IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Current Status and Prospects of Application of Sound Barrier for High-Speed Railway in China

Current Status and Prospects of Application of Sound Barrier for High-Speed Railway in China

Xiangyang Wu [a], Xing Chen, Lanhua Liu, Weishan Lu

China Academy of Railway Sciences, Beijing, China

[a] wuxiangyang@vip.qq.com

Abstract. The sound barrier is the main measure of noise control of high-speed railway in China. This paper analyzes the application status and effect of high-speed railway sound barrier, clarifies the noise reduction effect and main influencing factors of various types of vertical sound barriers used and analyzes the problems existing in the application of vertical sound barrier to high-speed railway in China. The prospects of three aspects of vertical sound barrier optimization, new sound barrier and enhanced noise source control technology are proposed to promote the comprehensive control of high-speed railway noise. Research on high-speed railway noise control technology provides reference.

1. Introduction

By the end of 2018, the total mileage of high-speed railway operations has reached 29,000 kilometers in China, accounting for more than 2/3 of the world's total mileage. The high-speed railway operation noise has a great influence, which has become a key factor restricting its further speed increase and development. China railway authorities have organized a large number of control measures for research institutes, universities and vehicle factories, but since high-speed railway is a multi-source coupling and broadband composite noise source. To control noise sources, first of all, it is necessary to master the dynamic characteristics of the vehicle-line-bridge-aerodynamic coupling system. Although some results have been achieved, the technique is difficult and the progress is time-consuming. It is still unable to meet the requirements of national environmental management and the public. Therefore, at present, China mainly adopts control measures of noise transmission path, which are simplest, economical and fast [1].

The sound barrier is the most widely used control measure for noise transmission for high-speed railway in China. The principle of noise reduction is to block the transmission path from the sound source to the sound receiving point, and it has a good effect in the sound shadow area. At present, the sound barrier has been installed on high-speed railways in China over 4000km [2].

This paper studies the application status of sound barriers in high-speed railways in China, analyzes the noise reduction effects of sound barriers when the different operating speeds of EMUs, different heights and different materials of sound barriers, and refines the main factors affecting the noise reduction effect of sound barriers. The future development of noise control technology for high-speed railway is proposed to lay the foundation for the continuous optimization of high-speed railway noise control measures in China.

2. Current status of sound barrier application in high-speed railways in China

The types of common sound barriers at home and abroad are shown in Table 1. In order to facilitate installation and maintenance, and not to invade the railway gauge, the vertical sound barrier is most frequently used on high-speed railway in China. It consists of noise barrier of 250 km/h high-speed railway and noise barrier of 350 km/h high-speed railway according to the design running speed; sound barrier on subgrade and bridge according to the railroad lines; sound barrier using metal sound-absorbing panels and sound barrier using non-metal sound-absorbing panels according to the material of sound barrier panels; inserted sound barrier and integral prefabricated concrete sound barrier according to the structure type, and the inserted sound barrier accounts for more than 90% of the total number of sound barriers [3].

Table 1. Types of common sound barriers at home and abroad.

Sound barrier type	structure type	description	Characteristics
upright	Inserted	Most common form	Easy to install, single shape, easy to assemble and disassemble
	Integral	Mostly used in typhoon areas	Easy maintenance and large structure weight;
	Masonry	Formed by using block masonry with sound absorption (isolation)	The structure is stable, the noise reduction effect is good; the structure is thick, the self-weight is large, and it is not suitable for the bridge. It can be combined with plants into an ecological barrier.
Angle-shaped	Inserted	Lower erect, top corner	It can improve the effective height of the sound barrier, improve the noise reduction effect, and easily generate additional aerodynamic excitation with the railway auxiliary structures.
arc	Inserted	Mostly used for lots with landscape requirements	It can improve the effective height of the sound barrier and improve the noise reduction effect; the landscape is good, but the curved structure has high requirement for the fabrication and installation of sound absorbing panel.
Semi enclosed	Inserted	Set on one side of the line, semi enclosed structure	The noise reduction effect is good, but the door structure is often used, making it difficult to manufacture and install, and the cost is high.
Fully enclosed	Inserted	Arched around the line	The noise reduction effect is excellent, the noise inside the interior noise is increased, the structure is complicated, the installation and maintenance are difficult, and the cost is high.

