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RONDA CPX Trailer Measurements in Queensland

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ABSTRACT

RONDA (ROad Noise Data Acquirer) is a CPX trailer conforming to ISO 11819-2 for the measurement of tyre-pavement noise. The trailer is of the open frame type without an enclosure. Tyre-pavement noise measurements along a major motorway in Queensland were recently undertaken to quantify noise levels for various pavement types along the motorway, which includes a variety of concrete and asphalt pavements. Measurement data was analysed to determine the tyre-pavement noise levels for each specific pavement type. It was found that tyre-pavement noise levels were not tightly grouped for the pavement types measured due to varying pavement conditions including levels of wear, presence of expansion cracks and road repairs.

1 INTRODUCTION

Various types of wearing courses on pavements have been used along the M1 Pacific Motorway in Queensland. Tyre-pavement noise measurements using the RONDA CPX trailer have been undertaken to determine the variability of noise results for the pavement wearing surfaces over an approximately 80km section of the M1 Motorway between the Gateway Motorway interchange in Eight Mile Plains and the Queensland and New South Wales border in Tugun, adjacent to the Gold Coast Airport.

2 EQUIPMENT AND INTRUMENTATION

The RONDA (ROad Noise Data Acquirer) CPX trailer conforms to ISO 11819-2 (2017) 'Measurement of the influence of road surfaces on traffic noise - Part 2: The close-proximity method' and is intended for measuring tyre-pavement noise. The trailer is of the open frame type without an enclosure, as shown in Figure 1.

RONDA incorporates two independent tyres (of the same type) fitted to a frame with no common axle. For the purpose of the noise measurements presented in this paper, SRTT tyres (Uniroyal Tigerpaw P225/60-R16) have been used (Figure 2) with a minimum tread depth of 7mm in accordance with ISO/TS 11819-3, which represent typical light vehicle tyres. The wheel-to-wheel spacing between the tyre centres is 1,690mm, which is in accordance with ISO 11819-2, and the distance between the centre of the RONDA tyres and the centre of the tyres of the towing vehicle is approximately 3,970mm. Each tyre can be independently aligned for toe and camber with variances of better than 0.2%.

For each tyre, there is a microphone located 200mm front of centre and one 200mm back of centre, spaced 200mm horizontally from the tyre sidewall and 100mm vertically from the road surface, as shown in Figure 3.

Trailer speed is measured using a Kistler Microstar II non-contact microwave sensor type CMSTRA with an operating range of 0.5 to 400km/h and a variance of 0.5%.

Tyre and road surface temperature are measured using Optris CT LT laser thermometers with tolerances of ±1degC. Ambient air temperature is measured using a Dwyer RHP OSA temperature transmitter with a tolerance of ±0.3degC. A laboratory surface thermometer type Measurement Specialties 4600 Precision Thermometer is used to measure the surface temperature of the tyres when testing durometer hardness with a tolerance of ±0.12degC. It is noted that no correction for temperature variances were applied to the measurement results as the coefficients incorporated in the ISO standard are yet to be verified for Australian conditions. Studies to obtain coefficients relevant to Australian conditions are currently planned. Nevertheless, temperature corrections would be minimal and would not affect the comparison of tyre-pavement noise levels for the various pavement types.

Tyre hardness is measured at 20±2degC using a Bareiss HP-AS Shore A Durometer. This instrument has been calibrated using a set of three test blocks for Shore A 40/60/80 duro.

The load on each tyre is measured using a Nuweigh MIL 589 weigh beam scale with has a range of 1000kg and 0.2kg resolution. The static load of the test tyres is 3200N ±200N per tyre.

The tyre and airbag inflation pressures are measured using a Dwyer DPG-200 digital pressure gauge which has a tolerance of ±0.7%. The tyres and airbag are inflated to 200kPA ±10kPa at normal ambient temperature.

The precision of all measurement equipment on the RONDA CPX trailer and the methods of measurements comply with the ISO standard.

Noise level measurements are made using a Sinus Soundbook Mark II and four GRAS 46AE microphones. This instrumentation meets the requirements of IEC 61672-1:2002 as a Class 1 instrument. The frequency range of measurements as specified in the standard is 315Hz to 5kHz. The microphones are fitted with Bruel & Kjaer UA1650 90mm foam windscreens.

At the beginning of any measurement and at the end, the measurement instrumentation is calibrated using a GRAS 42AA pistonphone sound level calibrator. The calibrator meets the requirements of IEC 60942 Class 1.

