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Analysis of Influencing Factors on Noise Reduction Effect of High-Speed Railway Sound Barrier

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Analysis of Influencing Factors on Noise Reduction Effect of High-Speed Railway Sound Barrier

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Abstract. As an effective and economical noise reduction measure, sound barrier has been widely recognized and applied in the research field of high-speed railway noise reduction. The equivalent sound source height corresponding to the two different sound barrier forms of subgrade and bridge are analyzed by the empirical formula calculation method, and the influencing factors of noise reduction effect of high-speed railway are analyzed. Some referential conclusions is obtained.

1. Introduction

Since its birth, high-speed railway has been rapidly developed in many countries due to its own advantages [1]. Especially in recent years, train speed has been continuously improved and load capacity has been gradually increased. However, the continuous improvement of train speed has also brought more and more serious noise impact to the surrounding environment, which has attracted general attention [2-4]. Chen Jianguo et al. [5] measured the environmental noise and noise barrier effect caused by high-speed trains running on the Wuhan-Guangzhou passenger line and obtained a large number of noise data. Su Weiqing [6] analyzed and studied the composition of high-speed railway sound source. Setting up noise barriers along the railway is the main method of controlling environmental noise of high-speed railway. The empirical formula method is based on the diffraction attenuation of noise at the top of the sound barrier and has the advantages of fast calculation speed, simple operation and relatively high accuracy [7-8]. At present, the acoustic calculation of railway acoustic barriers usually adopts the mono source model. The acoustic source location is assumed to be a certain height above the rail surface, and the appropriate selection of the acoustic source height directly affects the calculation accuracy [9].

In this paper, according to the different sound barrier forms of subgrade and bridge, by using the empirical formula method, the corresponding sound source height of two different sound barrier forms was analyzed and the influencing factors of noise reduction effect were analyzed.

2. Radiation noise of high-speed train operation

In order to analyze the spectrum characteristics of radiative noise of high-speed railway, the linear sound pressure level (SPL) of radiative noise of a high-speed train passing the subgrade and bridge section at a speed of 350 km/h was selected, as shown in Figure 1.
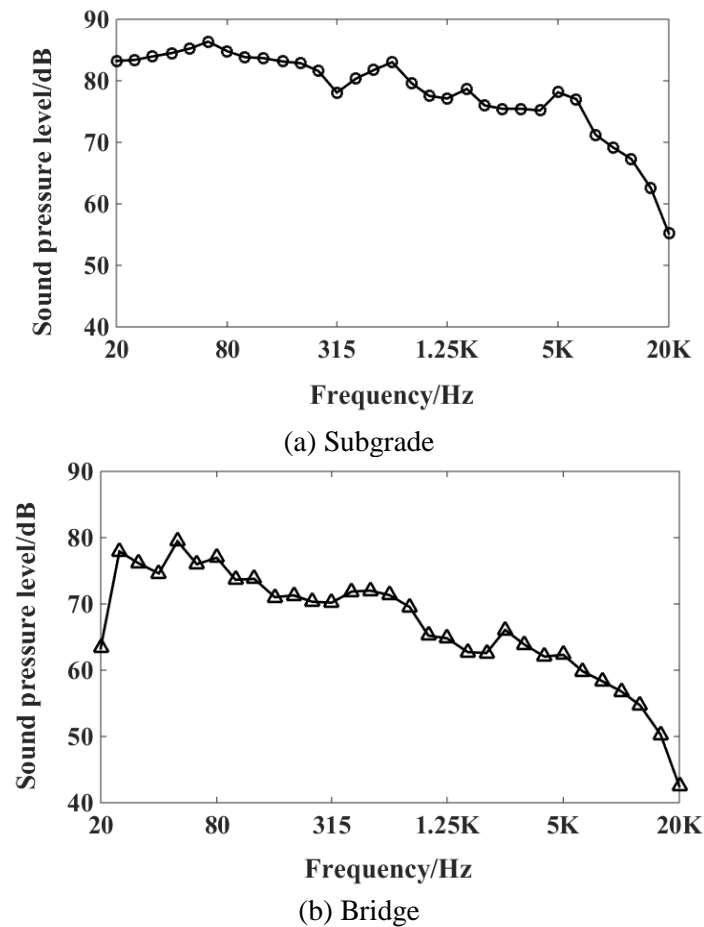
(a) Subgrade

(b) Bridge

Figure 1. Linear spectrum of radiation noise of high-speed train [5]

Figure 1 show that the noise of high-speed train has significant low-frequency characteristics. The significant frequency of linear weight SPL is mainly reflected in the low frequency (f= 40-80 Hz) and middle frequency (f= 500-8000 Hz). On the whole, the SPL of the subgrade section is slightly larger than that of the bridge, especially in the low-middle frequencies.

