Evaluation of Pavement Noise Using Statistical Techniques

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1. INTRODUCTION

Traffic noise is a growing concern as traffic demand increases with urban sprawl. The most common traffic noise mitigation methods include the construction of noise barriers and earth berms. Based on studies performed by different agencies around the world, the Regional Municipality of Waterloo (RMOW), Ontario, Canada, in partnership with the University of Waterloo Centre for Pavement and Transportation Technology (CPATT), have undertaken research into asphalt pavement, rubberized open friction course (rOFC) and rubberized open graded course (rOGC), to determine their noise reducing capability in the southern Ontario environment as compared to a typical pavement with a Hot-Laid 3 surface. This paper will also investigate the noise reducing capability of stone mastic asphalt mix, which is mainly used for heavy traffic conditions. Two types of sound level measurements were used in this study: Close-Proximity Method and Controlled Pass-By Method. A statistical analysis was performed utilizing the noise measurement results to determine if there is significant difference between mixes or within a mix.

2. DESCRIPTION OF THE STUDIED PAVEMENTS

In this study, the mix designs and gradations for the rOFC and rOGC are similar. The difference between these two mixes is related to the quality of the aggregates. The aggregates used in rOFC are premium grade and must meet much higher standards for the other aggregate tests. SMA also used a premium aggregate. The ones used in rOGC and HL-3 are local aggregates and do not meet all the requirements to qualify as a premium mix.

3. SITE DESCRIPTIONS

Four types of asphalt pavement surface courses were placed in a rural area surrounded by farmlands in Waterloo area. Pavement surface courses were placed in an order of rOFC, rOGC, SMA, and HL-3 from east to west. The length of each type of pavement section is approximately 600 m.

4. NOISE MEASUREMENT METHODS

Traffic noise measurements were taken a month after pavement placement. Thirteen testing vehicles were used for the noise testing: 5 light, 5 medium, and 3 heavy vehicles. Each noise measurement consisted of a single test vehicle passing through the test site. The driver of the testing vehicle drove through the centerline of the test road at constant speeds of 60 km/h, 70 km/h, 80 km/h, and 90 km/h from east to west and then made a return trip. Two sound level measurement techniques were utilized in this analysis: the Close-Proximity Method (CPX) and the controlled Pass-By Method (PBM). During the noise testing, the entire area was closed and, since the study site is located in a rural, the ambient noise should be minimized and constant.

4.1 Close-Proximity Method

In this project, a microphone was mounted on the test vehicle and was located approximately 50 cm away from the centre of the front or rear wheel. The CPX measurement is designed to measure the direct noise generated from the interaction between vehicle tire and pavement and to avoid measuring the engine noise generated from the testing vehicle.

4.2 Controlled Pass-By Method

Pass-by Method (PBM) measured the sound as vehicles travel passed a stationary microphone. Four pass-by monitoring stations were set-up at the midway point of each asphalt pavement section. Each monitoring station was located 15 m away from the centreline of the road, 1.5 m above pavement, and was monitored by a technician. The maximum sound level (L_{max}) was measured by the PBM.

5. NOISE MEASUREMENT RESULTS

All four pavements show that when the vehicle speed or size increases, the sound level increases in both measuring methods. The noise measurement range magnitudes, in terms of vehicle speed, are about 8 dBA (at 60 km/h) and 11 dBA (at 90 km/h) for CPX and PBM, respectively. Table 1 shows the amount of noise reduction as compared to HL-3 in terms of all vehicles, different vehicle speeds, and different vehicle sizes in a particular speed.

The noise reduction in this initial study for SMA has the worse performance of noise reduction among all pavement types. SMA did not reduce noise level in various categories. Both the rOFC and rOGC provide a significant amount of noise reduction as compared with HL-3 in all situations. The highest noise reductions for rOFC are 3.3 dBA and 2.5 dBA in CPX and PBM results, respectively. The highest reductions for OGC are 3.3 dBA and 2.8 dBA in CPX and PBM, respectively.

