Traffic noise testing and collaborative control of elevated and ground-level composite roads

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Abstract. Urban elevated roads increase noise pollution from high-rise buildings due to the sound source lift effect, posing a serious threat to residents' health. This study takes the Guangzhou Huangsha Avenue – Inner Ring Road Elevated bridge as the empirical object, establishes a three-dimensional noise propagation model, quantifies the intensity of vehicle sound sources, and verifies the reliability of the model through nighttime measured data. The study found that the noise peak on the building facade reached 73.4 dB(A), exceeding the standard limit by 18.4 dB, and the high floor area (7-10 floors) was particularly affected by the elevated bridge sound source. To address this issue, a synergistic solution of "5m high sound barrier (elevated bridge) + porous asphalt pavement (ground road)" was proposed. The simulation results show that the combined measures have reduced the building facade noise to A maximum of 18.8 dB(A), and the noise levels at all monitoring points have dropped below 55 dB(A). The research results provide a reusable technical paradigm for traffic noise control in high-density cities and have significant practical value for promoting the construction of quiet and livable cities.

Keywords: noise, ground road, elevated road, test.

1. Introduction

Urban traffic noise pollution has become a global environmental health threat. Long-term exposure to road traffic noise above 55 dB causes Europe to lose more than 1.6 million healthy life years each year [1]. Elevated roads, in particular, have a distinctive "three-dimensional pollution" feature due to their sound source lifting effect, where noise travels longer distances and has a more significant impact on high-rise buildings. Danish studies have confirmed that for every 10 dB increase in traffic noise, the risk of Alzheimer's disease increases by 16 % [2]. Basner et al. reported further indicates that such noise can cause a 28 % decline in sleep quality and lead to cardiovascular disease and cognitive impairment [3].

In the process of urbanization in China, the elevated road system is developing rapidly. Take the Guangzhou Inner Ring Road Elevated Bridge as an example. There is a large volume of traffic at night, which, when combined with the ground traffic on Huangsha Avenue, forms a composite sound field and has a significant impact on the surrounding residents [4]. This persistent noise exposure creates a sharp contradiction with the goal of building an environment where humans and nature coexist in harmony. The current mainstream noise reduction technology has obvious limitations. Sound barriers are effective for low-rise buildings, but the noise reduction efficiency in high-rise areas decreases due to the diffraction of sound waves [5]; Noise-reducing pavement can only reduce noise at the source by 3 to 5 dB, and it is difficult to independently solve the problem of severe over-limit [6]. Existing studies have mostly focused on the effect of a single measure, lacking a synergistic solution for elevated and ground-level composite transportation systems and high-rise sensitive buildings.

To break through this technical bottleneck, this paper establishes a high-precision noise propagation model, conducts an empirical study on the Guangzhou Huangsha Avenue - Inner Ring

Road Elevated Bridge, verifies the validity of the numerical model based on field test data, and studies the impact of noise reduction measures on surrounding high-rise buildings. The research results will provide a reusable technical paradigm for traffic noise control in high-density cities and promote the realization of the goal of "quiet and livable" cities.

2. Method

2.1. Study area and data collection

In this study, the Huangsha Avenue - Inner Ring Road elevated bridge system in Guangzhou City was selected as the research object. This area is a typical urban elevated - ground composite transportation hub. Huangsha Avenue is a two-way six-lane ground road, and the Inner Ring Road elevated bridge spans over it (two-way six-lane). The vertical projections of the two overlap to form a three-dimensional noise diffusion field (Fig. 1). The basic data were obtained through on-site measurements and traffic management records.

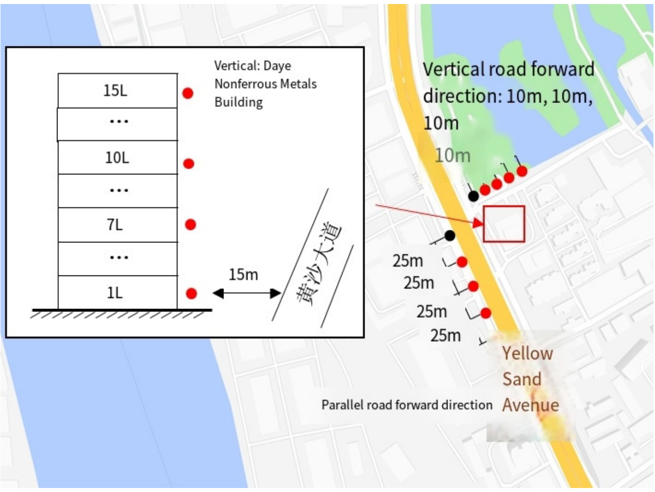

Fig. 1. Schematic diagram of the layout of measurement points on the Huangsha Avenue – Inner Ring Road elevated Bridge

