Study on application of comprehensive noise reduction technology in noise sensitive point of Expressway

Linguo Lu1a, Qinggang Chai2b, Guangyong Wang1c

1 Shandong Transportation Institute, Jinan Shandong 250102, China;
2 Xinning Expressway Co., Ltd in Shandong Hi-Speed Group, Taian Shandong 271000, China
a lulinguo@sdjtky.cn, b 402749188@qq.com, c wangguangyong@sdjtky.cn

Abstract—Compared with the traditional single way of setting conventional sound barrier, the noise reduction effect is significantly improved by using the comprehensive noise reduction technology combining low noise pavement technology with new high efficiency sound barrier on the highway. Field test data show that, the OGFC-13 low noise pavement structure has good sound absorption performance, which can effectively reduce the interior noise of the test vehicle by about 3.0dB. After using the comprehensive noise reduction technology shown in this paper, the noise reduction effect of the test section of the project is 9.9dB at 30m away from the noise barrier panel, which is about 4.3dB higher than that of the ordinary section. The monitoring data show that with the increase of the distance, the noise reduction effect of the section treated by the comprehensive noise reduction technology is more efficient.

1. Introduction
With the increasing demands of the masses for a better life, the need to strengthen the disposal of the impact of traffic noise along the expressway is also further increased. According to the existing investigation, the main noise reduction measures are to set up sound barrier to reduce the impact of traffic noise. However, due to the relatively single design and setting of sound barrier, unreasonable installation, lack of targeted design and setting for the uniqueness of sensitive areas and other defects, the noise reduction effect cannot effectively meet the actual needs. In order to solve this problem, research on related technologies such as the active reduction of traffic noise on low-noise road surface and the selection of new high-efficiency sound barrier materials is carried out in this paper to reduce the impact of noise, the comprehensive noise reduction technology is adopted at the noise-sensitive points and the actual noise reduction effect is analyzed and evaluated. Compared with the single noise reduction measure of setting the ordinary sound barrier, the comprehensive noise reduction technology can effectively improve the noise reduction effect by 4-7dB.

2. Principle and material design

2.1 Noise reduction mechanism of low noise asphalt pavement
At present, there are two main and commonly used low-noise asphalt pavement structures[1-2]. One is porous low-noise pavement, which mainly increases the porosity of the pavement to 15%-20%, and the vehicle noise is absorbed by part of the sound energy after passing through the pavement gap, so as to reduce the traffic noise. The other is elastic pavement, which can reduce the vibration of vehicles on
the road, so as to achieve the purpose of reducing traffic noise. In this paper, porous asphalt pavement structure is adopted according to the design indexes of cross and longitudinal slopes at the selected test section.

There are large pores in the porous pavement structure and they are connected with each other. When vehicle noise acoustic wave incident on the material surface, one part is reflected on the material surface, and the other part is transmitted into the material. In the process of transmission, the air in the pores moves and rubs against the inner wall of the pores. Under the action of viscosity and heat conduction effect, the sound energy is converted into heat energy for consumption, so as to achieve the purpose of sound absorption and reduce traffic noise\(^3\).

2.2. Noise reduction mechanism of sound barrier

When the sound wave passes through the sound barrier, it will propagate along three paths, as shown in Fig.1. Some of them diffracts across the top of the sound barrier to reach the sound receiving point, some of them penetrates the sound barrier and reach the sound receiving point, some of them reflect on the wall of the sound barrier. The insertion loss of sound barrier mainly depends on the sound energy distribution along these three paths \(^4\).

![Fig.1 Schematic diagram of sound wave propagation path through sound barrier](image)

It can be seen from Figure 1 that transmission and diffraction energy of sound wave should be reduced as much as possible when selecting the panel material of sound barrier. In engineering practice, the panel material with strong sound insulation performance should be selected to reduce the transmission of sound wave. At the same time, the sound absorption material should be added on the panel surface to absorb part of the sound energy to reduce the diffraction sound energy.

2.3. Design index of upper layer structure of porous low noise pavement

Combined with the engineering practice, the porous and low-noise pavement is mainly used in the upper layer. OGFC-13 upper layer structure is adopted, and the design thickness is 4cm. The coarse and fine aggregates are basalt and high viscosity asphalt adopts SBS modified asphalt to add high viscosity agent, dry method is used to put in while a waterproof bonding layer is set between the upper layer and the lower layer.

