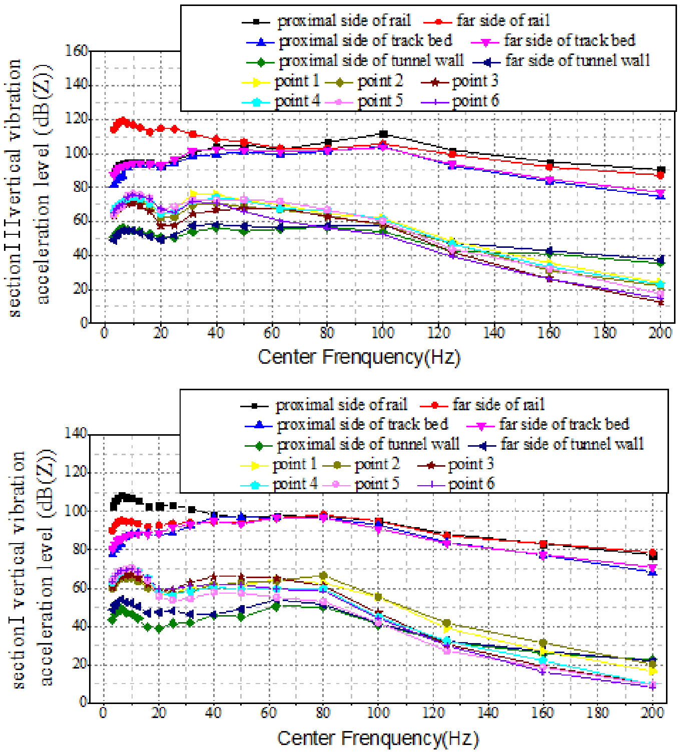


Figure 9: 1/3 octave vibration acceleration level diagrams from the underground to the ground

It can be seen from the figure 8 that the vibration caused by subway operation in the process of passing from the rail to track bed, and then to tunnel wall, then through soil mass to the ground, the vibration attenuation is not big from the rail to the track but in the process of from the track to the tunnel wall, the vibration impact has very obvious attenuation. Within 200Hz, the average attenuation can be up to 40dB acceleration. During the tunnel passing to the ground, the vibration is obviously enhanced, and the average acceleration level enhancement can reach the 15dB. The vibration is attenuated slowly in the transmission of ground from point 1 to point 6. As shown in figure 9, the vibration generated by the subway operation turns the fastest attenuation in the 100-125 Hz frequency band, while transmitted from the tunnel to the ground.

4 CONCLUSION

The following conclusions are obtained by analyzing the underground and ground vibration acceleration signals:

(1) With the steel-spring floating slab on the line and the curve, the vertical vibration acceleration level of the tunnel wall were both lower than that on the line with the ordinary track bed in the frequency range of 20- 200 Hz, and the corresponding vibration response of all the measurement points on the ground met the requirement of the Chinese standard “GB 50868-2013”. Therefore, the steel-spring floating slab on the line had a good vibration isolation performance which can effectively mitigate the vibration effect induced by the passing train underground to the ground buildings around the line.

(2) At the sites with the steel-spring floating slab on the line and the curve, the acceleration level of the measurement points on the ground were mainly concentrated on the frequency range of 0-160 Hz, with the significant peaks around 40-80 Hz. With the increase of the distance away from the central line of the tunnel, the levels decreased first, then increased and decreased again. Specifically, the increase of the acceleration level appeared mainly at the distance 5.5-10 meters away from the line.

(3) At the site on the curve, the acceleration levels of all the measurement points on the ground were higher considerably than that at the site on the line. Moreover, the results on the line were in accordance with the Chinese standard “JGJ/T 17-2009” while the results on the curve were not, which exceeded the upper limit almost 10 dB(Z). As a consequence, the vibration reduction effect of the steel-spring floating slab on the curve had a relative bad performance on the response of the surrounding buildings, which might be caused by rail corrugation, curve superelevation or track irregularity. This cause would be studied in the further study.

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