Table 1. Traffic flow on Huangsha Avenue (Unit: veh/20 min)

Time period	Small cars		Medium-sized vehicle		Large car	
	West side	East	West side	East	West side	East
Daytime flat peak	161	255	58	43	1	10
Daytime peak	220	319	25	26	4	3
Night	81	152	28	35	5	8

Table 2. Traffic flow on the Inner loop (Unit: veh/20 min)

Time period	Small cars		Midsize car		Large vehicle	
	West side	East	West side	East	West side	East
Daytime flat peak	1319	756	98	104	1	0
Daytime peak	1439	727	26	15	1	1
Night	818	690	86	74	6	9

The traffic flow was monitored continuously by video counting for three typical time periods (daytime peak, daytime peak, and nighttime), and the east-west two-way flow was classified and counted by small vehicles (≤ 3.5T), medium vehicles (3.5-12 t), and large vehicles (≥ 12 t) (see Tables. 1 and 2). The data showed that the night traffic volume on the elevated Inner Ring Road reached 1,514 vehicles per 20 minutes (95.3 % for small vehicles), and the proportion of large vehicles on Huangsha Avenue at night was significantly higher than that on the elevated road (6.5 % vs 0.8 %), suggesting that heavy vehicles made a significant contribution to ground noise. The elevated bridge is 8.5m above ground, with a longitudinal slope of no more than 4 percent; Ground road longitudinal slope ≤ 2 percent. The weather conditions on the test day were stable, with a temperature of 25±2 °C, humidity of 65±5 percent, and wind speed ≤ 1.5 m/s.

2.2. Construction of noise prediction models

Build a three-dimensional acoustic propagation model based on a professional noise simulation platform. Among them, the sound source model uses the British CRTN calculation specification to determine the vehicle sound power level. The intensity of noise sources for different types of vehicles is calculated according to Eq. (1):

$$L_w = a + \mathrm{blg}(v/v_0) + \Delta L_{pavement}, \tag{1}$$

where the base speed v_0 is 60 km/h, the small car coefficient $a = 28.5$, $b = 30.0$, the large car coefficient $a = 33.2$, $b = 33.7$; $\Delta L_{pavement}$ is the asphalt pavement correction value (–1.5 dB(A)) [7].

By importing the topographic map, precisely construct the calculation domain of length × width × height = 400 m × 300 m × 50 m (Fig. 2). Set the sound reflection coefficient of the building facade at 0.8, the surface sound absorption coefficient at 0.05, and the sound propagation algorithm using the mixed mode of Ray Noise and Virtual Source to calculate the grid resolution of 1.0 m × 1.0 m.

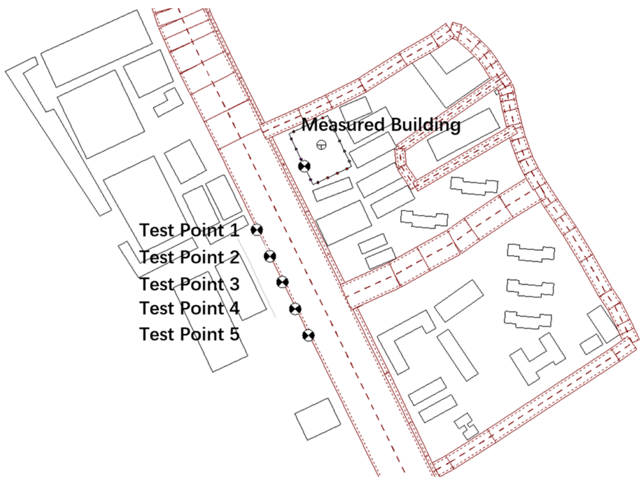

Fig. 2. Floor plan of the noise model of the Huangsha Avenue – Inner Ring Road Elevated Bridge

Five parallel monitoring points are set up along Huangsha Avenue (7.5 meters away from the curb), and 15 vertical monitoring points are set up on the facade of the adjacent Daye Metal Building (with a height of 3 meters, numbered 1L-15L), covering the monitoring height from 4.5 meters to 49.5 m.