The upper layer of OGFC-13 mixture is designed with a nominal maximum particle size of 13.2mm and a porosity target of 18-25%. The grading range is shown in Table 1.

| Mesh size /mm | 26.5 | 19 | 16 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
|---------------|------|----|----|------|-----|------|------|------|-----|-----|------|------|
| upper limit   | 100  | 100| 100| 100  | 80  | 30   | 22   | 18   | 15  | 12  | 8    | 6    |
| lower limit   | 100  | 100| 100| 90   | 60  | 12   | 10   | 6    | 4   | 3   | 3    | 2    |
2.4. Design of new high efficiency sound barrier material

Micro particulate plate is mainly adopted as sound absorption barrier panel structure in the project [5].

The panel structure of micro plate sound absorption and isolation barrier is mainly composed of micro plate sound absorption panel and panel framework as shown in Figure 2. As shown in the figure, micro plate sound absorption panel is fixed on the panel framework, the back plate and framework are designed with 1 mm steel plate. There is a cavity between the sound absorption panel and the back plate, and no other materials are filled in the cavity. The sound absorption panel mainly plays the role of sound absorption and has a certain sound insulation performance, while the back panel mainly plays the role of sound insulation.

![Fig.2 Structure of micro plate sound barrier](image)

Particle sound absorption board is a combination of sand, ceramsite and recycled construction waste particles with binder, which is closely squeezed by particles of different diameters. Skeleton particles are used to form the skeleton of sound absorption board, and then a certain proportion of filling particles are filled to form pores in the panel. At the same time, these pores are in a state of communication, which ensures that the sound wave can be effectively absorbed when it is introduced. The back plate is designed with 1 mm steel plate, which can effectively play the role of sound insulation. When the noise is at a certain frequency, it can play the role of cavity resonance, further reduce the transmitted sound energy and enhance the noise reduction effect of the sound barrier.

The results show that the porosity of this type of sound barrier is about 25%, the weighted sound insulation value of the sound barrier is 39dB, and the sound absorption coefficient is 0.73. According to the highway sound barriers -- Part 4: Technical requirements and test methods for acoustic materials (JTT 646.4-2016), the weighted sound insulation capacity of the non transparent sound barrier acoustic materials shall not be less than 26dB and the noise reduction and absorption coefficient of the acoustic materials with sound absorption performance requirements shall not be less than 0.60, results of this type of sound barrier in the paper are far more than requirements.

3. Project implementation plan

The selected test section of the project is a two-way four-lane expressway with a design speed of 120km/h. According to the natural environment of the environmental sensitive points of the selected test section and combined with the design indexes such as the longitudinal slope of the road, the sound barrier at the test section of the project is set in a single width, with a total length of 880m, including 730m sub grade section and 3.5m design height. The sound barrier is 150 meters along the bridge section with the design height of 2.5m, and the overall height is consistent. The sound barrier is made of micro plate.

The upper layer structure of OGFC-13 in this section is set on the side close to the sound barrier panel, which is the same as the sound barrier, and extends for 200m at both ends of each direction, with a total length of 1280m.
4. Results and analysis

4.1. Test method

(1) Measurement of pavement noise reduction effect

Combined with the construction period of the project, the test is carried out when the road construction is completed and the sound barrier is not installed, mainly through the test of the interior noise of driving vehicles and the comparative analysis of the noise reduction effect. The noise level meter is mainly used to measure the interior noise of the vehicle according to the method specified in the measurement method for interior noise of acoustic vehicles [6] (GB/T18697-2002). The medium-sized off-road vehicle is selected for measurement, and two groups of test speeds are set, which are 90km/h and 110km/h respectively. The constant speed cruise mode is adopted for uniform driving. Considering the limited length of low noise road section, the instantaneous noise value is mainly collected and recorded for comparison.

(2) Noise reduction effect test of sound barrier

The measurement of comprehensive noise reduction effect of sound barrier mainly refers to the indirect measurement method in the specification for acoustic design and measurement of sound barriers [4] (HJ/T90-2004). The reference points are set up to ensure that the terrain, landform, reflection of surrounding buildings, ground and meteorological conditions of the reference points and noise reduction measuring points are equivalent. Considering the relatively small traffic flow in the early stage of operation, the generator is selected to simulate the sound source for measurement.

4.2. Noise reduction effect test and analysis

(1) Road noise reduction effect (interior noise)

The F-time weighted sound level meter is used to measure and record the instantaneous noise inside the vehicle. The data are collected under the condition of vehicle uniform speed of 90km/h and 110km/h respectively, and 40 groups of data are selected for statistical analysis. The measurement results are shown in Fig. 3 and Fig. 4.