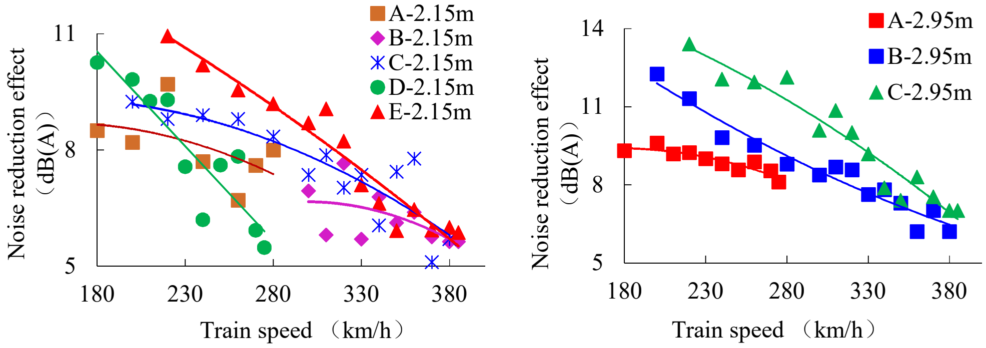
3. Analysis of noise reduction effect of high-speed railway sound barrier in China

3.1. Analysis of noise reduction effect of inserted sound barrier

The inserted type sound barrier is the main type of sound barrier for high-speed railways in China. It is divided into metal sound-absorbing panels and non-metallic sound-absorbing panels according to the type of sound-absorbing panels. Non-metallic sound-absorbing panels are mainly used for railroad lines with design speeds not higher than 250km/h. The sound barrier installed on the bridge is mainly 2.15m high, and the sound barrier disposed on the subgrade is mainly 2.95m high. Based on the analysis of the noise reduction effect of the typical inserted sound barrier, this paper further analyzes the influence of different height and different material sound absorbing panels on the noise reduction effect.

IOP Conf. Series: Earth and Environmental Science **300** (2019) 032051 doi:10.1088/1755-1315/300/3/032051

3.1.1. Analysis of noise reduction effect of typical inserted sound barrier. The noise reduction effect of a typical inserted metal sound barrier with 2.15m high on bridge and a 2.95m high on subgrade is shown in Figure 1.

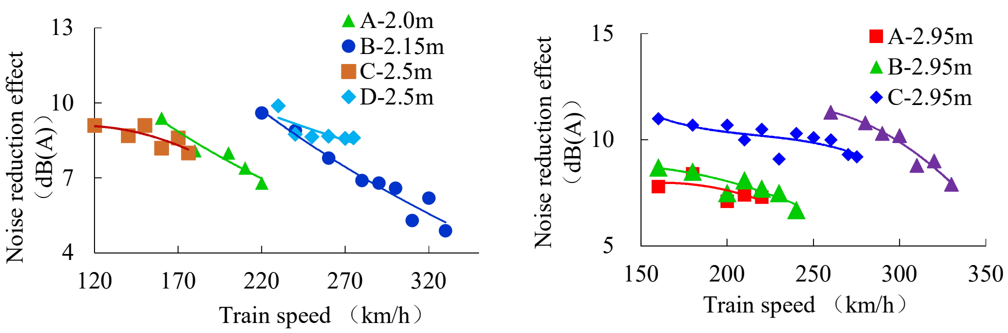


(a) Bridge (b) Subgrade

Figure 1. Noise reduction effect of the inserted metal sound barrier.

It can be seen from the figure that the noise reduction effect of the metal sound barrier on the bridge is about 5-11dB(A), and the noise reduction effect of the metal sound barrier on the subgrade section is about 6-13dB(A). The noise effect on the subgrade is increased by 1-2dB(A) which is compared with the sound barrier on the bridge. As the speed of the train increases, the noise reduction effect of the sound barrier is reduced.

The noise reduction effect of a typical non-metallic sound barrier with 2.0m~2.5m high on bridge and a 2.95m high on subgrade is shown in Figure 2.



(a) Bridge (b) Subgrade

Figure 2. Inserted non-metallic sound barrier noise reduction effect.

It can be seen from the figure that the noise reduction effect of the non-metallic sound barrier on the bridge decreases with the increase of the train speed. When the running speed is lower than 250km/h, the noise reduction effect exceeds 7dB(A), and when the running speed is higher than 250km/h, it is about 5~7dB(A). The noise reduction effect of the non-metallic sound barrier on the subgrade are all above 7dB(A).