A-weight SPL is the weight method adopted in noise control standards, which is sensitive to high frequency and not sensitive to low frequency. The A-weight SPL can be corrected by the linear SPL:

$$L_{Ai} = L_{Pi} + \Delta i \tag{1}$$

Where, L_{Pi} is the linear weighting SPL and Δi is the A-weight correction at frequency point f_i [10].

3. Comparative analysis of theoretical calculation and actual measurement of sound barrier insertion loss (IL)

3.1. Calculation method of sound barrier IL

The noise reduction effect of the sound barrier is usually measured according to the size of the IL. When the sound source length is far less than the sound barrier length, the sound barrier can be equivalent to an infinite sound barrier, and the IL of the infinite sound barrier is [8]:

$$\Delta L_{\mathrm{di}} = \begin{cases} 10\lg\left[\dfrac{3\pi\sqrt{1-t^2}}{4\arctan\left(\sqrt{1-t}/\sqrt{1+t}\right)}\right], t = \dfrac{40f_i\delta}{3c} \le 1 \\[4ex] 10\lg\left[\dfrac{3\pi\sqrt{t^2-1}}{2\ln\left(t+\sqrt{t^2-1}\right)}\right], t = \dfrac{40f_i\delta}{3c} > 1 \end{cases} \tag{2}$$

Where, ΔL_{di} is the IL of the sound barrier at the frequency point f_i, f_i is the sound frequency (Hz), c is the sound velocity in the air (c = 340 m/s), and δ is the sound path difference.

At present, the acoustic calculation of railway sound barrier usually adopts a single sound source mode, assuming the sound source position to be a certain height above the rail surface, as shown in point Sin Figure 2.
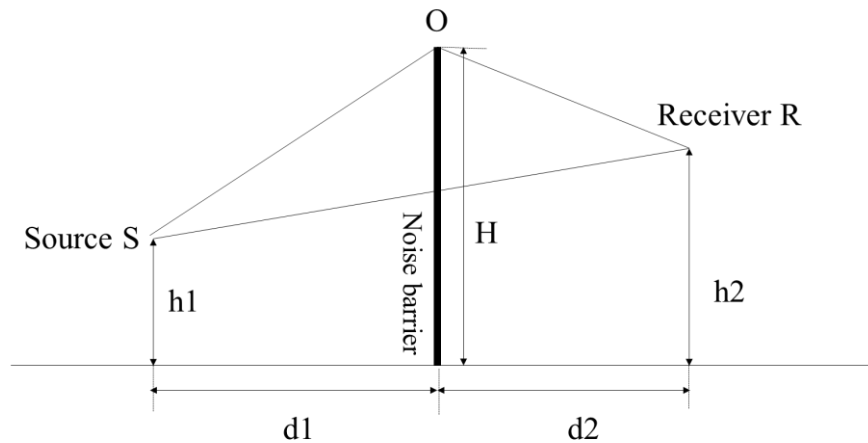

Figure 2. Schematic diagram of sound path difference.

In Figure 2, S is the equivalent sound source point, R is the sound receiving point, O is the highest point of the sound barrier, and the sound path difference is $\delta = SO + OR + SR$, $SO = \sqrt{(H-h_1)^2 + d_1^2}$, $OR = \sqrt{(H-h_2)^2 + d_2^2}$, $SR = \sqrt{(h_2-h_1)^2 + (d_1+d_2)^2}$.

Formula (2) does not consider the form of noise source or spectral composition and proportion when calculating the IL, but only needs to know the relative positional relationship of sound source, sound barrier and receiving point. However, when further calculating the total A-weighted IL value of the whole frequency band, the A-weighted spectrum characteristics of the noise at the measurement point at the silent barrier still need to be considered, and the specific calculation method is as follows:

The SPL of the sound receiving point after the diffraction of the sound barrier:

$$L_{\mathrm{a}} = 10\lg\left[\sum_{i=1}^{n} 10^{(L_{bi} - \Delta L_{di})/10}\right] \tag{3}$$

L_{bi} Is the SPL in the A-weighted band in the absence of a sound barrier at the sound receiving point, which can be obtained by the method described in Section 2.

