Key Points of Acoustic Consultation for Highway Noise barrier Design Optimization

Shufang Huang[1,2,3], Zhiqiang Sun[4], Huan Liu[1,2,3], Yanqin Wang[1,2,3], Minmin Yuan[1,2,3]

[1]Research Institute of Highway the Ministry of Transport, P.R.C.
[2]State Envirmental Protection Engineering Center of Traffic Noise Control, P.R.C.
[3]Key Laboratory of Envirmental Protection Technology on Road Traffic Ministry of Transport, P.R.C.
[4]China Airport Construction co. Ltd.

Abstract. Noise barrier treatment is a traffic noise pollution prevention project. Many domestic residents along high-grade highways are densely distributed and there are many sensitive points in the acoustic environment. Traffic noise will have a large environmental impact along the route. The design of the noise barrier from the EIA stage to the construction stage is inconsistent with the actual situation. Therefore, in order to improve and optimize the noise reduction measures along the line and reasonably control the cost of the noise barrier project, many should be optimized. We shoud clarify the noise barrier installation location, scale, acoustic material technical requirements, standards, and engineering cost estimates, focusing on the principle of no reduction in noise reduction, strong operability, and economical practicality, in order to highlight the purpose of reducing costs and increasing efficiency.

1 Introduction

Traffic noise will have a large environmental impact along the route. Noise barrier treatment is a traffic noise pollution prevention project. It is one of the "three major battles" proposed by the state. It usually takes 1 to 3 years or more from the EIA stage to the construction stage. The acoustic environmental protection goals along the line have changed a lot with the construction demolition and rural construction. In order to optimize the noise reduction measures along the line and rationally control the cost of noise barrier projects, many of them should be optimized for design. Including noise barrier installation location, scale, acoustic material technical requirements, standards, and engineering cost estimates should be clearly defined, focusing on the principles of not reducing noise reduction effects, strong operability, and economic and practical principles to highlight the purpose of reducing costs and increasing efficiency.

2 Survey of Acoustic Environment Status

2.1 Acoustic environment status

First, investigating the characteristics of the acoustic environment along the route is necessary, and the length of the route, the administrative area traversed, the distribution characteristics of population density, and the mix of industrial areas. The distribution characteristics of noise sources along the highway, such as aircraft, railway, high-speed rail, Daguang Expressway, Airport Expressway, Guanghe Expressway and Provincial Highway, etc. are densely distributed and complex.

2.2 Monitoring and analysis of current acoustic environment

According to the environmental characteristics of the area, the source of noise pollution, and the current status of the acoustic environmental functional zoning and acoustic environment sensitive points, based on "dominated by points and representative sections, feedback across the line" Environmental noise monitoring points should be in different functional areas. Table 1 shows the monitoring results and standards for a project.

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*Corresponding author's e-mail: sf.huang@163.com

Table 1. Monitoring results and compliance status

Serial number	Station	Monitoring point	Bearing distance （m）	Time	Noise value （dBA）				
					L_{Aeq}	L_{90}	standard value	Judge	Noise source
1	K6+010	Point 1	Right 20	11:50	54.1	48.0	60	Up to standard	Aircraft noise, building construction
2	K15+050	Point 2	Left 25	14:01	52.3	46.0	60	Up to standard	noise, industrial enterprise noise, social life noise
3	K54+840	Point 3	Right 45	16:40	64.1	56.3	60	Exceed 4.1	Road traffic noise, social life noise

2.3 Status analysis and evaluation

We should analyze the excessive standard sensitive points, including the implementation standards, several types of standards, excessive scalars, reasons for exceeding standards, etc. Compliance with the measurement points is also assessed. Summarizing the current status of the acoustic environment is necessary, such as aircraft noise, building construction noise, industrial enterprise noise, and social life noise within the evaluation range along the line.

3 Noise barrier design optimization

3.1 general idea

The "who pollutes and who governs" mentality of "Road construction is later than house".

Based on the implementation principles of noise barriers in the EIA, We should determine the acoustic design requirements of the project in order to reduce the incremental noise impact of the project on the surrounding environment.