IOP Conf. Series: Earth and Environmental Science **300** (2019) 032051 doi:10.1088/1755-1315/300/3/032051

3.1.2. Influence of different heights on the noise reduction effect of sound barriers. In addition to the most commonly used sound barrier of 2.15m high on the bridge, the sound barrier of high-speed railway has two types of sound barriers of 1.93m and 3.15m high. In this paper, the effects of height on the noise reduction effect of the sound barrier are analyzed by comparing the noise reduction effects of sound barriers at different heights on bridge, as shown in Figure 3.

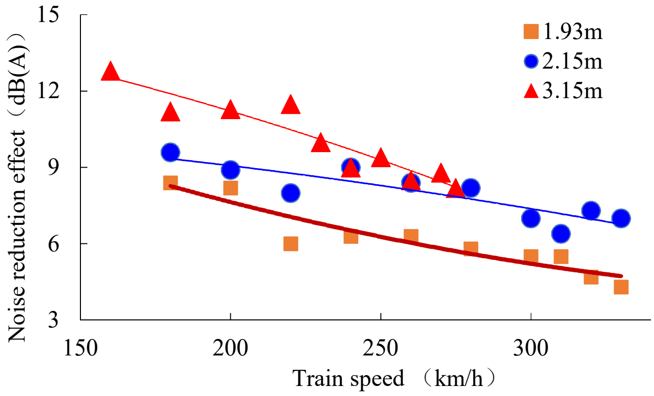


Figure 3. Noise reduction effect of inserted metal sound barriers at different heights on bridge.

Analysis shows that:

(1) At the same train speed, the noise reduction effect is improved by increasing the height of the noise barrier. However, studies have shown that the sound barrier can only significantly improve the additional noise reduction effect when it reaches "a certain height", and the additional noise reduction effect obtained by increasing the height after the height exceeds the "critical point" is not obvious [4].

(2) When the running speed of the EMU is lower than 200km/h, the wheel-rail noise is the main noise source. The higher the sound barrier, the better the noise reduction effect. The noise reduction effect of the 3.15m high sound barrier exceeds 11dB(A), the sound barrier of 2.15m high exceeds 9dB (A). As the train running speed increases, the contribution of the upper pantograph and aerodynamic noise increases, and the noise reduction effect of the sound barrier further decreases. When the running speed is 270km/h, the noise reduction effect of the 3.15m high sound barrier and the 2.15m high sound barrier is about 8dB(A); when the running speed exceeds 270km/h, the noise reduction effect of the sound barrier height in the range of 2.15m to 3.15m is not much different.

3.1.3. Influence of different material of sound absorbing panels on noise reduction of sound barrier. Sound barrier adopts two types of metal sound-absorbing panels and non-metal sound-absorbing panels for high-speed railway in China. In this paper, the noise reduction effect of sound barriers of different materials is adopted by comparing on the subgrade, and the influence of sound-absorbing panels of different materials is analyzed, as shown in Figure 4.

The analysis shows that under the premise of similar vehicle and line conditions, the noise reduction effect of sound barrier with the metal sound absorbing panel is better than that of the non-metallic sound absorbing panel by 1~2dB(A).

