Characterization of Textures for Low Noise Concrete Pavement

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ABSTRACT

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. As the results of research, surfaces of exposed aggregate, tining and grooving concrete pavements appear to provide better noise quality characteristics as well as good frictional characteristics and durability. In this paper, several methods of texturing were considered to reduce tire/pavement noise. As the results of this paper, PCC pavements with special texturing have superior surface friction as well as noise reductions when compared to conventional PCC pavement. Especially, Exposed Aggregate Concrete (EAC) surface appears to provide better noise quality characteristics. Conclusively, if overall noise and safety are considered simultaneously, EAC pavement that provides satisfactory friction as well as better noise reductions is suggested.

1. Introduction

Traffic noises from automobiles have been causing so serious environmental problem for people living close to road or in urban areas. Therefore, two broad categories of pavement are generally used for highway construction. These are portland cement concrete (PCC) pavement and asphaltic cement concrete pavement. The use of PCC pavement is often desirable because of its long service life when compared to asphaltic pavements. However, noise level measured to date show PCC pavements to create more noise than asphaltic surfaces. Therefore, recent research has suggested some PCC pavements with effective textures to reduce noise emission. It is now well known that useful and achievable traffic noise reductions may be obtained by appropriate application and design of pavement surface texture even in PCC pavements. When creating texture on PCC pavements it is important to consider the potential noise impact of the various alternatives. We considered several methods of texturing of pavements in this paper to compare ability of noise reduction each other and to suggest texture optimization for reducing traffic noise.

2. Methodology

2.1 Test equipment

The description of equipment adopted in this experiment is shown in Table 1. It include test tire and equipments for noise measurement.

Table 1. Overview of the equipment

Microphone	1/2" Condenser microphone (40AF)
Sound analyzer	Symphonie (01dB Ltd.): Dual channel real-time sound and vibration measurement
Analyze program	dBenv32: Combine the features of a data logging integrating sound level meter, a digital tape recorder and a real-time frequency analyzer at the same time.
Test tire	Tread pattern featuring attributes of the most popular car "summer tread" tire, intended mainly for use in temperatures above 0 ℃, Dimensions: 195/70 R14 91T (Air pressure: 30psi)

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2.2 Applied texturing

When creating texture on PCC pavements it is important to consider the potential noise impact of the various alternatives. 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. In fact, the most noisy pavement that has ever been measured was a smooth and polished cement concrete pavement. There are several methods that can be used which practically eliminate the necessity for noisy textures. The following texturing of PCC pavements which have been found useful for reducing traffic noise were considered in this study for texture optimization of low noise PCC pavements. The photographs of each textures adopted in this study as low noise pavements are shown in Fig. 1.