The reliability of the model was verified using nighttime measurement data. Among them, A sound level meter (grade 1 accuracy) was used in conjunction with a calibrator, and time weighting "Fast" and frequency weighting "A" were set. Eight characteristic measurement points (5 parallel points +3 elevation points 1L/7L/15L) were selected, and three consecutive nighttime periods (22:00-06:00) were measured. The maximum LAeq at each point was taken as the verification benchmark.

The final three-dimensional model diagram is shown in Fig. 3.

2.3. Model validation

To verify the accuracy of the model, the nighttime noise measured at the measured parallel measurement points and the vertical measurement points of the building were selected for verification. The comparison tables of the noise results are shown in Tables 3 and 4.

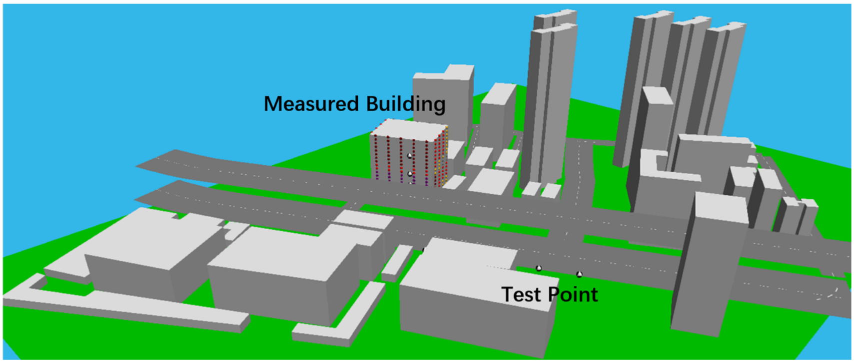

Fig. 3. 3D image of the noise model of the Huangsha Avenue – Inner Ring Road Elevated Bridge

Table 3. Comparison of measured and calculated results of parallel measurement points on the Huangsha Avenue – Inner Ring Road Elevated Bridge (Unit: dB (A))

Measurement points	Time periods	Measured data	Calculation results	Difference
Measuring Point 1	Night	72.0	73.0	1.0
Test Point 2	Night	72.1	73.0	0.9
Test Point 3	Night	72.0	73.0	1.0
Test Point 4	Night	72.5	72.7	0.2
Test Point 5	Night	76.0	72.8	3.2

Table 4. Comparison of measured and calculated results of the vertical measurement points of the Huangsha Avenue – Inner Ring Road Elevated Bridge building (Unit: dB (A))

Measurement points	Time periods	Measured data	Calculation results	Difference
1L	Night	68.1	70.4	2.3
7L	Night	73.4	72.6	0.8
10L	Night	72.8	73.1	0.3
15L	Night	72.4	71.8	0.6

As shown in the table, the calculated results fit well with the measured data as a whole, with a minimum error of 0.2 dB and a maximum error of 3.2 dB, which occurred at parallel measurement point 5.

From the measured results, it is known that the maximum noise value at the parallel measurement point at night is 76 dB(A), exceeding the limit (65 dB(A)) by 11 dB, and the minimum noise value is 72.0 dB(A), exceeding the limit (65 dB(A)) by 7dB; The maximum noise at the building measurement point was 73.4 dB, which exceeded the limit (55 dB(A)) by 18.4 dB, and the minimum noise was 68.1 dB(A), which exceeded the limit (55 dB(A)) by 13.1 dB. The measured noise at night exceeded the limit.

According to the calculation results, the maximum noise value at the parallel measurement point at night was 73.0 dB(A), which exceeded the limit (65 dB(A)) by 8 dB, and the minimum noise value was 72.7 dB(A), which exceeded the limit (65 dB(A)) by 7.7 dB. The noise levels at the measurement points were all above the limit; The maximum noise at the building measurement point at night was 73.1 dB(A), exceeding the limit (55 dB(A)) by 18.1 dB, and the minimum noise was 70.4 dB(A), exceeding the limit (55 dB(A)) by 15.4 dB.

In the case of road noise, the noise planar distribution map is shown in Fig. 4.

2.4. Design of noise reduction measures

The traffic noise on Huangsha Avenue and the elevated bridge of the Inner Ring Road is the main source of noise. Through the prediction of the selection of noise control measures, the results show that the noise in this section exceeds the standard relatively high. Huangsha Avenue may need to adopt both noise reduction pavement and sound barriers as noise reduction measures, and the Inner Ring Road needs to adopt sound barriers. A 5-meter-high sound barrier was used for Huangsha Avenue and the Inner Ring Road elevated bridge, and a porous asphalt pavement was adopted for Huangsha Avenue to increase the porosity of asphalt concrete to absorb noise, and a model was established for noise simulation calculation. The noise results after setting the noise reduction measures are shown in Fig. 5.