The precision of all measurement equipment complies with the ISO standard.

Figure 1: CPX Trailer RONDA Open Frame Design

Figure 2: 16" SRTT Tyre and Tread Pattern

Figure 3: Microphone Setup

3 MEASUREMENTS AND DATA ANALYSIS

The vehicle was driven at three speeds (70km/h, 90km/h and 100km/h) along each direction of the M1 Pacific Motorway. In order to maintain consistency and not be affected by traffic congestion, all measurements were conducted during the night time period and along the same single lane in each direction.

The meteorological conditions during the noise measurements were generally conducive for measuring tyre-pavement noise using the CPX trailer. However, during the measurements undertaken at 70km/h conducted on a particular night, there was light rain and damp roads for an approximately 8km section of road. Therefore, tyre-pavement noise measurements along the affected section of road have been excluded from the measurement results.

The recordings of the noise levels at the four microphone locations are made at 100ms intervals. During the pavement noise measurements, the following data is also recorded:

- tyre temperature;
- road surface temperature;
- ambient temperature;
- speed; and
- GPS location.

The energy average spectrum at the microphone positions is calculated in each one-third octave band centre frequency.

Regression analysis is conducted for each road segment of wearing course on pavement to determine the relationship between noise level and speed so that noise levels can be corrected to a reference speed.

The arithmetic average noise level is then determined over each road segment for each tyre and the arithmetic average of the left and right tyre is determined. The A-weighted arithmetic average noise level is termed the CPX noise level and is expressed in decibels.

The reported noise levels in this paper are designated as $L_{CPX:P,vr}$ where;

- L_{CPX} is the time averaged A-weighted sound pressure level of the tyre-pavement noise levels averaged for the four microphones (two per tyre) as determined by the CPX method as defined in the ISO standard, expressed in decibels,
- *P* designates that the standard light vehicle tyre (SRTT) was used for the measurements, and
- *vr* is the reference speed. The reference speed is in km/h and has been designated to be 100km/h.

4 TYPES OF WEARING COURSES

RONDA was used to conduct tyre-pavement noise measurements along various types of wearing courses on pavements along the M1 Pacific Motorway. Measurements were undertaken on both the southbound and north-bound carriageways of the road. The types of wearing courses on pavements along the subject section of the M1 Pacific Motorway are summarised in Table 1.

Table 1: Types of Wearing Courses on Pavements along the M1 Pacific Motorway (Eight Mile Plain to Tuigun)

Location ID	Approx. Length of Section (km)	Pavement Surface Description
	Southbound (Prescribed) Direction	
PS1	1.2	Stone Mastic Asphalt (SMA)*
PS2	8.3	Dense Graded Asphalt (DGA)
PS3	0.3	Open Graded Asphalt (OGA)
PS4	2.9	Dense Graded Asphalt (DGA)
PS5	4.1	Open Graded Asphalt (OGA)
PS6	0.2	Dense Graded Asphalt (DGA)
PS7	2.6	Open Graded Asphalt (OGA)
PS8	0.3	Dense Graded Asphalt (DGA)
PS9	0.4	Open Graded Asphalt (OGA)
PS10	19.3	Portland Cement Concrete (PCC) – 15 to 20 years
PS11	0.8	Dense Graded Asphalt (DGA)
PS12	7.5	Portland Cement Concrete (PCC) – 15 to 20 years
PS13	12.3	Open Graded Asphalt (OGA)
PS14	0.3	Stone Mastic Asphalt (SMA)*
PS15	1.5	Dense Graded Asphalt (DGA)
PS16	1.6	Stone Mastic Asphalt (SMA)*
PS17	4.9	Dense Graded Asphalt (DGA)
PS18	4.0	Portland Cement Concrete (PCC) – >20 years
PS19[#]	0.2	Dense Graded Asphalt (DGA)
PS20	1.3	Portland Cement Concrete (PCC) – >20 years
PS21	0.2	Open Graded Asphalt (OGA)
PS22	0.9	Dense Graded Asphalt (DGA)
PS23	0.5	Open Graded Asphalt (OGA)
PS24	1.7	Dense Graded Asphalt (DGA)
PS25	3.2	Open Graded Asphalt (OGA)