Segment screening. For the noise barrier design of the original construction drawing, the building or structure section that is not a noise-sensitive target, cancel the noise barrier setting. For newly added sensitive points which not be included in the noise barrier design, supplementary noise reduction measures are recommended.

Hight Optimization. Due to the large difference in filling and excavation heights of subgrades on a certain high-speed section, high-grade and low-grade subgrades have the same height and length of the same type of noise barriers, which have different noise reduction effects on protection targets of the same relative position. Therefore, acoustic design optimization is necessary.

Length optimization. In order to reduce the lateral diffraction of the sound source to the sensitive target, the length of the noise barrier should be longer than the length of the sensitive target, so that the sensitive target is completely within the sound shadow area of the noise barrier to achieve better noise reduction. Therefore, the actual length of the noise barrier is extended to both ends of the sensitive target based on the length of the sensitive target, and it should be judged and optimized based on the percentage of the shielding angle.

3.2 "Three Simultaneous" design review of noise reduction measures

The environmental protection "three simultaneous" system requires that the environmental protection measures and the main project are "designed, constructed, and put into use simultaneously", and the construction measures are reviewed for "simultaneous design" against the EIA and approval. As shown in Table 2. A text summary is provided after the table. For example, the measures proposed in the EIA are 28 sections. The noise barrier design of 70 sections is designed in the construction drawing design. 60 sections are actually set after the optimization.

Table 2. Comparison of sensitive point measures

Serial number	Protection goal	EIA	Construction drawing design	This report	Description
1	JiuLou	4m high noise barrier +19 noise insulation window	-	-	Out of protection
2	ZhongXinwu	-	4m high noise barrier	3.5m high noise barrier	The height of this report is 0.5m lower than the design of the construction drawing, and the length is consistent.

3.3 Segment screening

We Should determine which sections of the actual project require noise barriers. According to laws and regulations such as the Law of the PRC on Prevention and Technical guidelines for noise impact assessment, noise-sensitive targets refer to buildings that are sensitive to noise, such as hospitals, schools, institutions, research institutes, residences, and nature reserves. Objects or

areas. Screening of buildings or structures that are not noise-sensitive targets such as factory buildings, corporate units, tourist resorts, restaurants, uninhabited abandoned buildings, temples, pump rooms, breeding farms, fruit farms, etc., and eliminate noise barriers. See Table 3 for examples of noise barrier settings after road screening.

Table 3. Setting of noise barrier after road section screening

Serial number	Protection goal	Noise barrier station and location	Floor	Distance from road shoulder（m）	Height difference from road surface（m）	Subgrade type	Noise barrier length（m）
1	ZhongXinwu	K37+803~K38+037left	3	35	15	Subgrade	234
		K38+159~K38+340 left	3	5	8	bridge	181

3.4 Hight Optimization

Acoustic optimization is performed for bridge sections and subgrade sections. In order to reduce the production of shaped materials, save costs and optimize construction, the height of the optimized noise barrier is conservatively unified according to the building modulus. The optimization method is based on the principle of noise barrier noise reduction. As shown in Figure 1, the upright noise barrier is mainly based on the design target value (that is, the required noise reduction effect) to determine the noise reduction measure (noise barrier), and the height and length of noise barrier is calculated based on the degree and range of the noise intensity of its noise source. The range of the shadow area is determined by the amount of noise attenuation, the relative position between the barrier and the sound source receiving point. When the noise sensitive point is in the shadow area (diffraction sound area), the noise is blocked by the direct sound, and the noise barrier has a certain noise reduction effect on the sensitive point. When the noise sensitive point is in the noise direct area, the sensitive point is exposed. And the noise barrier has no noise reduction effect.
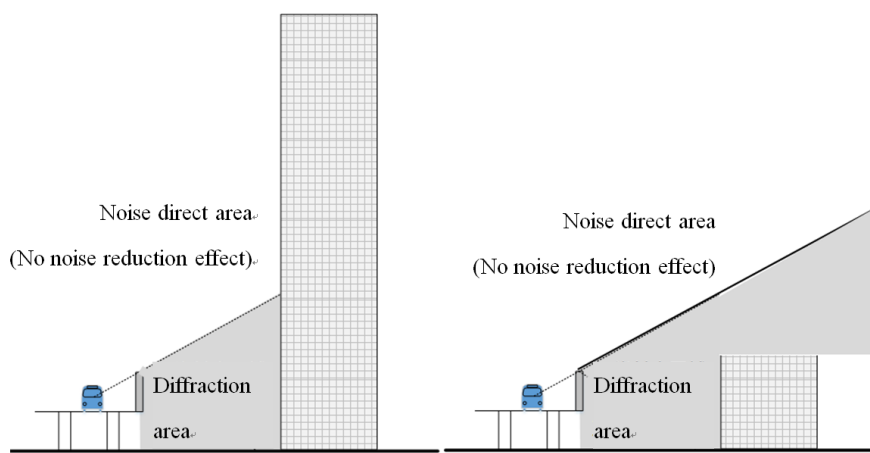

