# The Pollution Control of Urban Elevated Railway Traffic Noise

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**Summary**
The direct noise and the radiation structure noise of the urban elevated railway bring bad impacts to the residents along .Taking the 14th railway transit of Guangzhou as case，the paper analyses characteristics of railway traffic noise source， emission characteristics， common measures of pollution control and the disadvantage, and advances suggestions.

**Key words** urban elevated railway transit；noise；pollution control

## 1. Introduction

At present, China is facing many problems in urban traffic such as serious shortage of road capacity, resource consumption and severe traffic pollution. Urban rail transit (URT) is characterized by large capacity, fast speed, safety and high reliability, punctuality and comfort, and surpasses in promoting development of relevant industrial chain, speeding up urban region integration, mitigating energy shortage and urban air pollution, improving traffic efficiency and safety, etc.【1】
According to the statistics of China Association of Metros, by the end of 2013, there had been 87 URT lines constructed and put into operation in 19 cities around China, with total operation length of 2539 km. According to Plan for Comprehensive Traffic System over the 12th Five-Year Plan, by the end of 2015, the constructed length of URT in China will reach 3000 km.。
In Guangzhou City, six URT lines of 211 km have been constructed and put into operation, namely, Line 1, Line 2, Line 3, Line 4, Line 5 and Line 8. Besides, there are 3 lines under construction, i.e. northern extension line of Line 3, Line 6 and extension lines of Line 2 and Line 8. According to *Construction Plan for Guangzhou Mass Transit in 2015*, the total length of URT lines after completion in Guangzhou will reach 630.4 km. Compared with underground line, the elevated line surpasses in construction cost, construction duration and operation maintenance. However, the latter has been more and more restricted for its vibration and noise pollution due to its exposure to the environment. For Line 4 of Guangzhou, for example, as the only elevated line in operation where the elevated section of 48.26 km accounts for 69.3% of the total length, all the affected domiciles within 10 m from the center line of track have been relocated against vibration and noise. With the complete implementation of *Construction Plan for Guangzhou Mass Transit in 2015*, the elevated lines will account for 30% of the total length, of which the planned Line 14 (including branches) will have elevated line of 70.7 km, accounting for 97.1% of the total length. Therefore, if vibration and noise problems brought by such elevated lines are not solved, the development and use of land space along the lines will be probably restricted, hence further compromising the application and promotion of elevated lines.

### 1.1 Noise Source of Elevated Lines

The radiated noise of urban elevated rail transit includes wheel/rail noise, noise from vehicle equipment, noise from vehicle body during operation, and noise from viaduct structure.[2]

(1) Wheel/rail noise

Wheel/rail noise exists in 3 forms: first, squeal arisen from cutting and friction when the vehicle travels on a curve or wheel/rail hard bending; second, clash due to rail joint; third, "rumble" due to uneven contact between wheel and rail.

(2) Noise from vehicle equipment

Noise from vehicle equipment includes noise of traction motor, noise of gear box, noise of air compressor, noise of air conditioning and refrigeration equipment, brake noise, vehicle traction noise, electrical noise, noise of pantograph, aerodynamic noise during vehicle operation, whistling noise and those from untight doors or windows. Among them, traction motor, gear box and air compressor are main noise sources.

(3) Noise from vehicle body during operation

The noise radiated from vehicle body due to vibration and secondary radiated traction noise through vehicle body are of intermediate and low frequency characteristics. Air acts on the surface of vehicle body where gas viscosity causes negative pressure change, which produces surface vibration, and generates vortex flow and friction and impact, hence the formation of high-frequency pneumatic noise.

(4) Noise from viaduct structure

Structural noise is generated when a vehicle traveling on the viaduct structure transfers vibration to rail and base structure through wheel-rail contact, resulting in deck vibration hence secondary low-frequency noise.

