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Study of the traffic noise source intensity emission model and the frequency characteristics for a wet asphalt road

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ABSTRACT

The traffic noise source intensity emission model is the basis of traffic noise prediction. In addition, the presence of water on the road is an important factor of road traffic noise. However, to date, none of the traffic noise source intensity emission models account for a situation in which the road surface is wet. Therefore, the main objective of this paper is to build a traffic noise source intensity emission model on a wet asphalt road based on traffic noise measurements, in which speed, sound pressure level and frequency spectrum were recorded as a single vehicle passed by. By using statistical analysis on the measurement data, a traffic noise source intensity emission model on a wet asphalt road was acquired, which conforms to correlation test, F-test and *t*-test. The result shows that the sound pressure level increases considerably with the presence of water on asphalt road for all types of vehicles; the mean difference in the sound pressure level between the wet and dry asphalt roads for light, middle-size, and heavy vehicles are 10.09 dB(A), 5.56 dB(A), and 4.26 dB(A), respectively. In addition, the noise difference between a wet and dry asphalt road decreases as the speed and vehicle size grow. Furthermore, the frequency characteristics of the road traffic noise were analysed through the sound pressure level and noise energy percentage in the 1/3 octave band spectrum. The result shows that for the wet asphalt road, the sound pressure level is high at high frequency and low at low frequency, which is completely different from the response on a dry asphalt road. In addition, for a dry asphalt road, the vehicle's noise energy percentage at low frequency decreases as the speed increases, whereas at high frequency, the percentage increases as the speed grow. However, for a wet asphalt road, the noise energy percentage changes little with speed. The findings can be applied to the accurate traffic noise prediction and noise control, especially in the rainy regions.

1. Introduction

With the rapid growth in the number of vehicles, traffic noise has become one of the main sources of urban environmental noise pollution, which is a threat to human health, leading to issues, such as myocardial infarction [1,2], hypertension [3,4], and sleep disturbance [5,6]. In 2014, the regional environmental average equivalent sound level of 113 key environmental protection cities in China was 54.4 dB(A) while the road traffic average equivalent sound level of these cities was 67.6 dB(A) [7], which shows that the noise pollution along the roadside is much more severe than that in other urban areas. It is, therefore, important to quantify the effect of road traffic noise to control noise pollution.

Traffic noise prediction models are required as aids in the design of highways and other roads and sometimes in the assessment of existing or envisaged changes in traffic noise conditions [8]. These models usually consist of a traffic noise source intensity emission model and a sound propagation model. As the basis of the traffic noise prediction model, the traffic noise source intensity emission model is used to predict the single vehicle pass-by sound pressure level at the roadside, while the sound propagation model is used to calculate the attenuations between the source and the receiver. Urban planners often have to rely on road traffic noise prediction models for their assessment [9]. The more popular ones include the FHWA Traffic Noise Model in the US [10], the CRTN model in the UK [11], the ASJ model in Japan [12], and others [13–15]. In addition, in China, the most commonly used model is the model proposed in the Specifications for Environment Impact Assessment of Highways (JTG B03-2006) [16]. However, none of

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these traffic noise prediction models accounts for a situation in which the road surface is wet. Nevertheless, it obvious that the traffic noise generated by vehicles on a wet road surface is much higher than that on a dry road surface based on the auditory sense.

As a result, the influence of the surface wetness is a significant factor when considering traffic noise prediction especially for countries, such as China, where the weather is rainy 109 days per year. In fact, as early as 1987, Boullosa and Lopez [17] recorded the traffic noise in Mexico City on a sunny day and a rainy day and found that the traffic noise on the rainy day was 10 dB higher than that on a sunny day. In 2000, Descornet et al. [18] found that water may increase the vehicle noise emission level under dry conditions by up to 15 dB(A). Similarly, Freitas et al. [19] obtained a parallel result that the noise levels increase significantly with the presence of water, shifting the overall noise by 4 dB(A). By comparing the noise emission of test vehicles on wet and dry road surface constructed of asphalt concrete, stone, Gardziejczyk [20] found that the noise influenced by wetness depend on the type of surface and the influence of the surface wetness on the noise of a car passing-by decreases with speed. The 2nd version of Common Noise Assessment Methods in EU provide a correction of wetness of road surface for the light vehicle, which take the rain periods over the year into account [21]. In 2014, an asphalt status classification system based on support vector machines was introduced by Alonso et al. This on-board system can determine wet and dry status of asphalt road surface [22].

