Optimising New Zealand’s State highway low-noise road surface

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ABSTRACT

Since 2017 several porous asphalt trials have been constructed in New Zealand to investigate the effects of air voids, stone size and layer thickness on tyre/road noise. These trials have shown that all three variables play an important role in noise from porous asphalt surfaces. The trial results have led to a 40 mm thick PA7 surface (porous asphalt with 7 mm nominal stone size) becoming the preferred low-noise surface for use on New Zealand State highways, with a slightly thicker 50 mm version being preferred in particularly noise-sensitive areas. Regular CPX testing is being conducted to monitor the long-term acoustic behaviour of the surfaces, and this testing has not shown any significant changes in $L_{CPX:P1,80}$ to date. Further trials are planned for early 2022 to optimise the air voids content for the preferred PA7 surface.

INTRODUCTION

Since 2017 Waka Kotahi NZ Transport Agency has commissioned a series of research projects to optimise its road surfaces for low tyre/road noise. The initial focus of this work has been “low-noise” porous asphalt surfaces, given noise can be a primary reason these surfaces are specified, and the high cost of porous asphalt surfaces compared to the more commonly used chipseal surfaces (surface dressings).

The effect of changes in air voids content, stone size and thickness have been investigated through a series of short (250–300-metre-long) trial sections.

CPX trailer system

Waka Kotahi has operated its own close proximity (“CPX”) trailer system since early 2017 (Figure 1). The system was designed and built in accordance with the draft version of ISO 11819-2 [1], which was released as an official standard in mid-2017 [2].

Work was done in 2017/2018 to verify that tyre/road noise levels measured using the CPX trailer system (e.g. $L_{CPX:P1,80}$) were representative of noise levels at the wayside (e.g. Statistical Pass-by L_{veh}) and that the Standard Road Test Tyre (SRTT / P1) ranked surfaces in the same order as a modern tyre more common on small passenger vehicles in New Zealand [3].

Additional outputs from the NZ road surface noise research programme are available on the Waka Kotahi website [4].

Previous work on NZ “low-noise” surfaces

Work done on “low-noise” porous asphalt surfaces prior to 2017 primarily used the Statistical Pass-by (“SPB”) method to monitor tyre/road noise from different road surface. While the SPB method is necessary for fully quantifying road traffic noise at the wayside, something the CPX trailer system cannot do by itself, it is both time consuming and unable to characterise the longitudinal variability without taking measurements at multiple positions along a section of road.

Figure 1. Waka Kotahi / NZ Transport Agency CPX trailer system.

Epoxy-modified porous asphalt

OECD research on extending the life of road surfaces noted that epoxy asphalt was the only material with a track record of long life performance [5]. Over the past decade the inclusion of epoxy in porous asphalt surfaces has become common practice in New Zealand and it is now a requirement on major NZ State highway projects.

Bituminous binders oxidise as they age causing the binder to become brittle over time. This eventually causes the surface to begin to lose stones or “ravel”. The inclusion of epoxy in the binder slows down the bitumen oxidation process, thereby extending the life of the porous asphalt surface beyond its typical 8-year lifespan. The higher upfront cost of the epoxy (30% more expensive) is offset by lower overall life-cycle costs. Laboratory testing suggests a 5 times increase in life and field performance of similar products on major bridges have achieved 40-year lives [6][7]. Investigations into porous asphalt surface greenhouse gas emissions have also shown a reduction in greenhouse gases when epoxy-modified binders are used over conventional binders [8].

The epoxy currently being used in NZ porous asphalt binders is based on a high-strength bend originally designed for use on bridge decks. The epoxy is diluted with local bitumen. Given that the additional strength provided by the epoxy is not the primary reason for its use, there may be future opportunities to modify the epoxy blend to achieve a more flexible binder more in line with the novel PoroElastic Road Surfaces (“PERS”).

All of the NZ surface noise trial sections constructed since 2017 have made use of epoxy-modified binders. These surfaces are denoted by the “EPA” code for “Epoxy-modified Porous Asphalt”.