Location ID	Approx. Length of Section (km)	Pavement Surface Description
		Northbound (Counter) Direction
PN1	3.0	Open Graded Asphalt (OGA)
PN2	0.7	Portland Cement Concrete (PCC) – >20 years
PN3 #	0.2	Dense Graded Asphalt (DGA)
PN4	2.4	Portland Cement Concrete (PCC) – >20 years
PN5	2.5	Dense Graded Asphalt (DGA)
PN6	3.3	Portland Cement Concrete (PCC) – >20 years
PN7	4.1	Dense Graded Asphalt (DGA)
PN8	0.6	Stone Mastic Asphalt (SMA)*
PN9 #	0.7	Dense Graded Asphalt (DGA)
PN10	2.7	Stone Mastic Asphalt (SMA)*
PN11	12.1	Open Graded Asphalt (OGA)
PN12	7.8	Portland Cement Concrete (PCC) – 15 to 20 years
PN13	0.8	Dense Graded Asphalt (DGA)
PN14	19.4	Portland Cement Concrete (PCC) – 15 to 20 years
PN15	7.0	Open Graded Asphalt (OGA)
PN16	13.2	Dense Graded Asphalt (DGA)

Notes: * Likely to be SMA; however, unconfirmed

Data in this section not ideal due to bridge/overpass expansion joints and/or significant construction zone lane closures and vehicle speeds limited to as low as 40km/h

In addition to the measurements of the pavements along the M1 Pacific Motorway, a considerable number of tyre-pavement noise measurements using RONDA have been undertaken by Renzo Tonin & Associates along numerous pavements in NSW where Dense Graded Asphalt (DGA) wearing courses have been laid. Acoustically, DGA is accepted as the reference pavement (ie. 0dB(A) noise correction) when determining the noise performance of different pavement types. The noise level data from the DGA measurements underwent regression analysis so that $L_{CPX:P,vr}$ noise levels at the reference speed can be determined for the reference DGA pavement and compared to the $L_{CPX:P,vr}$ noise levels for the various wearing courses along the M1 Pacific Motorway.

5 MEASUREMENT RESULTS

Regression analysis was conducted using the RONDA measured data for the various speeds for each pavement type at each road section as presented in Table 1. Results indicate relatively good correlation coefficients; therefore, the regressions determined were appropriate in correcting noise levels to the reference speeds.

Using the results of the regression analysis for the various pavement types along the M1 Pacific Motorway, the tyre-pavement noise levels for the specific reference speed of 100km/h for each pavement type, including the reference DGA pavement, are presented overleaf in Figure 4 and Figure 5.