The difference between the SPLs at the sound receiving points before and after the construction of the sound barrier obtained by the above method is the total A-weighted IL:

$$\Delta L_d = L_b - L_a = 10\lg\left[\sum_{i=1}^{n}10^{L_{bi}/10}\right] - 10\lg\left[\sum_{i=1}^{n}10^{(L_{bi}-\Delta L_{di})/10}\right] \tag{4}$$

It is necessary to consider the relative position of noise source, noise barrier and measuring point in the calculation of noise reduction effect of sound barrier. When calculating the IL of sound barrier of high-speed railway with a single equivalent sound source model by using Equation (2), the equivalent sound source heights obtained by different scholars are quite different, and whether the sound source height is suitable or not directly affects the accuracy of calculation. Taking the high-speed railway sound barrier in document [5] as an example, the noise reduction effect of different equivalent sound source heights (H) is calculated according to equations (2)-(4) and compared with the noise reduction effect measured on site at 350 km / h in order to preliminarily determine a more reasonable H.

3.2. *Verification of measured data*

The measurement points of noise reduction effect of the sound barrier in document [5] are distributed at a distance of 30 m from the outer rail and 1.5 m above the rail surface, and the distance between the subgrade and the bridge sound barrier and the center line of the outer rail is 4.175 m and 3.4 m, respectively, as shown in Figure 3.
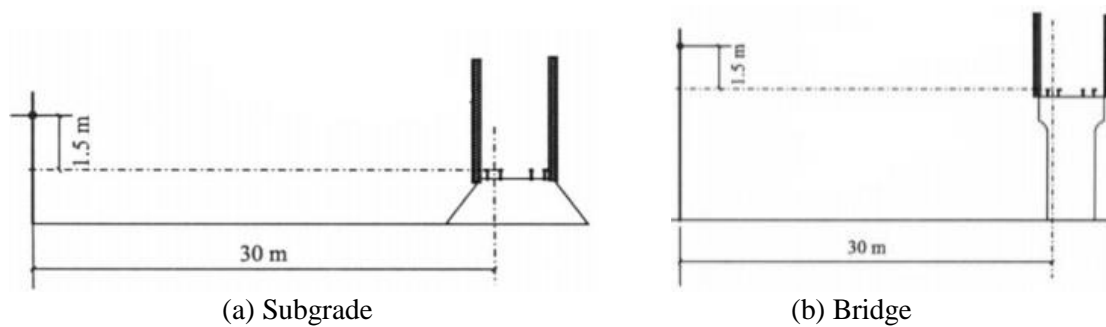

(a) Subgrade   (b) Bridge

Figure 3. Sound barrier noise effect measurement point layout

The height of the sound barrier and the measured total A-weight IL are shown in Table 1.

Table 1. Sound barrier IL measurement point arrangement.

Number	Line type	Speed of train / km / h	Distance / m	Sound barrier height / m	Insertion loss / dB
1	Subgrade	350	30	3	6.5
2	Bridge	350	30	3	6.5

When different equivalent sound source heights are selected, the calculated total A-weight IL of the sound barrier is shown in Table 2.

Table 2. Comparison of prediction and measured results (dB (A)).

Line type	h_1/ m									Measured results
	0.5	1	1.5	2	2.5	3	3.5	3.6	3.7	
Subgrade	15.8	14.8	13.4	11.6	8.0	5.4	6.0	6.7	7.4	6.5
Bridge	15.5	14.4	13.1	11.3	8.3	5.3	6.1	6.8	7.2	6.5

The comparison results in Table 2 show that the optimal equivalent sound source height of the sound barrier in reference [5], subgrade and bridge, is 3.6m. The total A-weight IL of the sound barrier calculated in this paper is slightly different from the measured value, with the difference being 0.2dB

and 0.3dB respectively. According to the above analysis, at the speed of 350 km /h, the noise source is equivalent to a line sound source with a height of 3.6m. The results of the calculation IL are relatively consistent with the measured data, which is close to the 3.5m recommended in literature [6].

