MODULAR EXPANSION JOINT NOISE IN B.C.

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1 Introduction

Greater Vancouver is geographically divided into several municipalities by the Fraser River arms. Bridges have been constructed across the arms and estuaries that employ modular expansion joints (MEJs) capable of rotation and translation within the 1 m range or more. A key element of the basic MEJ design is an array of I-beams whose upper flanges provide the supporting roadway surface over the joint. The basic design however leads to tire/joint interaction noise that can be a concern to neighboring communities. This study defines the tire/joint interaction noise of an MEJ design through a measurement program.

The measurement program involved a new abutment and a new pier MEJ. Specifications of the MEJs, bridge deck, pavement type and the setting of the bridge/community are discussed in [1]. Noise control is presented in [2].

2 Method

2.1 Monitoring Locations and Instrumentation

Microphones were mounted on tripods at a height of 1.7 m above the sidewalk of the bridge deck at longitudinal offsets measured from the transverse centerline of an expansion joint. The offset is taken to be a positive distance in the direction of traffic flow and negative in the direction opposite the flow. For example, for measurements taken at a longitudinal offset of -15 m, the microphone would be 15 m *behind* the vehicles as they passed over the MEJ. A tripod-mounted microphone was also located 1.7 m above local ground level at a distant residential location of 585 m away at an elevation of 7 m above sea level.

Instrumentation included a Larson-Davis Model 820 Community Noise Analyzer (CNA) and Larson-Davis Model 2800 Real Time Analyzer (RTA).

The CNA was set to log the L_{maxF} and L_{peak} in units of dBA at one-second resolution. The Larson-Davis RTA was used in Linear Single (LS) mode to store the one-third octave spectrum of the true RMS sound pressure averaged over the measurement interval. In LS mode, the RTA could alternatively be set to store the maximum spectrum (mxSpec). The mxSpec is the one-third octave band spectrum with the highest energetic sum of all those sampled within the measurement interval.

3 Results

3.1 Subjective Observations

Subjective observations including effects of tire type, vehicle weight and speed on tire/joint emission levels as well as the effect of overall width of the joint are discussed in [1].

3.2 Short Range Average Maximum Noise Levels - General Traffic

The maximum levels (L_{maxF}) of tire/joint interactions were logged with a CNA at the abutment joint from vehicles chosen "on the fly" from the general traffic flow. Vehicles were selected that would result in an MEJ emission with a high signal-to-noise ratio.

The L_{maxF}s of the highest quality events were sorted into vehicle weight categories and averaged. The results are presented in Table 1. Reproducibility may be limited [3].

Table 1: Average Maximum Levels at a -15 m Offset from Abutment Joint - General Traffic, August 2009

Vehicle Type	No. of Events	Avg. L_{maxF} (dBA)	Std. Error (dBA)
Full-size Car	2	87.1	1.0
Heavy Pickup	12	86.6	1.3
Mid-size Car	16	84.2	1.1
Sports Utility	15	83.0	1.2
Compact Car	6	79.4	1.1

3.3 One-Third Octave Band Spectra

One-third octave band spectra of tire/joint interaction noise of various single vehicles selected from the general traffic are shown in Figure 1. The microphone was positioned at an offset of -15 m and the RTA was set to LS mode.

From Figure 1, in eight of eleven cases, the dominant frequency was found within the one-third octave band centered on 630 Hz. In three cases, the 800 Hz band was dominant.

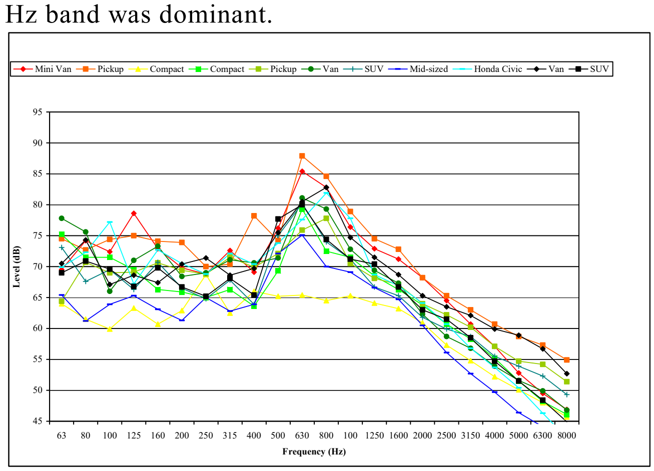

Figure 1: One-third Octave Band Spectra of Tire/Joint Interaction Noise with Tone in 630 Hz Band at Abutment Joint, August 2009

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These results were found to be insensitive to vehicle speed in the range 80 to 110 kph [1].