Figure 1. Schematic diagram of noise barrier protection area

The effective height design of the noise barrier is the key to the noise barrier design. According to the noise barrier noise reduction theory: To reduce the noise of sensitive targets, the sensitive target must be in the sound shadow area of the noise barrier, and the size of the sound shadow area is directly related to the height of the noise barrier. relationship. The formula used is as follows:

a) $r_1{}^2=D_N*D_F$
b) $d_1{}^2=(h-h_s)^2+r_1{}^2$
c) $d_2{}^2=(h+h_g)^2+r_2{}^2$
d) $d^2=（r_1+r_2）^2+（h_s+h_g）^2$
e) $\sigma=d_1+d_2-d$
f) $t=40f\delta/3c, \delta=\sigma$
g) *follows:*

$$\Delta L_d = \begin{cases} 10\lg\left[\dfrac{3\pi\sqrt{(1-t^2)}}{4arc\,tg\sqrt{\dfrac{(1-t)}{(1+t)}}}\right], & t=\dfrac{40f\delta}{3c}\le 1 \\[4ex] 10\lg\left[\dfrac{3\pi\sqrt{(t^2-1)}}{2\ln(t+\sqrt{t^2-1})}\right], & t=\dfrac{40f\delta}{3c}>1 \end{cases}$$

h) IL=ΔLd–ΔLt-ΔLr-（ΔLs, ΔLg）max

The schematic diagram of noise barrier effect analysis is shown in Figure 2. This figure is based on an example, the receiving point is 100 m from the road shoulder.
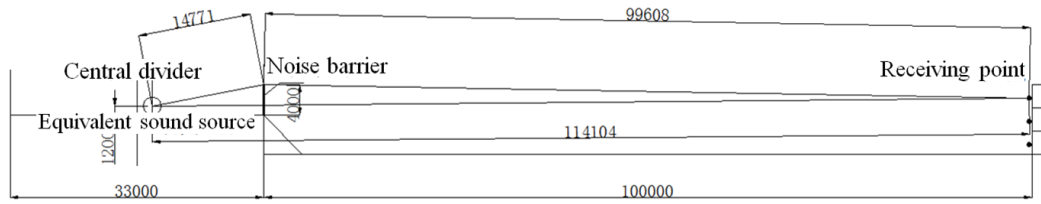
Figure 2. Schematic analysis of noise barrier effects.

The results of the height optimization calculation can be described in a list. Includ the names of sensitive points, the effective width of the roadbed, the floor, the distance from the road shoulder, the average height difference from the road shoulder, equivalent sound source distance, roadbed type, sound path difference, insertion loss, and masking angle Percentage, correction amount, actual noise reduction amount, mid-operation forecast exceeding scalar amount, noise barrier design height. A textual description of the highly optimized summary.