NOISE TRIAL SECTIONS

The noise trial sections are at least 240 metres in length (excluding transition areas), which meets the recommended minimum test section length requirement in ISO 11819-2 of 100 metres.

The trial sections have all been incorporated into existing NZ State highway roading projects around Christchurch city, which has allowed the construction costs of the trials to be kept to a minimum.

Apart from one of the small chip trials, all trial sections are located on relatively flat terrain with either no or only gradual corners.

Posted speed limits are either 80 or 100 km/h, depending on location. CPX testing is performed at a common 80 km/h reference speed.

Surface mix designs

The recent porous asphalt noise trials have utilised existing Waka Kotahi surface mix specifications [9]. This has allowed the research team to check findings of work done before the CPX trailer system was available, and to optimise the surface mix within the bounds of existing material supply and construction constraints.

The use of existing surface mix specifications has also meant that only the normal pre-construction laboratory testing has been required. This has allowed the trial sections to be incorporated within existing roading projects at relatively short notice.

Details of the noise trials are provided in Table 1. The surface mix specifications can be found in the P/11 specification document [9] (a version of the specification covering epoxy-modified binders is to be published shortly). The default air voids content is 20-25% unless specified otherwise. “EPA7” represents “Epoxy-modified porous asphalt” with 7 mm nominal stone size.

RESULTS

High voids trial (2018)

Previous work in New Zealand investigating tyre/road noise from porous asphalt surfaces (using Statistical pass-by measurements) showed that surfaces with high voids could provide a noise benefit over those with standard voids [11]. The first trail focused on investigating this effect in a controlled setting.

The $L_{CPX:P1,80}$ results to date are given in Figure 2 and Table 2. These show consistent ranking of surfaces with the EPA10 surface (standard voids) having the lowest tyre/road noise. No significant increases in tyre/road noise have been observed over the first 4 years. The apparent downward trends are heavily influenced by the first data point, so it is too early to tell if this is a true effect or simply the result of one measurement session.

There are clear differences between the lanes despite identical mixes being used, laid one day apart by the same equipment and crew.

Mean profile depth (“MPD”) measurements performed shortly after construction show good correlation with $L_{CPX:P1,80}$ (see Figure 3). Differences in MPD between the lanes may be the cause of the difference in $L_{CPX:P1,80}$. Discussions with the contractor revealed slightly different traffic management in the 36 hours following paving, which along with the narrower width of the right lane, mean that the right lane likely received more rolling than the left lane immediately after paving.

Propagation effects such as the sound absorption properties of the surface are not captured using the CPX trailer system due to the close proximity of the microphones to the tyre/road interface. Statistical pass-by testing performed in July 2018 did not reveal an additional wayside noise reduction from the high voids section compared to other sections with regular void content [3].

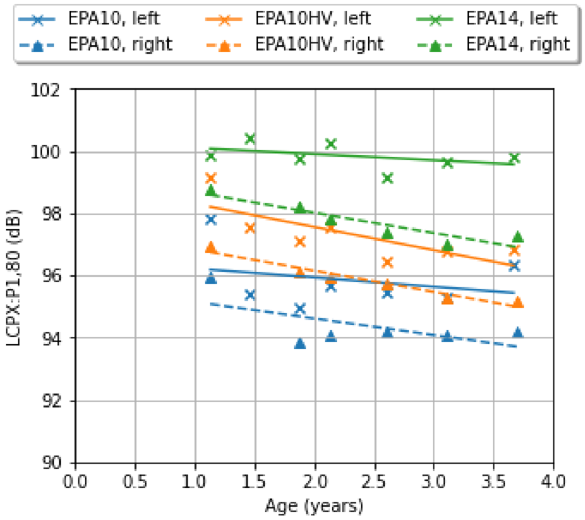

Figure 2. High voids trial $L_{CPX:P1,80}$ timeseries.

