Influence of Exposed Aggregate Texturing on the Reducing Traffic Noise Emission

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ABSTRACT

The effects of traffic noise are a serious concern in many urban communities throughout the world. Environmental noise at high intensities directly affects human health by causing hearing loss and indirectly affects human welfare by interfering with sleep, thought, and conversation. In general, portland cement concrete(PCC) pavement is known to create more noise than asphaltic surfaces though it has the advantage of durability and superior surface. However, the results of preliminary laboratory test showed exposed aggregate concrete(EAC) have an effect on reducing traffic noise. Based on the laboratory test, pilot construction of exposed aggregate concrete was performed and series of in-situ measurements were conducted for noise analysis which included the pass-by noise measurement and the close-proximity method. Conclusively, It is expected that tire/pavement noise which is represented much noise levels at higher frequencies would be significantly reduced on special textures of pavement as like exposed aggregate concrete.

1. Introduction

Traffic noise affects the ability of people to carry on conversation, to concentrate at work and school, and to sleep. Noise emission from motorized vehicle includes power unit noise, tire/pavement noise and aerodynamic noise. Among them, the tire/pavement noise is up to 30% of total noise and it tends to become dominant under high speed running condition. So the reduction of tire/pavement is essentially important for the abatement of road traffic noise. Portland Cement Concrete(PCC) pavements have the advantage of durability and superior surface friction when compared to most dense-graded asphalt. However, data collected to date generally show PCC pavements to create more noise than asphaltic surfaces. Therefore, it is now well known that useful and achievable traffic noise reductions may be obtained by appropriate application and design of road surface texture even in PCC pavements. Surfaces of Exposed Aggregate Concrete(EAC) pavements appear to provide better noise quality characteristics as well as good frictional characteristics and durability. As such, considerable interest exists in PCC surface treatment techniques that would lead to reduced noise levels for highway neighbors.

2. Methodology

2.1 Test pavements

It has been reported that smooth surface of pavement often causes high levels of air pumping noise which is major reason of tire/pavement noise. There are several methods that can be used which practically eliminate the necessity for noisy textures.

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Exposed aggregate texturing considered in this paper is also suggested as one of them. This texturing is achieved by means of removing mortar between the aggregate before it hardens. The process includes spraying retarder on the finished surface of pavement but still fresh concrete and then brushing away the loose mortar that has not set. It has been found that exposing the aggregate can reduce noise level, but only if the aggregate sizes are small and uniform depth of mortar are removed. In order to remove proper and uniform depth of mortar layer, it is very important to decide the time of brushing for removal of mortar, and it also depend on properties and dosage of retarder. As the results of laboratory tests, It is possible that sound pressure level(SPL) at the exposed depth of 1~2mm is approximately reduced as 10dB(A) as than plain concrete pavement when adopted maximum size of aggregate is 13mm. In conclusion, the exposed depth of 1~2mm and G_{max} of 13mm are suggested for texture optimization and this designed exposed depth of aggregate is acquired by means of removing of surface mortar at the hardness of 30~40. Surface hardness test of concrete was performed as the method for measuring of retardation. Generally, it is supposed that proper hardness value of 30~40 could be acquired later than 12hours after retarder is added as the adding amount of $200 g/m^2$. While the curing ages of concrete are elapsed more than 24hours, it would be impossible to expect effects of retarder.

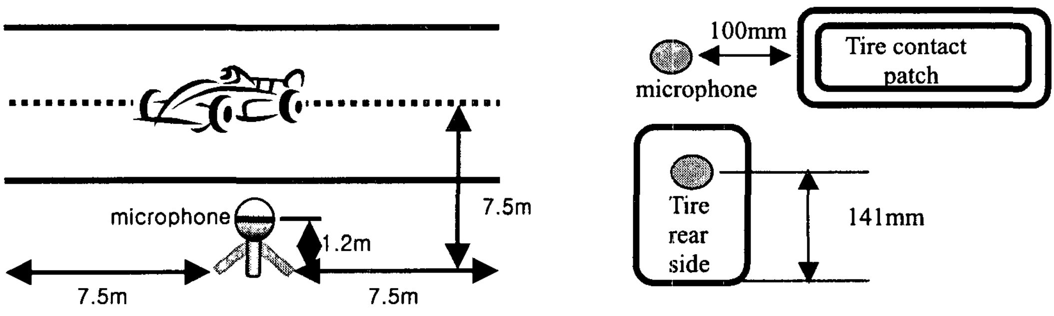
2.2 Measuring methods

2.2.1 The pass-by noise measurement

Exterior noise levels were recorded with microphone mounted 1.2m above the pavement and positioned 7.5m from the centreline of the nearest traffic lane as shown in Fig. 1. It is common to make a recording of the maximum A-weighted noise level and frequency spectrum at the moment of peak A-weighted noise. This method is often used to classify both the road surface and the tire influence on noise. All noise measurements were performed with the same car and tire, at operating speeds of 20, 40, 60 and 80 km/h in the right lane.