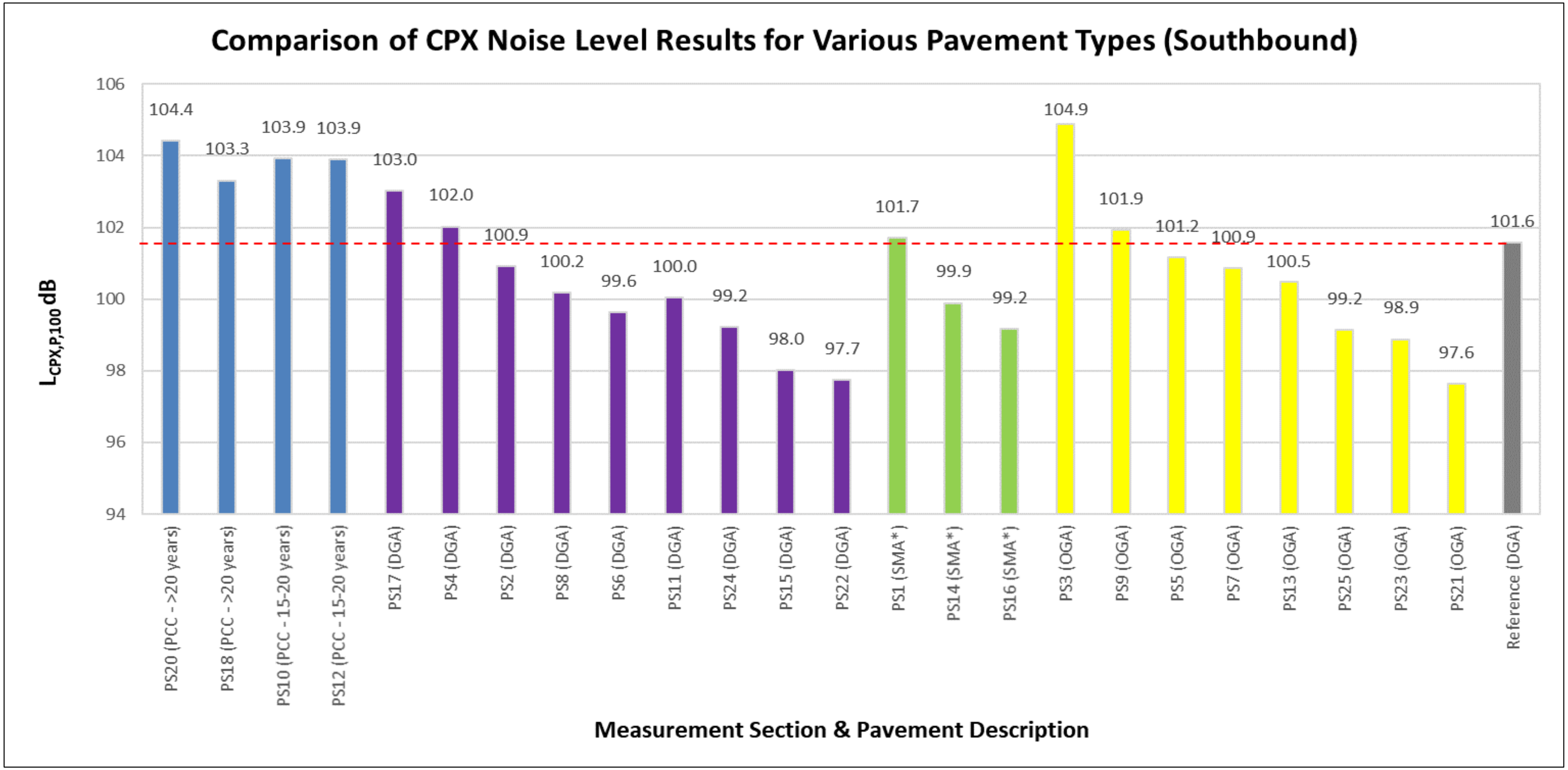

Figure 4: Comparison of Tyre-Pavement Noise Levels for Various Pavement Types (Southbound Carriageway)

