Dynamic Measurement of Tyre/Road Noise

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ABSTRACT

Road Traffic is the major environmental noise source impacting on numerous people in Australia. The main component of this noise is caused by the interaction of the road surface and the vehicle tyres. Current approved road surface noise test methods include static measurements (i.e. fixed microphone location beside the road) and dynamic measurement (i.e. microphone located on a moving vehicle). Currently, only the static measurement approach is widely used in Australia. ASK have developed and tested a dynamic test rig which can be used to gain a further understanding of tyre/road noise; provide details on variation in tyre-road noise level by road or air temperatures, and aging of the road surface; be used in the development of low noise road surfaces and low noise tyres; for cataloguing road surface types and their noise level emissions; post construction compliance testing of new roads; and mapping of road noise levels for integration into road authority databases or similar.

BACKGROUND OF ROAD TRAFFIC NOISE

Environmental noise is becoming an ever-increasing issue in many industrialised countries, such as Australia. "Surveys show that noise is the main environmental concern for most Australians. Many people complain that traffic noise has the greatest direct impact (Federal Department of Environmental Heritage, 2006)". The word 'noise' in the term 'environmental noise' is most commonly defined as unwanted sound. This means that noise is not a technical term but instead is a subjective term. Surveys have been conducted to determine what impacts noise has on the people of Australia. It has been estimated that more than 70% of environmental noise is due to road traffic (Australian State of the Environment, 2001). The Brisbane Noise Survey 1989 showed that people noted that they are 'seriously affected' by light and heavy vehicle traffic noise, ahead of aircraft noise and barking dogs. The issue of road traffic noise has been addressed in detail since then but is sure to remain an ongoing problem with continuing urbanisation.

The main contributing components of road traffic noise include noise from the tyre-road interaction; car transmission noise; engine noise; exhaust system noise; and intake system noise. Over the years considerable reductions in vehicle noise have been achieved with respect to reducing engine and exhaust noise via Australian Design Rules.

Tyre-road interaction noise is the dominant traffic noise source for speeds above 40-50 km/h for cars and 60-70 km/h for trucks (Sandberg, 2001). It is commonly assumed that the road surface interaction is the dominant noise source for freely flowing traffic travelling at over 70km/h. Tyre-road noise under most conditions is the dominant contributing factor to road traffic noise and therefore has been the focus of many studies and ongoing design of 'quiet, hush, low-noise' pavements/road surface finishes.

The option of low noise generating road surfaces becomes important if for example it either obviates the need to erect noise barriers, or the effective height of noise barriers can be substantially reduced. This reduces visual impact as well as other amenity issues associated with light and airflow.

TYRE-ROAD NOISE MEASUREMENT PROCEDURES

There are currently five major procedures for measuring tyre-road noise:

- Coast-By Method (CB)
- Trailer Coast-By Method (TCB)
- Laboratory Drum Method (DR)
- Statistical Pass-By Method (SPB)
- Close Proximity Method (CPX)

The Coast-By procedure involves a test vehicle coasting past a measurement location with minimal engine noise being emitted. The Coast-By procedure is normally performed on a specific test track and has been known to be time inefficient. The Trailer Coast-By procedure is similar to the Coast-By procedure except measures the noise emitted for a trailer being towed behind the test vehicle. Similar to the Coast-By procedure the Trailer Coast-By procedure is normally performed on a specific test track and has been known to be time inefficient. The Laboratory Drum procedure involves measuring noise emitted from a tyre rotating around a drum with representative road surfaces. The Drum method requires large and expensive test equipment.

The Statistical Pass-By method involves monitoring the maximum sound levels of vehicles in the 'normal traffic' as they pass-by a monitoring location on the side of the road. The Statistical Pass-By method is considered a static form of noise measurement as the microphone is in a fixed position.

To date, the most widely used measurement procedure in Australia has been the Statistical Pass-By method. ASK explored and experienced some of the restrictions from the above test methods and chose to develop Australia's first Close Proximity (CPX) method test rig. Based on our review of the test methods, the CPX appeared to have a number of advantages, which ASK chose to investigate in detail.

CLOSE PROXIMITY (CPX) PROCEDURE

The CPX procedure is a relatively new procedure for measuring tyre-road noise in Europe and the USA. As far as we are aware, it has not to date been used in Australia. The CPX procedure involves the dynamic measuring of tyre-road noise along stretches of road. The procedure emerged from the need for a tyre-road noise measurement procedure that had fewer variables present in comparison to other test methods. The CPX procedure achieves this by isolating the noise developed from the interaction between a tyre and the surface of a road and excluding other noise sources. To achieve this isolation CPX trailers usually consist of a chamber surrounding a test wheel. This chamber is treated with various materials and designed to a stage where it approaches a free field environment around the test tyre and road surface noise source.