2.2.2 The close-proximity method

All tyre/pavement noise measurement methods rely on certain assumptions and compromises are restricted by certain conditions. This means that one cannot expect to obtain exactly the same results when using different methods. The pass-by noise measurement is a sort of method not for pure tyre/pavement noise but for a mix of tyre/pavement noise and power unit noise. However, the close-proximity method which microphone is onboard has been rather extensively compared with pass-by noise measurement as the respect of characteristics of noise. In the onboard method used, the setup is somewhat different from the pass-by noise measurement and setup of this method is shown in Fig. 1.



< The pass-by noise measurement> < The close-proximity method>

Fig. 1. The physical set-up for noise measurement

3. Results and discussion

3.1 The pass-by noise

The noise measurement using the pass-by method was adopted to analyze the characteristics of traffic noise emission according to texturing of pavement. This method is independent of the type of vehicles or tires used and the acoustical results are only dependent on the road surface. A-weighted sound pressure level measurements were recorded as well as one-third octave frequency bands between 50 and 10,000 Hz. The Fig. 2 presents A-weighted sound pressure level at a speed of 20~80km/h for the two different pavement conditions. Several of bars represent not one measurement but the average of more than three times pilots. The results present that noise levels from traffic sources depend on vehicle running speed result from increasing sound pressure level according to vehicle speed. Generally, an increase in volume, speed, or vehicle size increases traffic noise levels. This figure also shows exposed aggregate concrete is quieter than conventional pavement with regardless of speed.

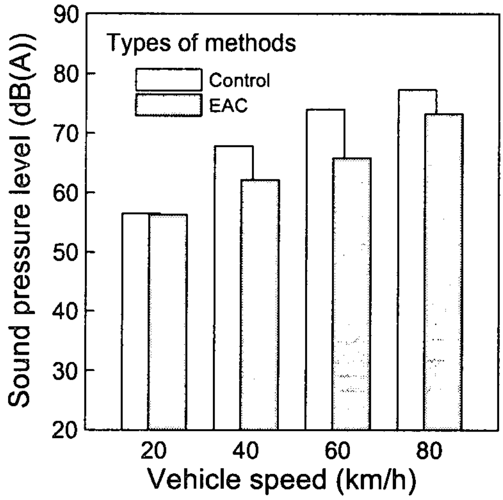


Fig. 2. A-weighted sound pressure level

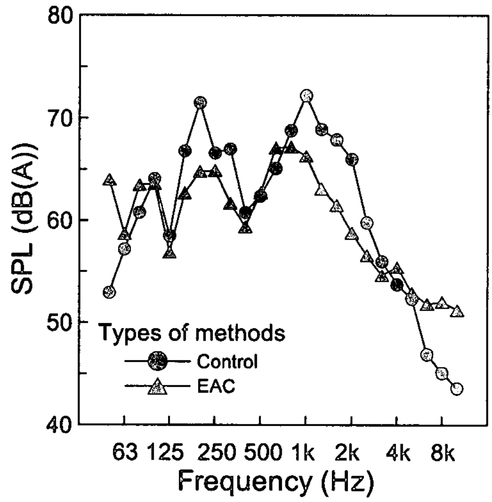


Fig. 3. Noise spectra

In the result of the noise level analysis at every frequency as shown in Fig. 3, the sound pressure spectrum is much varied for the difference of the pavement at higher frequencies. There is a distinct trend in the exposed aggregate concrete to have more attenuation in the frequency range above 1kHz, where the level difference between the highest and the lowest are 6dB(A). Because sound pressure levels at high frequencies are decreased with texture amplitude when considering texture within the texture wavelength range 0.5~10mm. It means that the effects of texture on exterior noise are conflicting, depending on how the texture is composed. In conclusion, it is expected that tire/pavement noise which is represented much noise level at higher frequencies would be significantly reduced on special textures of pavement with large amount of macrotexture.