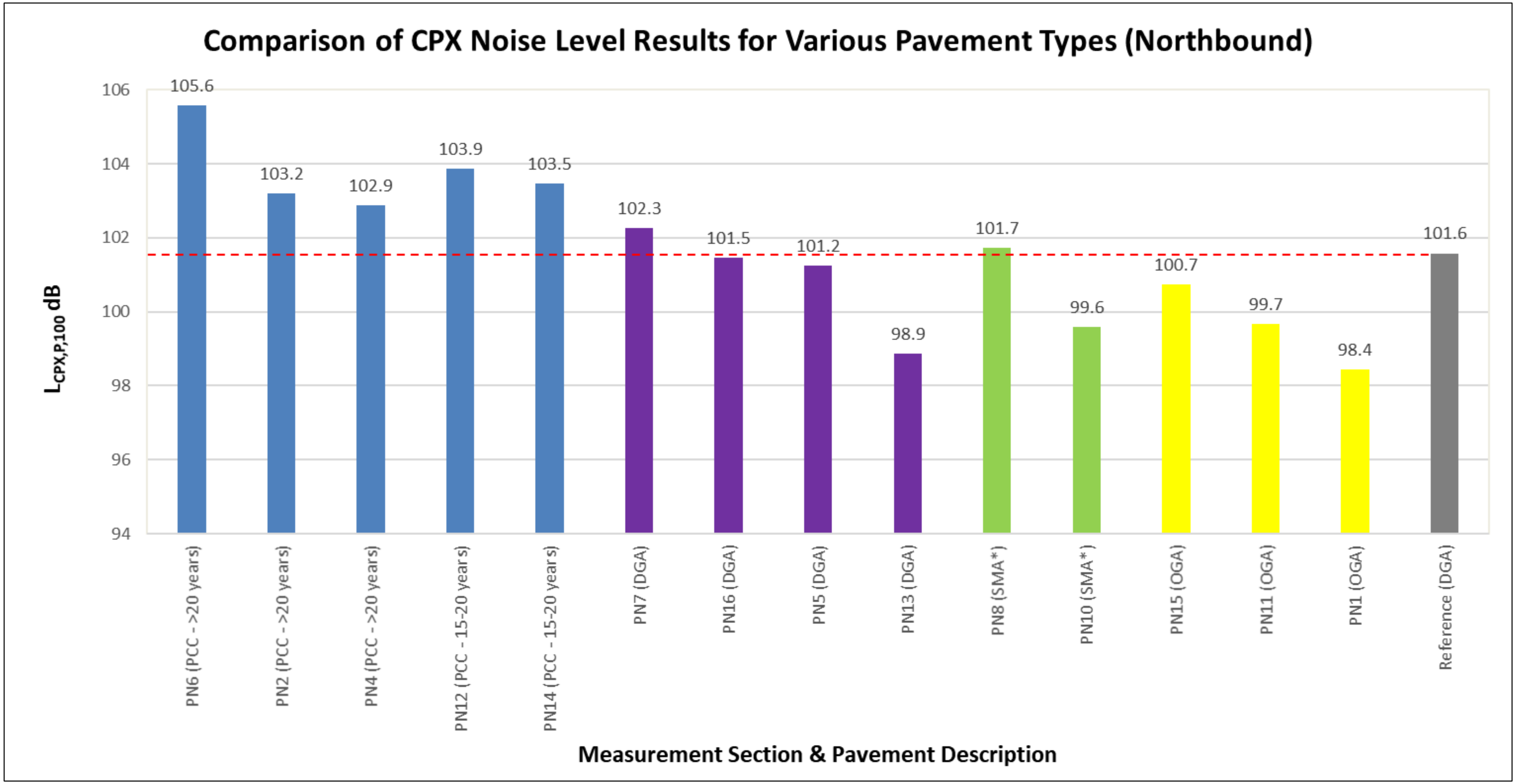

Figure 5: Comparison of Tyre-Pavement Noise Levels for Various Pavement Types (Northbound Carriageway)

From the results presented in the above figures, the CPX results show that the Portland Cement Concrete (PCC) pavements produce the highest tyre-pavement noise levels, which are up to 2.8dB(A) and 4.0dB(A) higher than the reference DGA pavement noise level for the southbound and northbound carriageways, respectively, along the M1 Pacific Motorway.

Tyre-pavement noise produced by the Dense Graded Asphalt (DGA), Stone Mastic Asphalt (SMA), and Open Graded Asphalt (OGA) pavements were found to be more varied. DGA pavements along the measurement sections were found to be between -3.8dB(A) and 1.5dB(A) higher than the reference DGA pavement noise level. SMA pavements were analysed to be between -2.4dB(A) and 0.2dB(A) higher than the reference DGA pavement noise level and OGA pavements were analysed to be between -3.9dB(A) and 3.3dB(A) higher than the reference DGA pavement noise level.

The variance in the noise levels of the asphalt pavements were likely due to different levels of wear on the pavements and the age of the pavements. It was observed during the measurements that many sections were affected by expansion cracks, road repair patches, road expansion crack sealant and expansion joints on bridges and overpasses. This is evident in asphalt pavements with higher than expected tyre-pavement noise levels and also a wider spread of data for the various measurement speeds. Furthermore, during the measurements there were some construction zones with lower speeds limits and lane closures which may have impacted the consistency of the results.

On average, PCC pavements produced the highest tyre-pavement noise levels followed by DGA pavements, SMA pavements and lastly OGA pavements. This is in line with expectations with concrete usually producing the loudest tyre-pavement noise levels and OGA producing lower tyre-pavement noise levels.

6 SPECTRAL ANALYSIS

One-third octave band spectral analysis for the various pavement sections at the reference speed of 100km/h was undertaken. For the various pavement types along the M1 Pacific Motorway, the spectral analysis in one-third octave band frequency detail for the southbound and northbound carriageways are presented in Figure 6 and Figure 7, respectively.