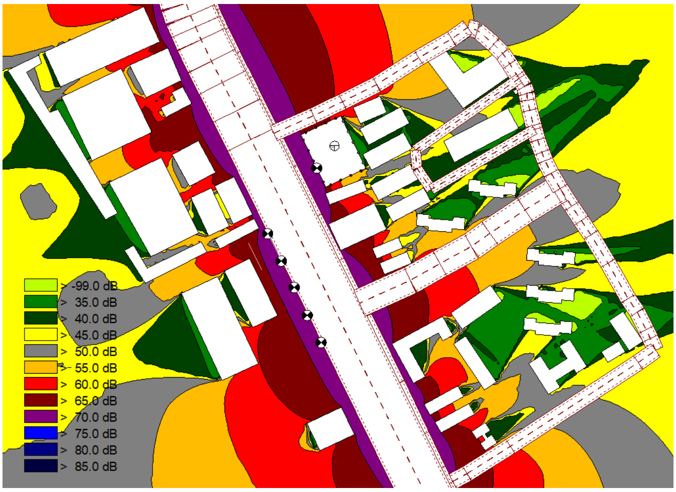

Fig. 4. Map of the noise results of the Huangsha Avenue – Inner Ring Road Elevated Bridge

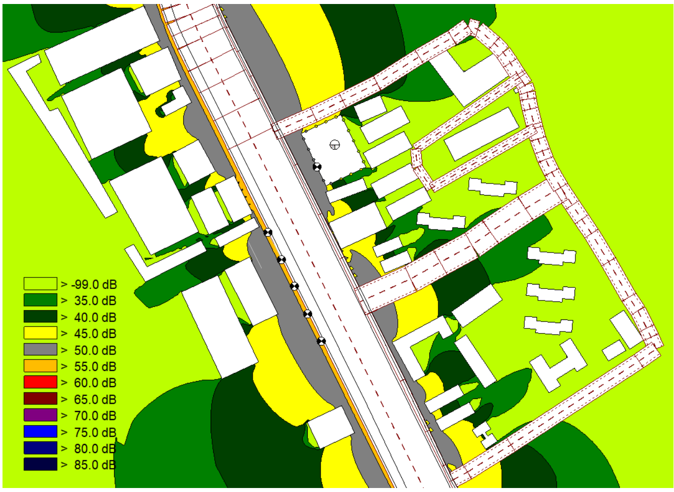

Fig. 5. Map of the night noise results of the Huangsha Avenue – Inner Ring Road Elevated Bridge with noise reduction measures in place

To better compare the noise reduction effect, the predicted values of each floor of Daye Metal Building without noise reduction treatment were compared with those of Daye Metal Building with noise reduction measures, as shown in Table 5.

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Table 5. Predicted building noise of Huangsha Avenue – Inner Ring Road Elevated Bridge after noise reduction measures were set (Unit: dB (A))

Floors	Nighttime peak	Nighttime Excess	Noise reduction
1L	51.8	0	18.6
7L	54.6	0	18
10L	54.3	0	18.8
15L	53.7	0	18.1

The results show that the sound barriers and noise-reducing pavement have a significant effect. The maximum noise reduction at each measurement point and building floor can reach 18.8 dB, and the impact on buildings is particularly significant. This indicates that noise reduction measures for elevated Bridges can greatly improve the noise impact on high-rise buildings.

3. Conclusions

This study systematically elucidates the noise impact mechanism of elevated and ground composite transportation systems on high-rise buildings through high-precision noise propagation models and empirical data analysis. The conclusions are as follows:

1) The sound source lifting effect of the elevated bridge caused noise to form a distribution pattern of "high in the middle and low at both ends" on the building facade. The noise peak in the 7-10 floor area exceeded the standard by 18.1 dB at night, making it a major pollution area.

2) The proposed "sound barrier – noise reduction pavement" synergistic governance scheme breaks through the limitations of traditional technologies. The sound barrier effectively blocks the vertical transmission of noise from the elevated bridge, and the porous asphalt pavement reduces the intensity of ground traffic sources by 3-5 dB. Together, they achieve a maximum noise reduction of 18.8 dB on the building facade. After the treatment, 100 % of the monitoring points in the entire area met the standards.

3) It is recommended to increase the height of the sound barrier to 5 meters when promoting in buildings over 30 meters along the street to optimize the control effect of the sound diffraction zone.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest

The authors declare that they have no conflict of interest.

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