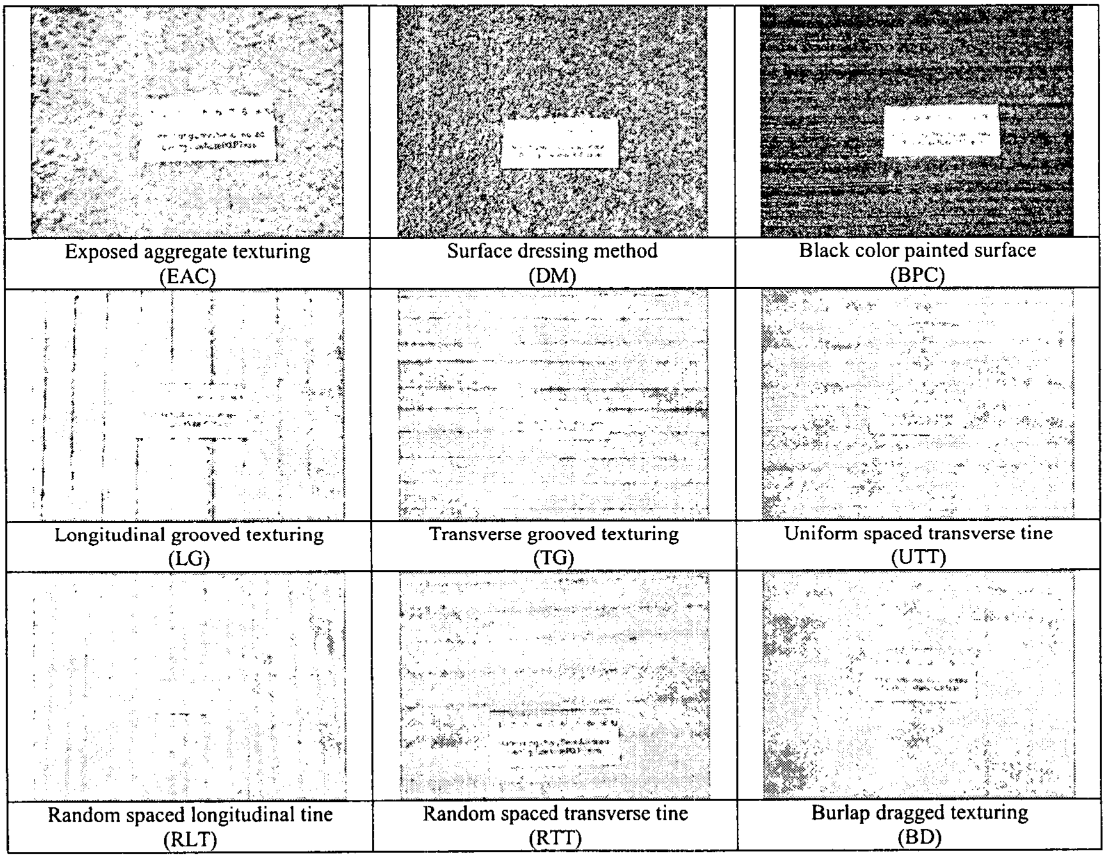
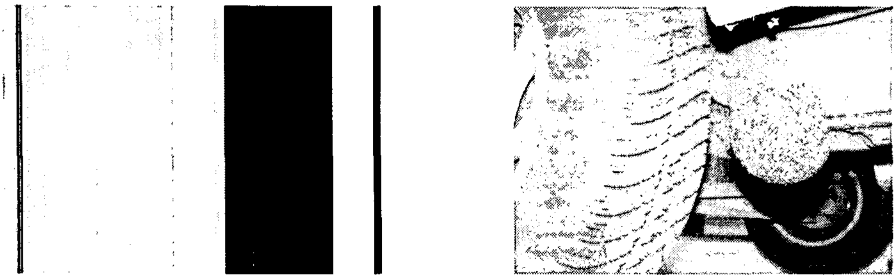


Fig. 1. Textures of pavement adopted in this study

2.3 Measuring methods

Exterior noise levels were measured by the pass-by noise measurement and the close-proximity method. 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. The pass-by noise measurement is a sort of method not for pure tire/pavement noise but for a mix of tire/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. The setup of this method is shown in Fig. 2.



(a) Pass-by noise measurement (b) Close-proximity method

Fig. 2. Physical set-up for tire/pavement noise measurements

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. Such measurements are performed with a test vehicle under real traffic conditions. This method is independent of the type of vehicles or tires used and the acoustical results are only dependent on the pavement surface. Furthermore, the influence of all other noise sources is not a significant factor because noise from test vehicle is much higher than any other noise sources. A-weighted sound pressure level measurements were recorded as well as one-third octave frequency bands between 50 and 10,000 Hz. The results of pass-by noise measurements on several types of pavement surface appear in Fig. 3. This figure shows the results of measurements of A-weighted sound pressure levels at a speed of 20~80km/h. Several of bars represent not one measurement but the average of more than one surface. The results conclude that the longitudinally grooved pavement is quieter than that of transverse and same trend is occurred at tined pavement without regard to speed. Furthermore, exposed aggregate concrete also represent the effect of noise reduction.