Table 1. Details of porous asphalt trial sections. All surfaces mixes are designed for 20-25% air voids unless stated otherwise.

Trial name	Construction date	Surface mix	Target thickness	Test section length	Notes
High voids trial	Feb 2017	EPA10	30mm	240m	
		EPA10HV	30mm	310m	EPA10 "high voids", 25-30% voids
		EPA14	30mm	260m	
Small chip trials	Oct 2017	EPA7	40mm	489m	
	Apr 2018	EPA7	30mm	338m	Descending bridge abutment
				365m	Ascending bridge abutment
Thickness trial	Nov 2018	EPA7	30mm	262m	
			40mm	260m	
			50mm	274m	
Low voids trial	Early 2022 *(planned)*	EPA10	*TBC*	*300m*	
		EPA7	*TBC*	*300m*	
		EPA7HS	*TBC*	*300m*	EPA7 "high strength", 12-16% voids
		EPA7VHS	*TBC*	*300m*	EPA7 "very high strength", 8-10% voids
		SMA7	*TBC*	*300m*	Stone mastic asphalt, 4% voids [10]

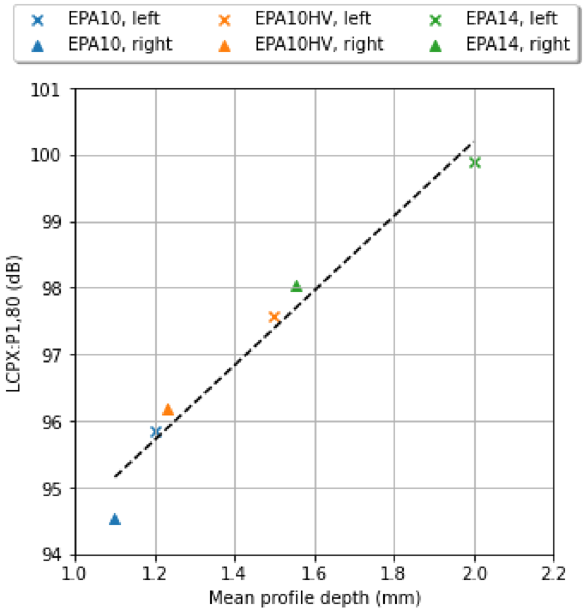

Figure 3. Relationship between mean profile depth and $L_{CPX:P1,80}$ from the high voids trial sections (all nominally 30 mm thick).

The results of the trial show that macrotexture is a strong driver of differences in tyre/road noise between different porous asphalt mixes. It is hypothesised that construction processes aimed at increasing air voids content could promote an increase in macrotexture, which may outweigh any benefits from the air voids, at least in the current EPA10 / EPA10HV mixes.

Small chip[1] trials (2017 and 2018)

The high voids trial results indicated that surfaces with higher MPD resulted in higher noise levels. It was expected that a reduction in chip size, and hence mean profile depth, would result in a surface with lower tyre/road noise.

Two separate sections were constructed in late 2017 and early 2018 by two different contractors. One section had a target thickness of 30 mm and the other 40 mm.

The $L_{CPX:P1,80}$ results to date are given in Figure 4, Figure 5 and Table 2. The $L_{CPX:P1,80}$ results from the 30 mm thick sections are approximately 1 dB lower on average than the 30 mm thick EPA10 section in the high voids trial, suggesting a slight tyre/road noise benefit for the smaller stones. The results from the 40 mm thick section were approximately 1.5 dB lower on average than the 30 mm thick sections, suggesting the presence of thickness effect.

As was the case with the high void trial sections, the EPA7 sections show higher noise levels in the left lane compared to the right lane, although the difference on 30 mm thick sections is small. The cause of these lane differences has not been investigated but is thought to be the result of differences in mean profile depth (as seen in the high voids trial) and/or as-built thickness.