Calculation icon

Figure 3. Design and calculation of noise barrier length

The infinite noise barrier is calculated according to the method in 4.2.1.2 of HJ / T 90. The calculation formula is:

$$A_{bar} = \begin{cases} 10\lg\dfrac{3p\sqrt{1-t^2}}{4\arctan\sqrt{\dfrac{1-t}{1+t}}} & t=\dfrac{40fd}{3c}?\,1 \\[4mm] 10\lg\dfrac{3p\sqrt{t^2-1}}{2\ln\left(t+\sqrt{t^2-1}\right)} & t=\dfrac{40fd}{3c}>1 \end{cases}$$

f——Sound frequency, Hz;

δ——Sound path difference, m;

c——Speed of sound, m/s.

The attenuation of the barrier calculated by a sound wave at a frequency of 500 Hz can be pproximated as the attenuation of the A sound level.

Attenuation of finite-length noise barriers (A'_{bar}) Can be approximated by formula:

$$A'_{bar} \approx -10\lg\left(\frac{\beta}{\theta}10^{-0.1A_{bar}}+1-\frac{\beta}{\theta}\right)$$

3.5 Length optimization

In order to reduce the lateral diffraction of the sound source to the sensitive target, the length of the noise barrier should be longer than the length of the sensitive target, so that the sensitive target is completely in the shadow area of the noise barrier. The design length of the noise barrier should extends to both ends of the sensitive target on the basis of the length of the sensitive target. The extended length of the noise barrier design calculation diagram is shown in Figure 3.
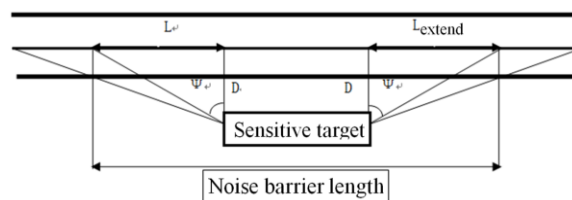
β——The angle between the receiving point and the line at both ends of the noise barrier, （°）;

θ——The included angle between the receiving point and the connecting line at both ends of the line sound source, （°）;

Abar——Attenuation by wireless long noise barrier，dBA.

Masking angle is shown in Figure 4.

Generally speaking, the design of noise barriers with a shielding angle percentage less than 0.6 requires a length optimization.

3.6 Non-acoustic performance design

The design of non-acoustic performance of noise barrier design is equally important. The acoustic characteristic design of the noise barrier itself includes the selection of noise barrier materials, the location of the installation, the scale and shape of the construction, etc .; the non-acoustic characteristics also include safety, the influence of sight, maintenance, fire protection, dust exhaust, etc. A series of issues.
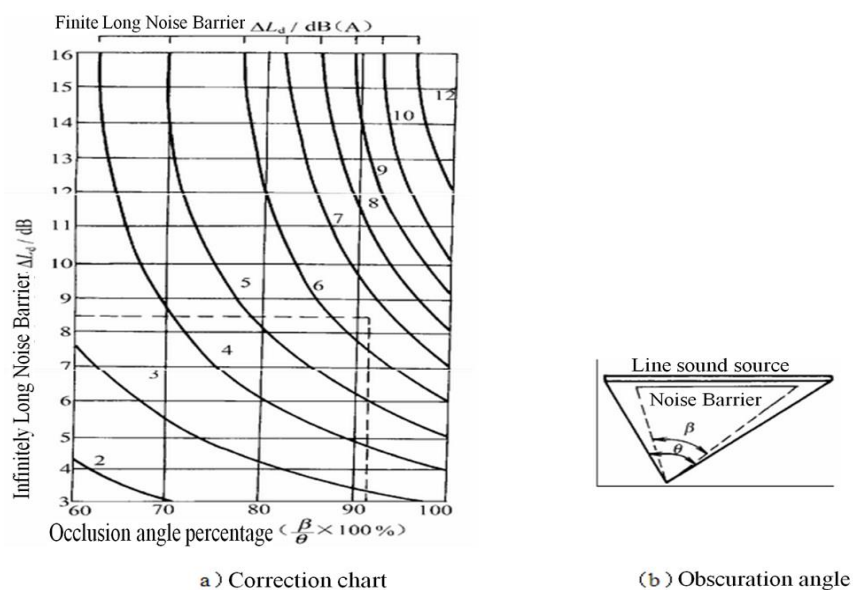
Figure 4. Masking angle

4 The rationality of the optimization plan

4.1 Technical feasibility demonstration

Removal of noise barriers on sections of non-noise sensitive buildings

The noise barrier setting of non-noise sensitive buildings can be canceled.