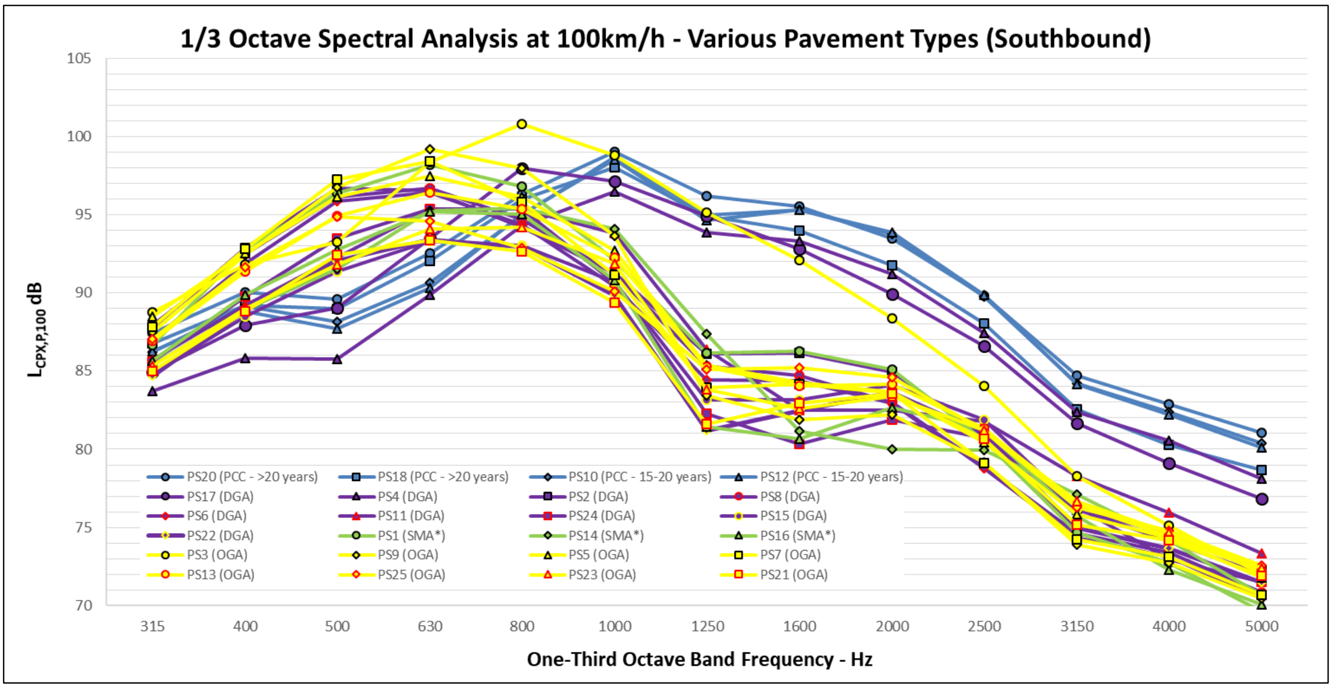

Figure 6: One-Third Spectral Analysis at 100km/h Reference Speed for Various Pavement Types (Southbound)