## 2. Characteristics of Noise from Elevated Lines

According to the survey, the urban rail transit in China generally operates at 60~80 km/h, and wheel/rail noise contributes most to the total sound pressure level with frequency band to which human ears are most sensitive. The sound energy of wheel-rail noise mostly lies in broadband over 250 Hz and usually its peak exits between 500~1250 Hz. When the vehicle travels at the speed less than 80 km/h, the structural noise will become the main source of noise. The structural sound energy lies in the broadband below 250 Hz with the peak sound pressure existing between 40~125 Hz.[3]

### 2.1 Structural noise

2~10dB Noise of viaduct structure has greater effect for its low frequency, slow noise attenuation, high elevation of sound source, farther transmission distance and broader influence area, especially when the viaduct goes through densely populated areas. According to statistics, when the vehicle travels on a viaduct, the noise will increase by 2~10 dB.[5] It is reported that the viaduct structure of light rail in London Docklands has caused severe radiation of low-frequency noise, especially at 63 Hz octave band, which causes noise nuisance to residents along the line.

### 2.2 Wheel/rail noise

Ballastless track structure is commonly used for elevated lines at present. On monolithic ballastless track, the steel rail is directly fastened to the track connected to the viaduct, and since in this case the attenuation rate of vibration along steel rail is smaller than that in the case of ballast track, the vibration of steel rail is 5~10 dB higher, thus the radiated noise of steel rail is also greater. Meanwhile, since some special rail fasteners are used for elevated lines, rail corrugation and other serious irregularity defects may arise, resulting in much noise radiated along steel rail of elevated lines than that along steel rail of ground lines.

## 3. Law of Noise Transmission

For traffic noise, within the range of certain distance from the vehicle, the vehicle can be regarded as a line source.

$$L_p = L_{p0} - 10\lg(r/r_0) - \Delta L \quad (1)$$

Where, $L_p$—sound level produced by the line source and measured at the prediction point (octave band sound pressure level or A-weighted sound pressure level);

$L_{p0}$—sound level at the reference position $r_0$ of line source;

r—vertical distance between prediction point and line source;

$r_0$—vertical distance between where the reference sound pressure is measured and the line source;

$\Delta L$—various attenuations, including those caused by air absorption, sound barrier or obstruction, and ground effect.

## 4. Vibration-noise Control Technology for Elevated Rail Transit

From the analysis on noise sources, we know that the noise of elevated rail transit is closely relevant to vibration.

The vibration damping measures for track structure mainly include elastic fasteners, low vibration track, floating ladder track and floating slab track. The noise reduction measures for vehicle mainly include resilient wheel, noise-reduction wheel, composition brake shoe, regular grinding of wheel tread, timely and adequate application of lubricant to wheel/rail contact part, installation of lateral elastic coupling device between front and rear bogies, sound proof apron and so on. The noise reduction measures for track mainly include low vibration track, apposite grinding of rail surface, using seamless heavy-duty rail, reasonable setting of support stiffness of rail, application of oil to rail surface, setting of sound barrier, etc.

## 5. Examples of Noise Reduction Practice of First Construction Stage of Guangzhou Mass Transit Line 14 (Including Branches)

### 5.1 Project overview

(1) Profile

The first construction stage (Jiahewanggang ~ Jiekou) of Line 14 of Guangzhou mass transit is 54.1 km in length with 13 stations, of which underground line is 15.6 km, and ground line 38.5 km. Knowledge City Branch, with 7 stations and full length of 21.8 km including underground line of 19.6 km and ground line of 2.2 km, starts from Xinhe Station of Baiyun District, and ends in Zhenglong Station of Luogang District, covering SINO-SINGAPORE GUANGZHOU KNOWLEDGE CITY and Zhenglong Town. The project is designed with one depot and two stabling yards and the total investment amounts to CNY 33.621 billion, of which investment for environmental protection accounts for 1.34%.

(2) Prediction of passenger volume

At the initial stage (2019): passenger flow of 249 thousand person-time/day; in the near term (2019): 582 thousand person-time/day; in the long term: 842 person-time/day.

(3) Vehicle type selection and train formation

B-type vehicle is adopted; 6-car formation is adopted for initial stage, near term and long term; Max. speed of 120 km/h, with average operation speed ≥ 35 km/h.