The Close Proximity (CPX) procedure is based on the committee draft ISO 11819:2 entitled Acoustics – Method for Measuring the Influence of Road Surfaces on Traffic Noise – Part 2: the Close Proximity Method, and Sandberg, 2002.

One of the main variables controlled by the CPX procedure is the tyre type. The CPX procedure uses four reference tyres in its procedure. Each reference tyre has a different tread pattern and represents a different group of vehicles. These are detailed in Table 1 and shown in Figure 1.

Table 1. Reference Tyre Summary

Reference Tyre	Tread Pattern	Represents
Tyre A	Summer A	Summer tyres used on new vehicles
Tyre B	Summer B	Summer tyres used on older vehicles produced in the time period 1990 – 1997
Tyre C	Winter	Tyres used in winter conditions
Tyre D	Block	Heavy vehicles

Figure1. CPX Reference Tyres

The CPX procedure was first developed in Europe with the majority of current CPX trailers being developed and used in that part of the world. In recent years road and transport authorities in America have utilised the CPX procedure. To date there are no other known developments of the CPX procedure and CPX trailers in Australia.

The advantages of the CPX procedure are as follows:

- Testing is efficient & cost effective
- Enables continual assessment of long sections of road
- Ideal for comparing noise emissions from various road surfaces
- Test rig isolates tyre-road noise
- Direct measurements – minimal operator interpretation

Close Proximity Index (CPXI)

The CPX procedure measures the noise emitted from road surface / tyre interaction by using four different reference tyres. The reference noise levels obtained by the CPX procedure are developed into a Close Proximity Index (CPXI). The CPXI represents the measured noise levels for the subject section of road surface.

To correctly calculate a CPXI the following equations from committee draft ISO 11819:2 are applied:

Representing light vehicle traffic:

$$CPXL = 0.25\,LA + 0.25\,LB + 0.25\,LC + 0.25\,LD \quad [dB]$$

Representing heavy vehicle traffic:

$$CPXH = 1.00\,LD \quad [dB]$$

Representing mixed traffic:

$$CPXI = 0.20\,LA + 0.20\,LB + 0.20\,LC + 0.40\,LD \quad [dB]$$

Where: L_A, L_B, L_C and L_D are the averaged tyre sound levels calculated for each reference tyre A, B, C and D as per committee draft ISO 11819:2.

DEVELOPMENT OF THE CPX TEST RIG

After researching CPX test rigs overseas, ASK undertook the challenge to design and develop a CPX test rig. A CPX Test Rig was developed with the lengthy Australian road system and potential large travel distances as a design factor. The resulting trailer is called the 'Road Ear' and is shown in Figure 2.

The CPX test rig achieved full compliance certification in accordance with the committee draft ISO 11819:2. and is now on an even standing with other international CPX test rigs.

Figure 2. 'Road Ear' Test Rig – for CPX Testing.

CERTIFICATION OF CPX TEST RIG

To ensure a CPX Test Rig is acoustically sound in its noise monitoring it must undergo certification testing. The certification tests are outlined in the committee draft ISO 11819:2. The certification testing outlines influences the CPX Test Rig may have on noise measurements. Any influences found during certification testing are to be corrected in future measurements. The results of the certification tests and any required corrections must be published in a publicly available test report.

Influence of Sound Absorption Within an Enclosure

The first of the three certification tests assesses the influence of sound absorption within an enclosure. The test involves comparing the noise emitted from an artificial noise source placed within the enclosure against the noise emitted from the same artificial noise source in a free field environment. The differences in noise measured shall be acknowledged as the influence of the enclosure. Any influence greater than 1 dB across the one-third octave band spectra from 315 Hz to 4000 Hz shall be reported in the publicly available report and corrections shall be made in any future testing. If the uncorrected influence of the enclosure is greater than 3 dB across the one-third octave band spectra from 315 Hz to 4000 Hz then the enclosure fails the certification test and is not fit for noise measurements even after corrections. As shown in Figure 3 ASK achieved full compliance with this test.