Despite these results, the impact of water on the surface in relation to the noise level and the frequency characteristic has not been studied in depth to date. Because these studies just involved either qualitative analysis, or recording data from several certain vehicles, which cause they lack universality. In addition, their data on vehicle noise for a wet road was not inadequate to obtain a traffic noise source intensity emission model.

Therefore, first, the main objective of this paper is to establish a traffic noise source intensity emission model for a wet asphalt road based on traffic noise measurements, in which the speed, sound pressure level and frequency spectrum were recorded as a single vehicle passed by. Second, the models on wet and dry asphalt roads are compared in terms of speed and type of vehicle. Finally, the frequency characteristics of traffic noise on wet and dry asphalt roads are analysed and compared from the aspect of frequency, type of vehicle and speed.

2. Study methodology

The study was conducted at Yonghe Rd. in Guangzhou. The road surface is constructed of stone mastic asphalt. The grading is SMA-16 and the voids is 4.5% [23]. The measurements refer to the Limits and Measurement Methods for Noise Emitted by Accelerating Motor Vehicles (GB 1495-2002) [24]. The measurement setups are shown in Fig. 1.

A sound level metre (HzAiHua AWA 6228) and a speed gun (Stalker basic radar speed gun) are placed at point 1 and point 2 respectively. The microphone of the sound level metre is positioned at 1.2 m above the road surface and 7.5 m away from the center of the carriageway. In addition, the distance between the speed gun and the sound level meter is 20 m.

The measurement was conducted on the well-drained road after rain, when the road surface was covered by a thin layer of water, which was a typical situation for wet pavement surface. Since it is hard to quantify the depth of water on road surface, the rain gauge was once used to measure the intensity of rainfall, but we found that the rain intensity and period could hardly reflect the amount of water on the road surface. As a result, the measurements were conducted under a typical situation to represent the common vehicle noise emission on wet pavement surface.

The vehicles' speed, type, driving lane, sound pressure level and the 1/3 octave band spectrum data are recorded as a single vehicle passes the sound level metre without any other vehicle in the vicinity of 100 m on both sides of the road. In addition, the vehicles are classified by weight as light vehicles (less than 3.5 t), middle-size vehicles (3.5–12 t) and heavy vehicles (more than 12 t), referring to JTG B03-2006 [16]. Because of the angle α between the road and the passing-by vehicle, the measured data of speed must be corrected by the following formula:

$$v' = \frac{v}{\cos\alpha} \tag{1}$$

where v is the measured value of speed determined by the speed gun; v' is the true value of the passing-by vehicle.

Although the wet condition of the surface was achieved by rain, the measurements were performed without rain and the wind speed in the vicinity of the sound level metre should be less than 5 m/s. Varying weather conditions, such as rain intensity and duration, and road sections conditions, such as drainage capability were hard to measure by degree. As a result, the degree of the road surface humidity was evaluated visually, treating the surface as wet when it was covered by a thin layer of water.

3. Data processing

3.1. Data size

In total, 480 data points were recorded by three times in the same place, including 235 light vehicles, 58 middle-size vehicles, and 137 heavy vehicles. The data size of each types of vehicles for different speeds range is listed in Table 1.

3.2. Distance correction of the sound pressure level

For vehicles that do not run on the outermost lane, the distance between the vehicles and the microphone is more than 7.5 m; as a result, it requires a correction. The vehicle running on the road can be regarded as a point source, emitting noise in a half-free sound field, the decrement of the sound pressure level by distance can be calculated by the following formula:

$$K = 20\lg\frac{R_0}{R} \tag{2}$$

where K is the decrement of sound pressure level (dB); R_0 is the distance between the microphone and the center line of the outermost

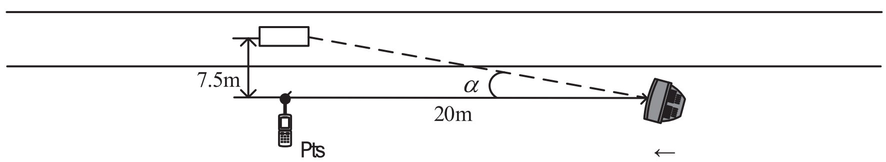

Fig. 1. Measurement arrangements.