(4) Main technical parameters

| | |
|---|---|
| Number of Main Lines | Double-line |
| Minimum radius of vertical curve | Section and station line: 8000 m /4000 m; assistant line: 2000 m |
| Minimum radius of plane curve | Main line: normal: 800 m; poor case: 550 m; special case: 300 m<br>Assistant line: normal: 250 m; poor case: 150 m |
| Maximum gradient | Main line: normal: 30‰; poor case: 35‰; assistant line: 40‰; station: 2‰ |

(5) Track

| | |
|---|---|
| Gauge of track | 1435 mm |
| Steel rail | 60kg/m steel rail for main line, entrance/exit depot line and testing line, 50kg/m steel rail for other lines. |
| Fastener | Separated elastic fasteners. |
| Switch | 60kg/m No. 12 or 60kg/m No. 9 curved point rail switch for main line and assistant line, No. 7 switch for other lines. |
| Track bed | Reinforced concrete monolithic track-bed for main line and assistant line. Concrete sleeper ballast bed for other ground lines like entrance/exit depot line, testing line, and lines outside stabling yard and depot. |

(6) Operation organization

The operation mode of express/slow train combination is adopted. The operation time is from 6: 00 to 24: 00, i.e. 18 hours/day. At the initial stage: 170 pairs per day; in the near term: 216 pairs per day; in the long term: 368 pairs per day.

(7) Power supply

DC1500V overhead contact system is adopted for traction power supply.

(8)Structure of viaduct: simply supported box girder.

### 5.2 Overview of vibration, acoustic environmental sensitive target

There are 130 acoustic environmental sensitive targets and 145 vibration sensitive targets within the range of the project, including 107 and 74 respectively along the elevated section. The main sensitive targets are kindergartens, schools, hospitals, nursing homes, institutions, residence and cultural relics protection sites.

### 5.3 Vibration-noise control measures for elevated lines

#### 5.3.1 Prediction

In case no measure is taken, the vibration values at all the environmental sensitive targets along the elevated line would meet the requirements; in the near term the traffic noise values at 74 acoustic sensitive targets would exceed the standard, and the environmental noise at 90 sensitive targets would exceed the standard. In the elevated section, the track is 10～15 m above the ground, which causes broader range of acoustic environmental influence over the entire elevated section.

#### 5.3.2 Proposed noise reduction measures

Relocating those targets within the range of 15 m away from the center line of track; setting sound barriers for large-scale, centralized sensitive targets near the line; setting semi-closed sound barriers for 10 sensitive areas within the range of 20 m away from the elevated line. The elevated line is designed with provisions for future installation of sound barriers.

## 6. Problems of Noise Control Measures for Elevated Lines in China

### 6.1 Lack of deeply theoretical research and understanding of laws

Currently, the theoretical researches mainly focus on medium and high-frequency vibration noise from such sources as wheel/rail noise and vehicle-related noise, but seldom probe into low-frequency noise from viaduct structure. There is still lack of comparison among common box girder, channel girder and T-shaped girder of viaduct, and the researches on increased wheel/rail vibration noise caused by high-elastic fasteners and rail corrugation are just in their initial steps. At the same time, the noise evaluation indicator of equivalent continuous A-weighted sound pressure level also weakens the low-frequency noise greatly, thus it’s impossible to correctly reflect the noise level of elevated rail transit. [4]

### 6.2 Lack of diversified vibration-noise control measures

Hong Kong West Rail Line is a good practice of vibration-noise control for elevated rail transit. The project fully considers viaduct structure, vibration damping measures, integrated acoustic absorption and insulation measures, adopts low-impedance simply supported double-box girder, vibration insulation track integrating high-elastic Cologne-Egg and supported short rubber floating slab, a variety of sound barriers (inter-track sound barriers, sound barriers along viaduct and high-elevation sound barriers for special road section and fully enclosed sound barriers), and multi-chamber sound absorber structure, thus minimizing the wheel/rail noise and radiated noise of low-vibration track structure. By means of the above measures, the requirement that the equivalent continuous A-weighted sound pressure level $L_{eq30}$ shall be below 55 dBA at the points 25 m away from the West Rail Line has been met.