It can be seen from Fig. 3 and Fig. 4 that when the vehicle speed is 90km/h, the interior noise value of the test vehicle is 56.2-57.4dB when driving on the OGFC noise reduction road, 59.1-60.2dB when driving on the ordinary SMA road, and the interior noise value of the test vehicle is reduced by 2.7-3.2dB. When the vehicle speed is 110km/h, the interior noise value of the test vehicle is 58.2-59.3dB on the OGFC noise reduction road, 61.5-62.3dB on the ordinary SMA road, and the interior noise value is reduced by 3.1-3.5dB. It can be seen that the OGFC noise reduction road can reduce the traffic noise in the vehicle at different vehicle speeds, with a decrease of about 3.0dB.

Figure.3 Instantaneous noise of the vehicle at speed of 90km/h
(2) Comprehensive noise reduction effect and analysis

The comprehensive noise reduction effect and analysis are conducted on different materials of sound barrier sections by using sound source sounder simulation sound source. The results are shown in Table 2.

Table 2 Comparison of comprehensive noise reduction effect of sound barrier with different materials

| distance (m) | 10 | 15 | 20 | 30 | remarks                        |
|-------------|----|----|----|----|--------------------------------|
| Micro plate sound barrier (dB) | 13.9 | 12.5 | 10.6 | 9.9 | Sound source: 76dB Place on road centerline |
| Color steel plate sound barrier (dB) | 11.0 | 9.7 | 7.9 | 5.6 |                                  |
| Noise reduction difference (dB) | 2.9 | 2.8 | 2.7 | 4.3 |                                  |

It can be seen from Table 2 that in the test section of the project, OGFC low-noise pavement structure is adopted, and particle board sound absorption and isolation barrier with better comprehensive effect is adopted as the sound barrier. The comprehensive noise reduction effect is as high as 9.9dB at 30m behind the sound barrier, while the noise reduction effect is only 5.6dB at 30m of ordinary color steel plate sound barrier and ordinary SMA pavement section. The noise reduction effect of the road section treated by the comprehensive noise reduction technology is about 4.3 dB higher than that of the ordinary road section, and the noise reduction effect has been greatly improved. At the same time, according to the analysis of the data in Table 2, it can be seen that the closer the distance from the noise barrier screen, the noise reduction effect difference between the comprehensive noise reduction technology section and the ordinary section is relatively small. With the increase of the distance, the noise reduction effect of the section treated by the comprehensive noise reduction technology is more efficient, so it has greater significance in practical application.

5. Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

1. Based on the investigation of the noise reduction measures for the environmental sensitive points of current highway. The comprehensive noise reduction technology of low-noise pavement and new high efficiency sound barrier is proposed in this paper to deal with traffic noise, and the field test results are good.

2. The OGFC-13 pavement upper layer structure adopted in the project has greatly improved the sound absorption performance of the pavement. By testing the interior noise, the comparison between OGFC-13 low noise pavement and SMA-13 pavement shows that OGFC noise reduction pavement can reduce the interior traffic noise by about 3.0dB.
(3) After using the comprehensive noise reduction technology adopted in this paper, the noise reduction effect of the test section is 9.9dB at a distance of 30m from the sound barrier screen, which is about 4.3dB higher than that of the ordinary section. The monitoring data show that with the increase of the distance, the noise reduction effect of the section treated by the comprehensive noise reduction technology is more efficient.

Acknowledgments
This work was financially supported by the Science and technology project of Department of transportation Shandong Provincial(2020B24-02).

References
[1] YIN Yong sheng. Research on low noise asphalt pavement [D]. Xi'an: Chang'an University,2005.
[2] CAO Wei dong, ZHOU Hai sheng, et al. Study on noise reduction mechanism and performance of porous elastic pavement [J].SHANGHAI HAGHWAYS, 2004(2) :17-19.
[3] WEI Jian jun, et al. Research on the reduced noise mechanism of low-noise asphalt pavement [J].Journal of Heilongjiang Institute of Technology, 2004(18) :12 -14.
[4] State Environmental Protection Administration. HJ/T 90-2004, Norm on Acoustical Design and Measurement of Noise Barriers [S]. 2004.10.
[5] QIAN Wei xin, SHEN Jia shu. Particle noise barrier and its sound absorbing and isolating panel:China, 201420573459.6[P].2014-09-30.
[6] The People's Republic of China, GBT18697-2002, Acoustics-Measurement of noise inside motor vehicles[S].2002.03.