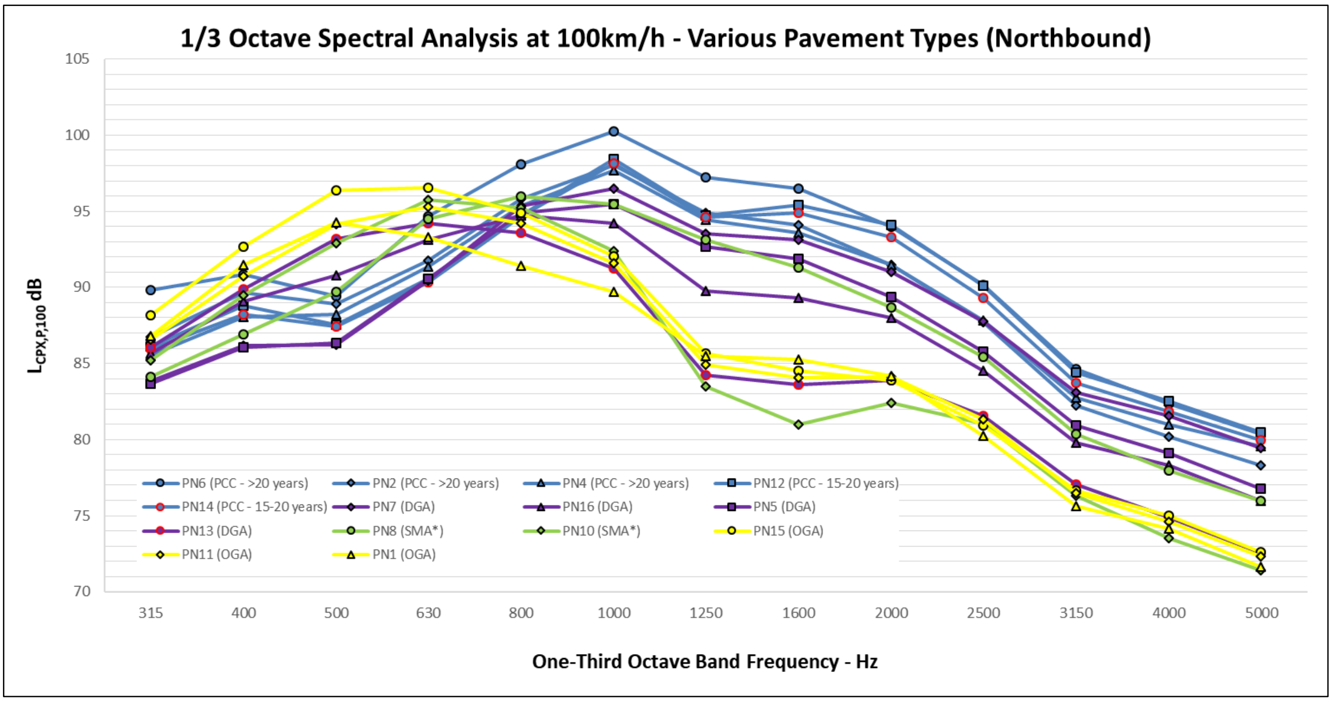

Figure 7: One-Third Spectral Analysis at 100km/h Reference Speed for Various Pavement Types (Northbound)

From the spectral comparison for the various types of wearing courses on pavements along the southbound and northbound carriageways as presented in the figures above, it can be seen that in general the Portland Cement Concrete (PCC) pavements typically produce higher tyre-pavement noise levels compared to the Dense Graded Asphalt (DGA), Stone Mastic Asphalt (SMA), and Open Graded Asphalt (OGA) pavements at frequencies from 800Hz upwards. However, at frequencies below 800Hz, tyre-pavement noise levels from the SMA, DGA and OGA pavements are higher than the PCC pavement.

Some unexpected results are apparent from the spectral analysis results, namely for pavement PS3. The spectral analysis for pavement PS3 shows unexpectedly high tyre-pavement noise levels for an OGA pavement for frequencies greater than 630Hz. This is likely due to a large amount of repairs to cracks with expansion sealant across the whole pavement section.

In general, the DGA, OGA and SMA pavements appear to have similar characteristics based on the spectral analysis with peak tyre-pavement noise levels at 630Hz frequency and dropping significantly at 1250Hz frequency. It is noted that the dominant frequencies of the tyre-pavement noise levels are generally between 630Hz and 1kHz, which is typical of the characteristics of road traffic noise.

7 CONCLUSIONS

Tyre-pavement noise measurements along an approximately 80km section of the M1 Pacific Motorway in Queensland have been undertaken by Renzo Tonin & Associates using the RONDA CPX trailer which conforms with the international standard ISO 11819-2.

Measurements of various pavement types along the M1 Pacific Motorway on both the southbound and northbound carriageways were conducted and results were analysed to determine the L_{CPX} (or L_{Aeq}) tyre-pavement noise levels. Results indicate that Portland Cement Concrete (PCC) pavements along the M1 Pacific Motorway produced the highest tyre-pavement noise levels, while Open Graded Asphalt (OGA) pavements generally produced the lowest, which is typically expected. The measurement results show that there was a large variance in tyre-pavement noise levels for Dense Graded Asphalt (DGA), Stone Mastic Asphalt (SMA) and Open Graded Asphalt (OGA) which was attributed to the varying conditions of pavements including different levels of wear, expansion cracks and road repairs.

In comparison to the reference DGA pavement the following outcomes were determined:

- PCC pavements produced higher tyre-pavement noise levels.
- DGA pavements on average had similar tyre-pavement noise levels.
- SMA pavements typically had similar or lower tyre-pavement noise levels.
- OGA pavements had mostly lower tyre-pavement noise levels; however, some sections had higher tyre-pavement noise levels.

Furthermore, spectral analysis of the noise measurement data was also undertaken in one-third octave band frequency detail. Results of the spectral analysis were as follows:

- PCC pavements produced higher tyre-pavement noise levels at frequencies from 800Hz and above.
- Although DGA, SMA and OGA pavements produced lower overall pavement noise levels than PCC, at frequencies below 800Hz these pavement produced higher tyre-pavement noise levels than PCC pavements.
- The dominant frequencies of the tyre-pavement noise levels were between 800Hz and 1kHz, which is typical of the characteristics of road traffic noise.

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