Table 1: CPX – Average Sound Level Reduction

Categories	Noise Reduction as compared to HL-3, dBA					
	CPX (Leq)			PBM		
	rOFC	rOGC	SMA	rOFC	rOGC	SMA
All Vehicle	-1.8	-2.0	0.0	-1.0	-1.7	+0.2
60 km/h	-1.4	-1.7	+0.5	-0.6	-1.2	+0.7
60 – L	-0.4	-0.6	+2.3	-0.1	-0.5	+2.1
60 – M	-1.8	-2.4	-0.7	-0.3	-1.9	-0.6
60 – H	-2.5	-2.5	-0.7	-1.9	-1.6	+0.1
70 km/h	-1.7	-1.8	+0.3	-0.8	-1.3	+0.4
70 – L	-0.7	-0.9	+1.8	-0.5	-0.5	+1.7
70 – M	-2.9	-2.8	-1.0	-1.2	-2.4	-1.2
70 – H	-1.8	-2.0	-0.3	-0.8	-1.7	-0.3
80 km/h	-2.2	-2.3	-0.2	-1.4	-2.2	0.0
80 – L	-1.0	-1.2	+1.6	-0.6	-1.6	+1.4
80 – M	-3.3	-3.3	-1.6	-1.8	-2.8	-1.6
80 – H	-2.3	-2.4	-0.7	-2.5	-2.4	-0.5
90 km/h	-1.9	-2.3	-0.5	-1.5	-2.3	-0.1
90 – L	-1.2	-1.8	+1.0	-1.2	-2.3	+1.2
90 – M	-2.7	-3.1	-1.6	-2.4	-2.8	-1.4
90 – H	-1.8	-1.9	-1.1	-1.2	-1.8	-0.7
L: Light Vehicle; M: Medium Vehicle; H: Heavy Vehicle						

6. STATISTICAL ANALYSIS

A statistical analysis was carried out to examine if a significant difference existed between the asphalt mixes and within a particular asphalt mix in terms of vehicle speeds or sizes. The paired comparison method was used to compare the similarities between pavements by performing a t-distribution hypothesis test on the difference between two pavement mixes. A typical t-distribution hypothesis test was utilized to compare the similarity within pavement by comparing two sets of data in terms of vehicle sizes or speeds in the same mix. Four asphalt pavement mixes were studied in this project: rOFC, rOGC, SMA, and HL-3, therefore six comparisons in between mixes in terms of vehicle speed or size would be analyzed. Comparison within mix would also be analyzed in terms of vehicle speed or size.

The statistical analysis shows that there is no significant difference between rOFC and rOGC in terms of traffic speeds of 70 km/h and 80 km/h, and heavy vehicles for both sound measuring methods. No significant difference was observed between the SMA and HL-3 mixes for all vehicle speeds in both measuring methods, except for 60 km/h in PBM. In terms of vehicle sizes, significant difference was observed between the SMA and HL-3 mixes for all vehicle sizes in both measuring methods, except for heavy sized vehicle in PBM. The statistical analysis of both measuring methods also revealed that most of the other paired pavements, rOFC/SMA, rOFC/HL-3, rOGC/SMA, and rOGC/HL-3, were statistically significant different in terms of vehicle sizes or speeds.

Four types of pavements have the same statistical results in terms of the comparison between vehicle speeds within its pavement type. In CPX statistical analysis results, all the pavements have no significant difference in the comparison between 70/80 km/h and 80/90 km/h. PBM statistical result shows that all the pavements have no significant difference in the comparison between 60/70 km/h, 70/80 km/h, and 80/90 km/h. Also, PBM statistical analysis has also shown that there are no significant differences in the comparison of 60/80 km/h in rOFC and rOGC, 70/90 km/h in rOGC and SMA.

7. CONCLUSIONS

It was found that vehicle noise increases when the vehicle speed or size increases for both test methods. Also, the SMA did not provide any noise reductions in most of the vehicle speeds and/or sizes in both test methods. rOFC and rOGC provided the highest amount of noise reduction in both testing methods. The statistical analysis for both measurement methods shows that there was no significant difference between rOFC and rOGC in most of the vehicle sizes or speeds comparison. It also had the same results between SMA and HL-3; there was no significant difference in some comparisons between vehicle sizes or speeds. In the statistical analysis of within mix, all pavements had no significant difference when comparing the vehicle speed of 80 km/h to 70 km/h and 90 km/h in the both measuring methods. In addition, all pavements also had no significant difference in PBM results when comparing the vehicle speeds of 60 km/h to 70 km/h; rOFC and rOGC had no significant difference when comparing the vehicle speeds of 60 km/h to 80 km/h; and rOGC and HL-3 had no significant difference when comparing the vehicle speeds of 70 km/h to 90 km/h.

8. RECOMMENDATIONS

It is recommended that additional sound level measurements be conducted in the future to monitor the pavement acoustical performance. Also, a comparison of the noise measurement results obtained from the two test methods should be performed and measurements of pavement acoustical absorption should also be conducted.

A life cycle cost for each pavement should also be performed for noise reducing pavement selection. Also, a further analysis of the correlation between mix design and sound level measurement should be performed which may be used to act as a noise reduction prediction model.

REFERENCES

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