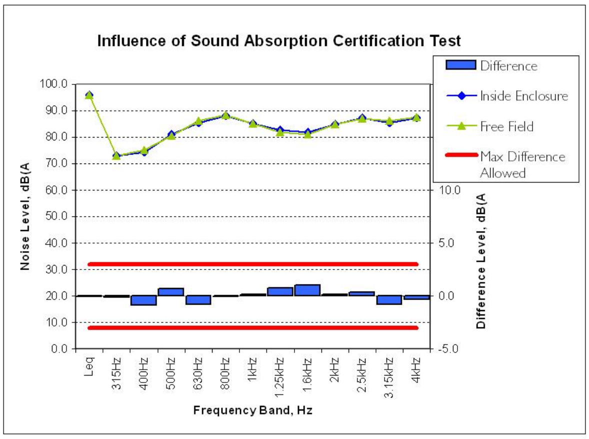

Figure 3. Summary of Sound Absorption Certification Test.

Other Acoustical Reflections

The second certification test assesses the influence of any other reflective surfaces within the enclosure. The other reflective surfaces of concern in this test include microphone holders, suspension and any other reflective surfaces other than the road. This test involves the artificial noise source again however this time the results compared are between the enclosure as it would be under normal testing conditions and the enclosure with 100mm thick mineral wool, or similar treatment, wrapped around the other reflective surfaces. The differences in noise measured shall be acknowledged as the influence of the other reflective surfaces. Any measured influence shall be no greater than 0.5 dB across the one-third octave band spectra from 315 Hz to 4000 Hz. If any one-third-octave band is over the 0.5 dB limit then the fails the test and is not fit for noise measurement.

After some initial tests it was decided to cover all reflective surfaces with absorptive acoustic treatments. This certification test is to assess the influence of any reflective surfaces within an enclosure. However due to the inclusion of acoustic treatments on all potential reflective surfaces the requirements for this test had been eliminated. However, a confirmation test proved this treatment to be successful.

Background Noise

The third certification test assesses the performance of the enclosure to reduce the intrusion of outside noise sources into the enclosure. This test involves performing two measurements along the same stretch of road. The first measurement is under normal test conditions with all three test rig wheels in contact with the road. The second measurement is performed with the test wheel suspended above the road surface and the two support wheels in contact with the road. The first measurement represents test conditions and the second measurement represents background noise conditions. The results of the two measurements are compared. The difference between the two measured noise levels is attributed to the influence of the test wheel. The requirements, outlined in committee draft ISO 11819:2 are as follows:

- for the influence of the test wheel are the difference of the overall A-weighted level needs to be at least 10 dB;
- one-third octave spectra between 500Hz – 4000 Hz being at least 6 dB difference; and
- one-third octave spectra between 315 Hz and 400 Hz at least a 4dB difference.

If the influence of the test wheel is less than any of these requirements then the enclosure has failed the test and is not suitable for noise measuring. As shown in Figure 4 ASK achieved full compliance with this test.

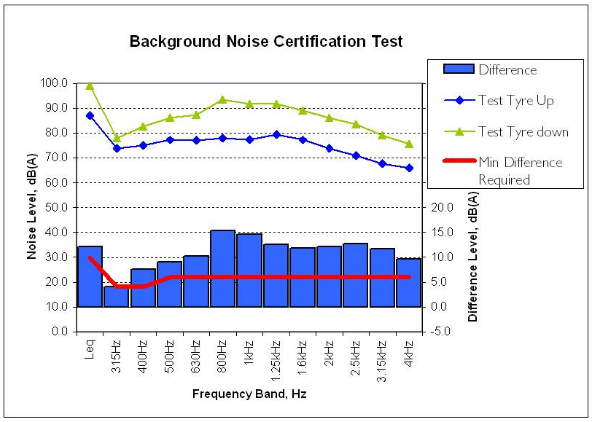

Figure 4. Summary of Background Noise Certification Test.

Certification Summary

Full compliance with the certification tests means the CPX test rig can be used to perform tyre-road noise measurements to international standards.

PRELIMINARY CPX TESTING

Preliminary results are encouraging with respect to reproducibility and integrity with other CPX test data.

The road surfaces chosen for testing were an Open Graded Asphalt (OGA) surface and a Portland Cement Concrete (PCC) surface. OGA is made up of a porous layer (usually 25mm to 45mm thick) laid over the top of a dense graded asphalt base. OGA surfaces generally have above average drainage and low noise generation. PCC surfaces are cement concrete. The surface is usually textured through various methods that increase drainage. The texture tends to increase the noise levels generated.