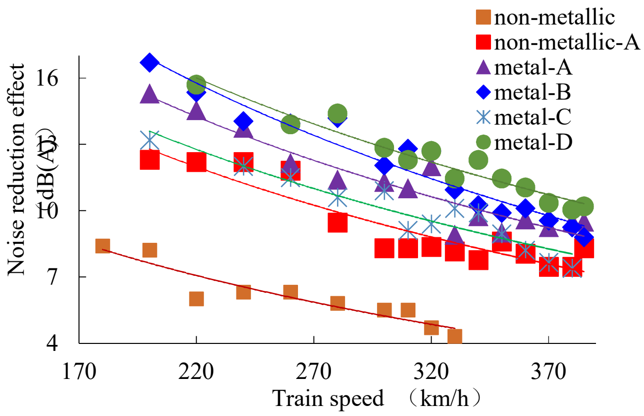
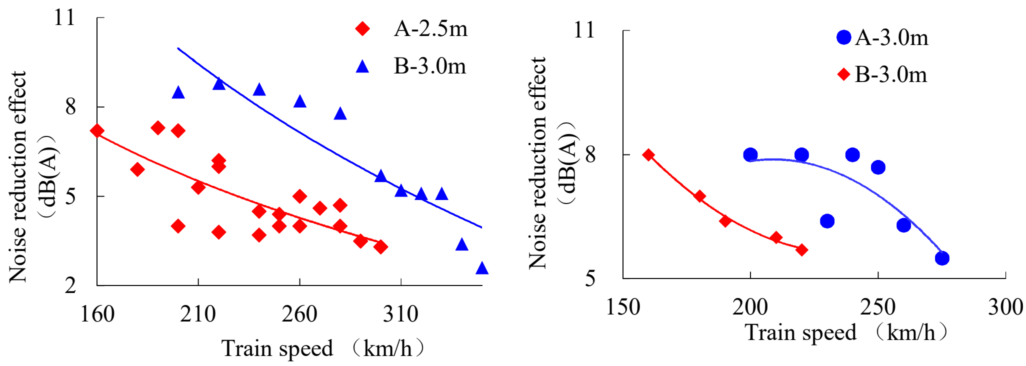


Figure 4. Noise reduction effect of sound barrier with different material sound absorption panels on subgrade.

3.2. Integral sound barrier noise reduction effect

Integral prefabricated concrete sound barrier commonly used for high-speed railways in typhoon areas of China. The integral sound barrier is 2.5m and 3.0m high on bridge, and is 3.0m high on subgrade. The noise effect is shown in Figure 5.



(a) Bridge (b) Subgrade

Figure 5. Noise reduction effect of integral sound barrier of high-speed railway.

It can be seen from the figure that when the running speed of the EMU is 200km/h~280km/h, the noise reduction effect of the 2.5m high integral sound barrier on the bridge is about 4.0-7.0dB(A); when the running speed of the EMU is not higher than 330km/ h, the noise reduction effect of the 3.0m high integral sound barrier on the bridge is greater than 5.0dB(A); when the EMU running speed is not less than 340km/h, the noise reduction effect of the 3.0m high integral sound barrier on the bridge is less than 4dB(A).When the speed of the EMU is lower than 280km/h, the noise reduction effect of the integral sound barrier on the subgrade is 5.5-7.0 dB(A).

3.3. Summary and problems

Through the analysis of the noise reduction effect of the typical sound barrier of high-speed railway in China, the following summary is made:

(1) Because the effective sound absorption area of the sound barrier on the subgrade is large, the noise reduction effect of the sound barrier on the subgrade is 1-2 dB(A) higher than that on the bridge.

(2) As the running speed of the EMU increases, the noise source such as the pantograph noise increases, and the noise reduction effect of the sound barrier decreases.

(3) The effect of noise reduction can be improved by increasing the height of the noise barrier, but it is not linear. Only when the height of the sound barrier is increased to block the sound source, the additional noise reduction effect can be obviously improved. As the height is increased from 2m to 3m, the noise reduction effect of the sound barrier is not obvious because the height cannot effectively shield the noise of the pantograph.

(4) The performance of the metal sound absorbing panel is obviously better than that of the non-metal sound absorbing panel, and the noise reduction effect of the sound barrier is better than that of the non-metallic sound absorbing panel sound barrier 1~2dB(A).

4. Prospect of China's high-speed railway sound barrier

Through the above analysis, it can be clarified that the sound barrier is the main measure for the control of the noise transmission path of high-speed railways in China, but the application form is single, and the vertical type is the main one. The identification of high-speed railway noise sources has shown that when the running speed of the EMU is lower than 200km/h, the wheel-rail noise is dominant; when the running speed is higher than 200km/h, the aerodynamic noise increases rapidly; when the running speed is higher than 300km/h, aerodynamic noise gradually dominates with wheel-rail noise[5].Due to the requirement of railway gauge, the current sound barrier height is limited, and only the noise reduction effect of the wheel-rail area noise is obvious. For the aerodynamic noise with high sound source position and the noise of pantograph, the noise reduction effect is not obvious. Therefore, it is urgent to develop a new generation of high-speed railway noise control technology to achieve comprehensive control of high-speed railway noise, mainly for the following aspects:

(1) Improvement of existing vertical sound barrier.