Demonstration of height change of noise barrier

When the height of the noise barrier changes, it is necessary to perform the calculation of the effects of self-weight load, wind load, earthquake load, etc., and perform technical feasibility demonstration on the construction difficulty, engineering quantity and construction period. The bridge section of the subgrade section shall be demonstrated separately.

4.2 Demonstration of noise reduction

An analysis of "who pollutes, who take measures "

Article 6 of the " Environmental Protection Law of the People's Republic of China" states: A unit that has caused pollution to the environment and other public hazards should formulate a plan and actively manage it in accordance with the principle of whoever pollutes, or report to the competent authority for approval to transfer or relocate. The law mphasizes the responsibility of those who pollute and damage the environment. The implementation of the project's noise barrier will effectively reduce the traffic noise of the project, and the construction unit fulfills its responsibility for pollution control.

Reduction of "Noise Emission Value" Analysis

The noise barrier can effectively block the direct sound, so that the noise emission value at the sensitive point is reduced. There is no noise emission standard for highways in China. As a barrier to the transmission path between the sound source and the receiving point, the noise barrier can reduce the noise emission value of the project's traffic noise at sensitive points by 3.6 ~ 12.5 dBA, which essentially reduces the noise emission value.

When the noise reduction effect and compliance analysis of sensitive points after optimization are performed, and environmental noise is difficult to meet the requirements of the acoustic environment functional area, other noise reduction measures are proposed (fully enclosed noise barriers, sound insulation windows, demolition, etc.)

5 Implementation recommendations

5.1 Noise barrier effectiveness guarantee

Acoustic performance guarantee

In order to ensure the noise reduction benefits and ease of implementation of the noise barrier, the design type adopted by the noise barrier is specified first. We should ensure the construction process is achievable, and reduce the gap between the noise barrier contact parts as much as possible. For example, the sound absorption plate, H-shaped steel, and the surface of the anti-collision pierce must be treated with noise reduction. In order to reduce the intensity of the reverberation noise within the range of the noise barrier facing the roadside, a sound-absorbing screen material is installed on the roadside facade of the noise barrier.

Security protection of noise barrier

Under the action of self-weight load, wind load, earthquake load and snow load, it is guaranteed that the noise barrier will not be structurally damaged. Under the impact of a force of not more than 400kg, the noise barrier will not fall and hurt pedestrians (such as a car scratch, a heavy load by the vehicle, and a bump on the noise barrier), except for vehicles impacting on the viaduct or crossing the viaduct. When the continuous length of a noise barrier exceeds 500m, We must design the escape door or escape channel. Drainage device is

designed so that the rain (snow) water on the road and bridge surface can be discharged into the designated pool or ditch in time. There are also weather-resistant design and maintainability design.

5.2 Noise barrier acceptance

Noise barrier materials shall be inspected and accepted and shall meet the requirements for design. The noise reduction effect of the noise barrier should be monitored by a professional unit recognized by the state. The engineering quality and appearance acceptance of noise barriers shall be implemented in accordance with the relevant requirements of Standard for quality inspection and evaluation of Highway Engineering (JTG F80/1-2017). After the noise barrier is completed, environmental protection facilities will be inspected.

6   Conclusion

We should describe the current situation of the environment, the distribution of current noise sources, and give the comparative changes of noise sensitive points, focuses on the optimization of noise barrier measures, including the number of changed sections, the number of length changes, the percentage change, and investment estimates. Demonstration of the noise reduction effect of noise makes the technical and economic effects and environmental benefits achieve a good unity. Reasonable suggestions for noise barrier construction can also be carried out, such as: minimizing the gaps where the noise barrier contacts, setting up sound-absorbing screen materials on the side facades of noise barrier roads, and installing escape channels.

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