3.2 The close-proximity noise

Following results are conducted by the close-proximity method. Generally, the onboard data from the microphones set on the near one of the tires was recorded to capture a noise signal that was predominately tire/pavement noise and less power unit noise or aerodynamic noise as compared to the pass-by noise measurement. The sound pressure levels for all vehicle speed are shown in Fig. 4, and it shows that the trend of results is similar to that of pass-by noise measurement except that overall noise levels are higher. In all speed except 20km/h, sound pressure levels in exposed aggregate concrete are approximately 2~6dB(A) lower than those of conventional concrete. In addition, this trend is especially significant at higher running speed, and the reason is why tire/pavement noise tends to become dominant under high speed running condition. Therefore, humans respond to a sound's frequency or pitch. The human ear is very effective at perceiving sounds with a frequency between approximately 1,000 and 5,000 Hz, with the efficiency decreasing outside this range.

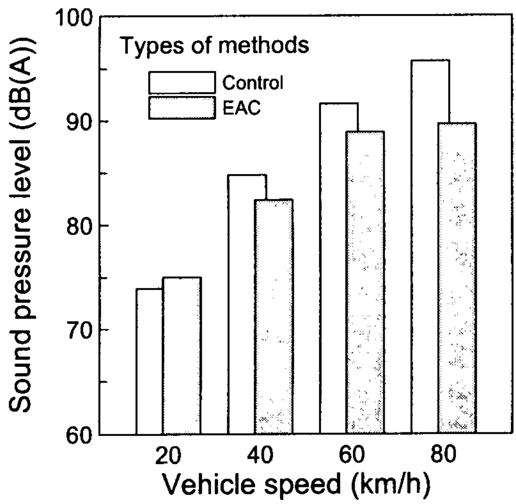


Fig. 4. A-weighted sound pressure level

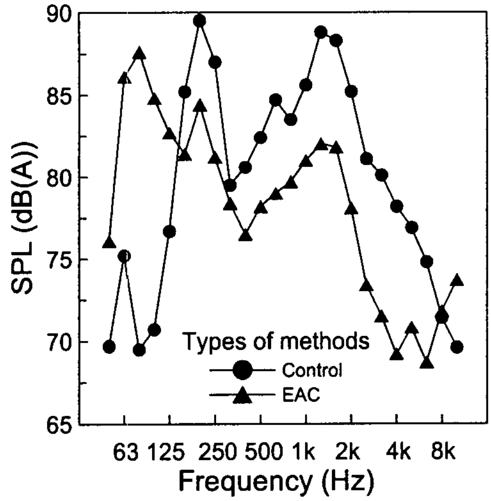


Fig. 5. Noise spectra

Fig. 5 shows the spectrum analysis conducted by the close-proximity method in one-third octave band at a speed of 80km/h. Compared to pass-by noise measurement, the onboard noise levels for adopted pavements represent overall higher sound pressure levels at all frequencies. When hearing sensitivity is considered, the frequency content below 500 Hz is not significant such that the frequency content of tire/pavement is from 500 to 2,000 Hz. As the result of spectra analysis, the spectrum of exposed aggregate concrete are reduced by 5~10 dB(A) in the high frequency range compared to conventional concrete pavement. Conclusively, in the case of exposed aggregate concrete, distribution of sound pressure levels at high frequencies were much lower than those of conventional pavement as well as lower equivalent sound levels. It is expected according to these results that traffic noise levels are dominated by tire/pavement noise at highway speeds and surface treatment are able to reduce traffic noise with regard to human ear's perceiving.

4. Conclusion

(1) Based on the results of the exterior measurements, noise levels from traffic sources depend on vehicle running speed, and the results from close-proximity method showed overall higher sound pressure levels than those of pass-by noise measurement at all frequencies due to set-up of microphone.

(2) Sound pressure levels in exposed aggregate concrete were approximately 2~8dB(A) lower than those of conventional concrete. Since tire/pavement noise tends to become dominant under high speed running condition, this trend was especially significant at higher running speed.

(3) In the case of exposed aggregate concrete, distribution of sound pressure levels at high frequencies were much lower than those of conventional pavement as well as lower equivalent sound levels. It is expected that tire/pavement noise which is represented much noise levels at higher frequencies would be significantly reduced on special textures of pavement with large amount of macrotexture.