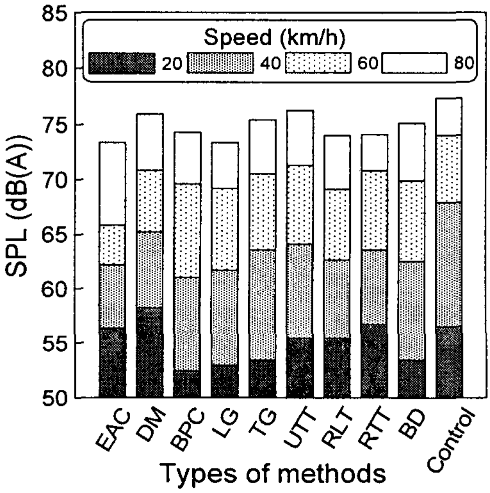


Fig. 3. A-weighted sound-pressure levels

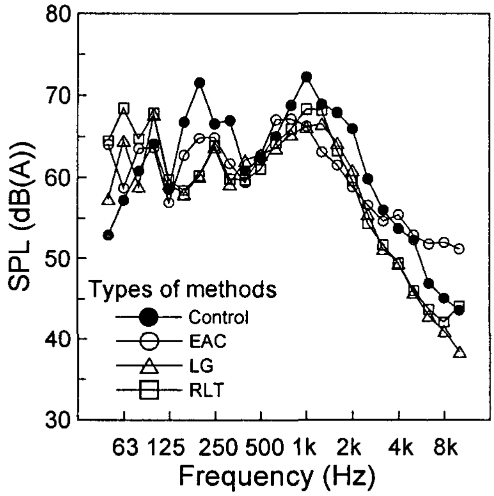


Fig. 4. Tire/pavement noise spectra

In the result of the noise level analysis at every frequency as shown in Fig. 4, the sound pressure spectrum is much varied for the difference of the pavement at higher frequencies. There is a distinct trend in the EAC, LG and RLT 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 (above a "cross-over frequency") decrease 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 vehicle machine noise or aerodynamic noise as compared to the pass-by noise measurement. A-weighted sound pressure levels were recorded as well as one-third octave frequency bands between 50 and 10,000 Hz. The sound pressure levels for all 10 pavements are shown in Fig. 5 and the trend of results is similar to that of pass-by noise measurement.

Fig. 6 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. The spectrum of suggested textures as like EAC, LG and RLT are reduced by 5~10 dB(A) in the high frequency range compared to plain concrete pavement. Conclusively, In the cases of special textures, distribution of sound pressure levels at high frequencies were much lower than that of conventional pavement as well as lower equivalent sound level.

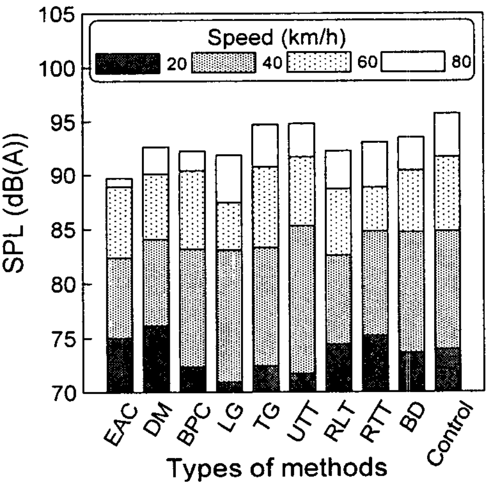


Fig. 5. A-weighted sound-pressure levels

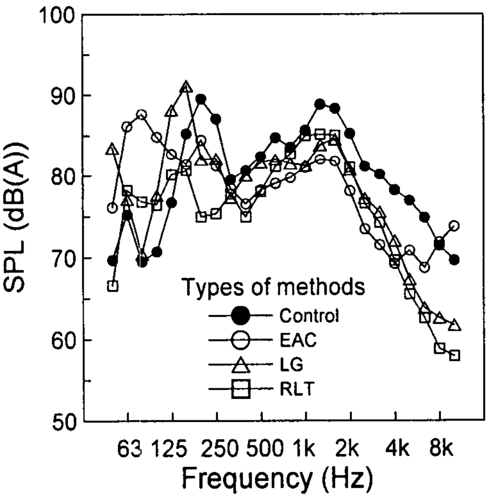


Fig. 6. Tire/pavement noise spectra

4. Conclusion

1. Exposed aggregate texture (EAC), longitudinal grooved texture (LG) and random spaced longitudinal tining texture (RLT) are recommended for low noise pavements.
2. When the removing direction of tining and grinding is considered, transverse removing can cause a discrete frequency or whine. If overall noise considerations are paramount in pavement, longitudinal removing is recommended.
3. Because tire/pavement noise is significant in high frequency range from 500 to 2,000 Hz, the proper surface treatments as shown in preliminary results are able to reduce traffic noise to human ear. The reason is that these textures can reduce not only maximum sound pressure level but sound pressure spectrum in high range of one-third octave frequency bands.