Preliminary CPX Results

The CPX test rig can provide output data in many different forms.

Sound level traces are one form of data output. Sound level traces are useful in identifying sections of road that differ acoustically from the norm eg. expansion joints on bridges. A representative trace for both the OGA and PCC road surfaces are shown in Figure 5 and Figure 6 respectively. The PCC road surface shown in Figure 6 indicates more variation across the length of the site than the OGA surface shown in Figure 5. This could be due to different texturing techniques along the PCC surface or due to aging of the PCC surface.

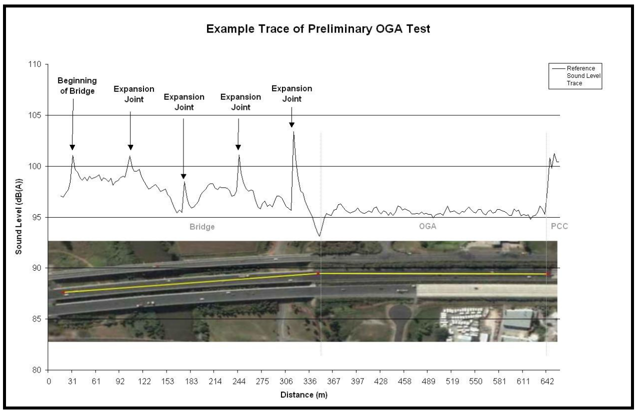

Figure 5. Example Trace of Preliminary OGA Test

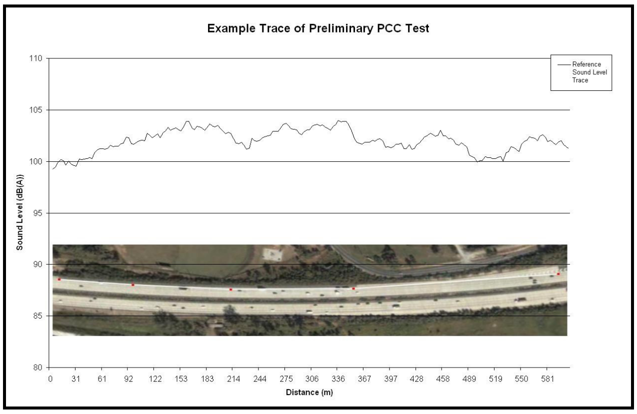

Figure 6. Example Trace of Preliminary PCC Test

Another way to analyse data output from the CPX test rig is to calculate the CPXI for the road surface. The averages for each reference tyre within a 100m CPXI test section are used to calculate a CPXI for each road surface, as shown in Table 2.

Table 2. Preliminary CPXI's for OGA and PCC at 110 km/hr Reference Speed

Pavement Surface Type	Average CPXI (dB) 110 km/hr Reference Speed
PCC	103.2
OGA	98.1
Difference PCC-OGA	5.1

The preliminary test result in Table 2 indicates that the PCC is 5.1 dB noisier than the OGA in the tested road sections. This difference is similar to that measured using other measurement procedures, and as seen in Figure 7 agrees favourably with overseas CPX test results.

Note: International data is an approximation of averages published in Jones (2005).

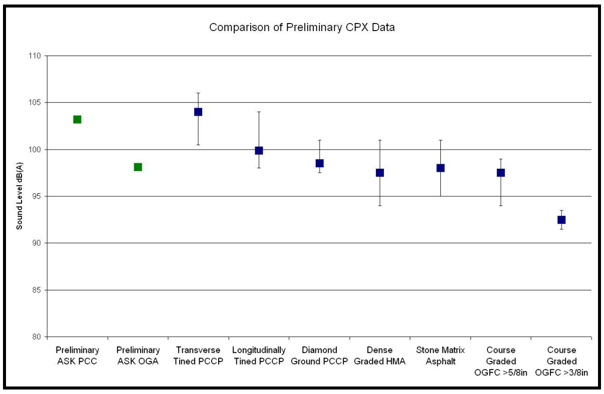

Figure 7 Comparison of Preliminary CPX Data

CONCLUSION

The CPX test rig will assist in the following relevant environmental planning related activities:

- Understanding tyre-road noise of Australian road surfaces.
- Providing details on variation in tyre-road noise level by road or air temperatures, by aging of the road surface, and by rain events.
- Assist in developing low noise road surfaces, and low noise tyres.
- Cataloguing road surface types and their road-tyre noise levels.
- Post construction compliance testing of new roads.
- Mapping of road noise levels, for integration into road authority databases.

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