In order to make up for the lack of noise reduction effect of existing vertical sound barriers, China is currently studying on a new generation of sound barrier technology for high-speed railways, mainly in two aspects: The First is the development of broadband sound-absorbing materials and structure for high-speed railway noise source characteristics to improve the sound absorption performance of the sound barrier; the second is to develop top noise reduction measures of sound barrier to improve the effect of the sound barrier on the upper sound source, mainly to study different bending angles or radians and the top interference device to effectively reduce the upper noise under the condition of ensuring the safety of high-speed railway operation

(2) Study the feasibility of applying a fully enclosed, semi enclosed sound barrier to high-speed railways.

Study the fully enclosed, semi enclosed sound barrier of high-speed railways to completely block the noise propagation between sound sources and receivers. Sound barriers that further reduce noise, such as fully enclosed sound barriers, semi-enclosed sound barriers, etc. Although the types of sound barriers that have been widely used in urban rail transit to reduce noise, there are few applications in high-speed railways. The semi enclosed sound barrier is only applied to the low-speed section of the Shanghai-Hangzhou High-speed Railway [6]. The fully enclosed sound barrier is only used in the low-speed section of the Shenzhen-Maoming Railway in China, and has not been applied to high-speed railways at home and abroad.

(3) Further strengthen the noise source control technology.

Source control is the most effective way to control noise. China has studied a large number of noise source control measures. In the past 10 years, the noise of high-speed EMUs has shown a downward trend. The noise of CRH380 series EMUs is lower than that of the early CRH3 EMUs by 2dB(A). The latest Fuxing EMU noise is about 2dB (A) lower than the CRH380 series, which is the result of years of research on noise source control such as lightweight technology of EMU, bogie low-dynamics design, and aerodynamic shape optimization of key appearance. Therefore, it is necessary to further develop low-noise EMUs on this basis, optimize the shape of key aerodynamic appearances such as pantograph, bogie and vehicle body, change the structure of the surrounding flow field, study the influence of the fully enclosed windshield, and the surface of the vehicle body is not smooth on aerodynamic noise, carry out the smooth design of the air conditioning system and the smooth design of the exterior components and structures such as the door structure to reduce the influence of aerodynamic noise. Study the damper wheel and damping rail of high-speed railway to reduce the dynamic response of the wheel-rail and reduce the influence of wheel-rail noise. Strengthen the research and development of low-noise infrastructure such as track sound absorbing panels and low barriers on the side of track to further reduce the noise level of high-speed railways.

5. Conclusion

This paper analyzes the current application of sound barriers in China, the actual noise reduction effects of different railroad lines, different types and different materials of sound barriers in different speeds of EMUs and the main factors affecting the noise reduction effect of sound barriers, and it clarifies main problems of noise reduction to the sound barrier of high-speed railways in China. On the basis of the above, the development and prospect of noise control technology of high-speed railway in China are put forward from three aspects: optimization and improvement of existing noise barrier, new types of noise barrier and noise source control technology, which can provide reference for subsequent noise control study of high-speed railway.

Acknowledgments

This work was supported by Research and Development Project of China Railway Corporation (Project No. 2016Z001, 2015G009-A), and Research and Development Project of China Academy of Railway Sciences (Project No.2015YJ024).

References

[1] Gu Xiaoan,Guo Huaiyong,Zhou Tiejun,YIN Hao.The Research and Development Survey of Railway Sound Barriers in China. Railway Energy Saving & Environmental Protection & Occupational Safety and Health, 4(2015):143-147.

[2] Yin Hao, Liu Lanhua, Li Yanliang, Gu Xiaoan. The Research Status and Development Trend of China's High-speed Railway Noise Barrier.Railway Energy Saving & Environmental Protection & Occupational Safety and Health.4(2015) 148-151.

[3] Li Yanliang.Analysis on Application Effects of Noise Barrier of High Speed Railway.Railway Engineering.8(2016) 164-167.

[4] Wu Xiaoping,Fei Guanghai,Liao Chenyan.Analysis on Noise Reduction Effect of Sound Barriers with Different Heights for High Speed Railway. China Railway Sciences.5(2015) 127-132.

[5] Wu Xiangyang.A Study on the Prediction Methods of Railway Environmental Noise. Railway Transport and Economy.12(2018) 98-103.

[6] Lei Bin.Design and Research on Acoustics of Semi-sealed Barrier for Shang hai-Hangzhou High-speed Railway. Railway Construction Technology.11(2013) 72-77.