4. Analysis of Factors Affecting IL

4.1. Influence of Sound Barrier Height H
The height of the sound barrier is closely related to the sound path difference, which directly affects the size of the IL. Under normal circumstances, the sound barrier should not be designed too high, and the straight arm type sound barrier is usually designed at 2-5m. When other geometric parameters remain unchanged, select the sound barrier with a height of 2, 3, 4 and 5 m, and calculate the A-weight IL of the two structures respectively, as shown in Figure 4.
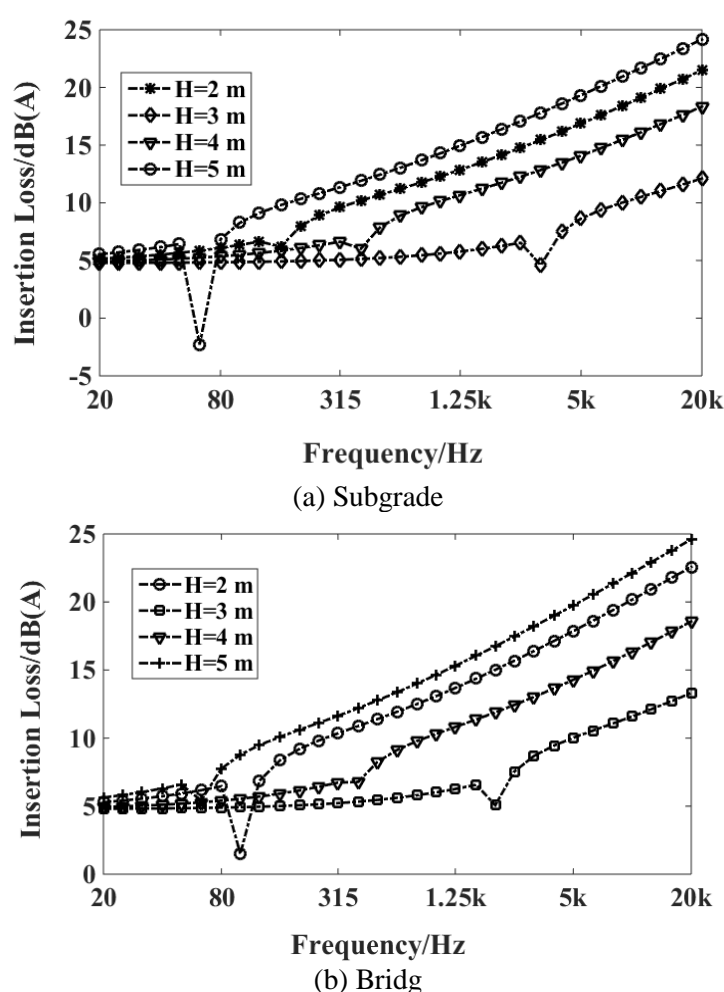

(a) Subgrade

(b) Bridg

Figure 4. IL at different noise barrier heights

The results of Figure 4 show that the IL shows an increasing trend with the increase of the acoustic barrier height (from 3 to 4 to 5), and the increasing trend is especially significant in the middle and high frequency band. However, 2m height is an exception, and its IL value is obviously better than 3 m and 4 m. Therefore, the height value of the sound barrier should be selected reasonably according to the specific environment and noise reduction requirements.