3.4 Long Range Average Maximum Noise Levels - General Traffic

Joint noise events from the general traffic were monitored at a distant residential location on the boundary of an exposed neighboring community. The monitoring station was located at a range of 585 m from the abutment joint and 1200 m from the pier joint along a line tangent to the direction of the traffic flow over the joint. The intervening ground consisted of tall natural grasses over which MEJ emissions propagated at an average height of 7 m. Sound travel times from abutment and pier joints to the microphone were approximately 1.6 and 3.6 seconds, respectively. Crosswind conditions prevailed along the propagation path since the winds were seen to follow the river.

Maximum levels of tire/joint interactions were identified using the recorded audio track. These short-term results are presented in Table 2.

Table 2: Average Noise Levels at Residential Location at a -585 m Offset from Abutment Joint - General Traffic, August 2009

Data Set	No. of MEJ Events	Avg. L_{maxF} (dBA)	Avg. L_{peak} (dBA)	Std. Error
1	30	58.1	70.1	0.6
2	30	57.0	69.6	0.6
3	30	56.6	68.4	0.7

In addition, maximum levels of joint events measured over 3-hours at the residence averaged 55.6 dBA against an ambient level of 52 dBA.

3.5 Directionality - Controlled Drive-bys

Motivation to investigate directionality was provided by numerous observations made at a variety of locations at two new bridge projects in B.C. that employ MEJs. In March 2010, the directionality of the tire/joint acoustical radiation field was more closely explored using a test vehicle at the pier joint. Noise levels were logged with the RTA using the mxSpec feature at longitudinal offsets of 7 m and 100 m from the transverse centerline of the pier MEJ. The results are presented in Table 3.

Table 3: Directionality of Tire/Joint Interaction Emissions

Microphone Longitudinal Offset(m)	Lane	Speed (kph)	mxSpec Level (dBA)	Difference
-7 m (behind) +7 m (ahead)	Middle	100	87.6 87.5	0.1
-100 m (behind) +100 m (ahead)	Middle	100	76.6 68.0	8.6

Column 5 of the table shows the difference in levels was negligible for an offset of 7 m on either side of the MEJ and this is believed to be the case up to a range of approximately 50 m. However, the difference for the 100 m offset indicated the MEJ emission level received 100 m behind the test vehicle was mxSpec 8.6 dBA higher than that received 100 m ahead of the vehicle. Subjective observations indicate this effect persists over longer distances and at the residential location at a range of 585 m, receding vehicles traversing the abutment MEJ were audible but approaching vehicles were not. MEJ emission directionality was also observed on a second new bridge project in B.C. employing a different type of MEJ.

4 Conclusion

Tire/joint interaction noise from the passage of general traffic over MEJs was found to be a complicated matter with numerous variables. Emissions from five vehicle classes varied as much as L_{maxF} 7.7 dBA. However, the tonal quality of MEJ emissions was quite consistent and the dominant frequency was found within the 630 Hz one-third octave band in eight of eleven cases. Moreover, this result was independent of vehicle speed; a result consistent with a resonance source mechanism [1]. Both subjective observations and measurements of MEJ emissions suggest factors leading to higher levels include higher vehicle speeds, tires that are more flexible and higher loading (kg/m^2) of the tire contact patch.

Joint noise imissions measured at a range of 585 m over largely soft ground averaged a clearly audible L_{maxF}(3-hour) 55.6 dBA against the ambient level of 52 dBA. The dominant 630 Hz tone of the tire/joint noise signature was audible at even lower levels that approached ambient. However, emissions from MEJ events would not be expected to contribute significantly to the L_{eq}(24-hour) since their durations were short on the order of 250 ms per event.

The directionality of tire/joint interaction noise was investigated. During controlled drive-bys it was found that the MEJ emission level received 100 m behind the test vehicle was L_{maxF} 8.6 dBA higher than that received 100 m ahead of the vehicle; an effect that persisted to the residential location at a range of 585 m. It was found that the joint emission level received 7 m behind the vehicle was approximately the same as the level 7 m ahead. More trials are necessary to determine the cause of the directionality property. The directionality property of the tire/joint radiation pattern may be of importance for noise mitigation purposes.

References

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