In contrast, currently the vibration-noise control measures in China mainland are basically restricted to few types based on preliminary predicted value in combination with noise reduction effect and cost, etc. rather than comprehensive optimization. For example, since the operation of Guangzhou mass transit in 1997, many vibration-noise control measures such as Vanguard fastener, rubber floating slab, short resilient sleeper, steel spring floating slab track bed, resilient low-vibration track, ladder sleeper and sound barrier have been adopted. Based on the operation experience of the previous years, at present, basically the following measures are adopted for each line: medium vibration damping (vibration attenuation ≤ 6dB) by means of GJ-III type vibration-damping fastener; high-grade vibration damping (vibration attenuation of 6 ~ 8 dB) by means of ladder sleeper, and special vibration damping (vibration attenuation ≥ 8 dB) by means of steel spring floating slab track bed. For noise reduction, vertical or semi-closed sound barriers are adopted. However, the currently-used sound barriers are incapable of controlling the radiation of noise from viaduct structure.

### 6.3 Unreasonable planning

When planning a new elevated line of urban rail transit, the relationship between railway and surrounding buildings and road planning shall be fully considered for reasonable routing and convenient urban environmental space. In China, however, although in the preliminary environmental impact assessment it is generally said "it is suggested not to construct new school, hospital, centralized residential area and other special noise sensitive targets within the range of 100 m along the elevated line", in practice this principle is not always followed, which has caused nuisance to residents in the operation stage and hence increased investment for noise reduction measures. Moreover, the remedial measures taken are always restricted by various factors and can barely obtain satisfactory results. At present, Appraisal Center for Environment & Engineering under Ministry of Environmental Protection of the People's Republic of China requires a control distance of 15 m along elevated line of urban rail transit, that is, there shall be no noise/vibration sensitive target within the range of 15 m away from the center line of track.

### 6.4 Need of improvement in operation management level

Since the operation of URT in China, there is still lack of scientific and systematic follow-up monitoring on vibration and noise and a complete data and management system. Therefore, it is impossible to verify the effect of vibration-noise control measures, hence no further guidelines for future management and newly constructed lines with respect to vibration-noise control measures, which reflects a considerable gap from foreign advanced level. For example, some departments of Germany have established grinding schedules for noise sensitive areas, and once the noise is 3 dB higher than the specified limit, the acoustic grinding will be performed to rail. In addition, some countries have realized real-time remote monitoring on sound barriers along elevated lines of urban rail transit.

## 7. Proposals on Noise Control Measures for Elevated Rail Transit

There are various complex factors that may affect the noise of elevated lines, and the noise sources also differentiate at different frequency band and make different contribution to the overall noise. In the process of preliminary prediction of radiated noise, these factors shall be combined with vehicle state with the noise characteristics as low-frequency noise fully considered.

In the design of viaduct of urban rail transit, the good practices both home and abroad shall be studied. Studies shall start from the characteristics of vibration and its transmission of steel fasteners and low-vibration track on elevated lines, optimization of wheel/rail irregularity control and viaduct structure, fully consider the characteristics of wheel/rail noise and structural radiated noise and realize balance between them, so as to avoid "solving one problem only to find another cropping up", i.e. reducing viaduct radiated noise but increasing the noise from steel rail or track. In addition, in the design of elevated lines, not only the vibration damping measures on track shall be considered, but also the design of section form of viaduct shall be optimized in light of acoustic aspect.

For elevated lines in operation, the technical content of maintenance measures like grinding and friction management shall be improved and their affect on noise reduction shall be further studied for the purpose of establishing standards in light of acoustic grinding and controlling wheel/rail noise in light of maintenance.

As mentioned above, the vibration-noise control of elevated rail transit is a very complex issue which shall be solved by means of thorough theoretical research and comprehensive vibration and noise control measures.

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