4.2. Influence of sound barrier distance from sound source distance d1
Under the condition that the distance size of other structures remains unchanged, the influence trend of d1 on noise reduction of sound barrier is discussed. Figure 5 shows the A-weighted IL obtained by selecting different values between 2-10 m in d1.
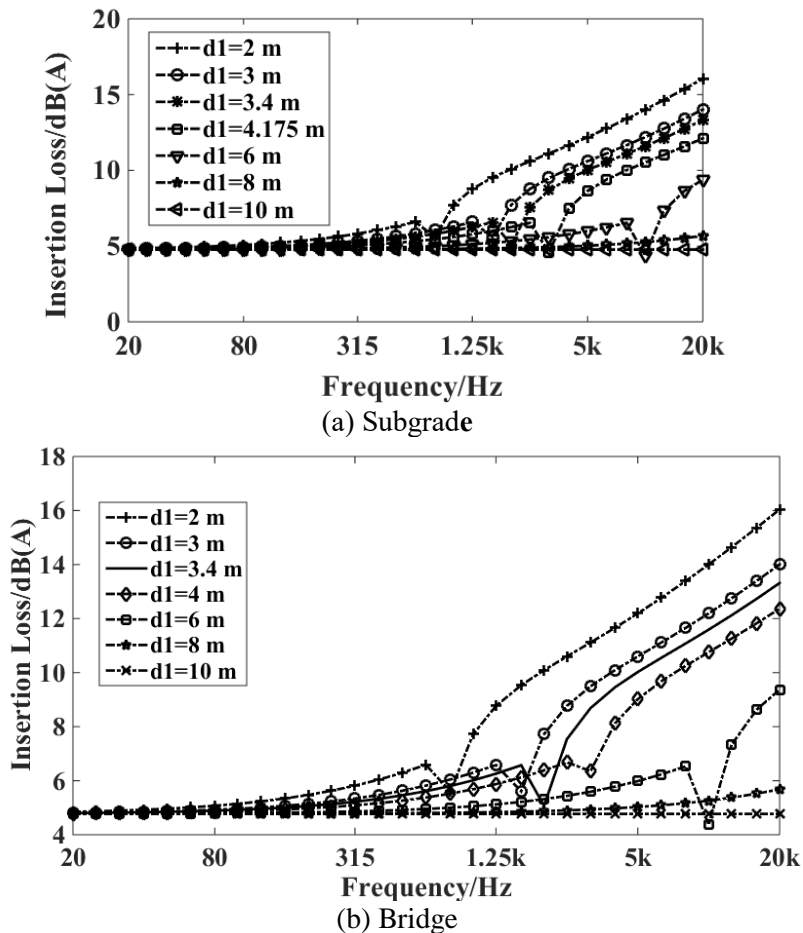

(a) Subgrad**e**

(b) Bridge

Figure 5. IL at different distances from the sound barrier to the source.

The above results show that the IL is inversely proportional to d1. When the closer the sound barrier is to the sound source, the larger the IL value is, and the more obvious the noise reduction effect of the sound barrier is. Therefore, the sound barrier should be designed as close to the source as possible according to the actual situation.

5. Conclusion
(1) The noise source of the high-speed railway at 350 km / h is equivalent to a line sound source at a height of 3.6m, so it has certain reliability and application value to predict the noise reduction effect of the sound barrier.
   (2) The height value of the sound barrier should be reasonably selected according to the specific environment and noise reduction requirements.
   (3) The IL of the high-speed railway sound barrier is inversely proportional to the distance between the sound barrier and the sound source. When the sound barrier is closer to the sound source, the larger the IL value is, the more obvious the noise reduction effect of the sound barrier is.

References

[1]   He, Bin, et al, Investigation into External Noise of a High-Speed Train at Different Speeds, China's High-Speed Rail Technology. Springer, Singapore, 2018, (11): 403-425.

[2]   Su, Miao, et al, A Brief Review of Developments and Challenges for High-speed Rail Bridges in China and Germany. Structural Engineering International. 2018, (8): 1-7.

[3]   WANG Hongxia, SUN Wenjuan, Research Status and Development Trend of Sound Barrier Technology for Reduction of Noise on High-speed Railway, Journal of Changchun University, 2016,26(10):6-10+21.

[4]   F. Poisson, Railway Noise Generated by High-Speed Trains, Noise and Vibration Mitigation for Rail Transportation Systems, 2015, 126: 457-480.

[5]   Chen Jianguo, Xie He, Cai Chaoxun,Yu Xiuwei, Test and analysis of high-speed trains induced environmental noise and sound barriers, Journal of Vibration Engineering, 2011, 24(3): 229-234.

[6]   SU Wei-qing, Study on Noise Impact Evaluation of HighSpeed Railway, Railway Standard Desig, 2011, (5): 100-104.

[7]   Liu Lanhua, Experimental Study on Noise Source Characteristics of High Speed Railway, Railway Engineering, 2018, (11): 403-425.

[8]   Norm on Acoustical Design and Measurement of Noise Barriers: HJ/T 90-2004, BeiJing: China Environmental Science Press, 2004.

[9]   LI Yangliang, Analysis on Application Effects of Noise Barrier of High Speed Railway, Railway Engineering, 2016, (8):164-167.

[10]   Ma Dayou, Modern acoustics theory foundation, BeiJing: Science press, 2004.