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[1] Here "chip" is used as shorthand for 'maximum aggregate size'

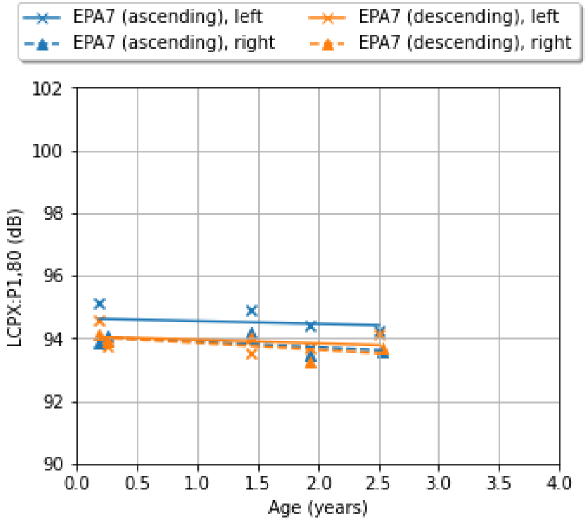

Figure 4. 30 mm thick EPA7 small chip trial $L_{CPX:P1,80}$ time series.

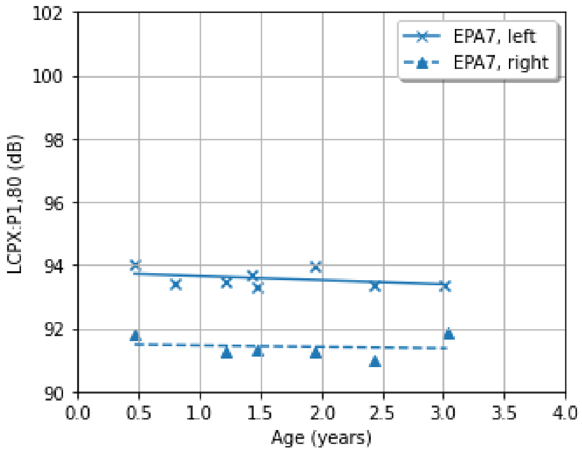

Figure 5. 40 mm thick EPA7 small chip trial $L_{CPX:P1,80}$ time series.

Thickness trial (2018)

Following on from the small chip trials there was a desire to investigate the effect of thickness on porous asphalt tyre/road noise. As well as being of interest as a bulk surface property, variations in thickness along the length of a road (with the same surface mix specification) was thought to be a possible reason for the longitudinal variability seen in $L_{CPX:P1,80}$. The topic of longitudinal variability is covered further in a companion paper [12].

The $L_{CPX:P1,80}$ results to date are given in Figure 6 and Table 2. These show a clear noise reduction with increased thickness (see Figure 7), with a target layer thickness (t, in mm) to $L_{CPX:P1,80}$ relationship of:

$$L_{CPX:P1,80} = -0.24t + 102.4$$

It should be noted that several attempts were made to measure the as-built thickness of the trial sections, but all failed to yield acceptable results [13].

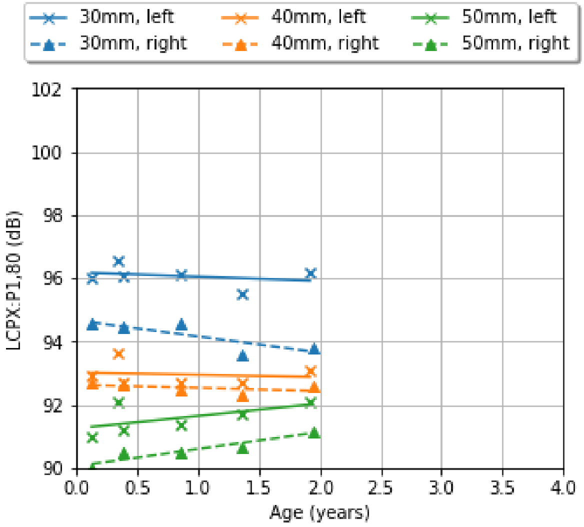

Figure 6. Thickness trial $L_{CPX:P1,80}$ time series.

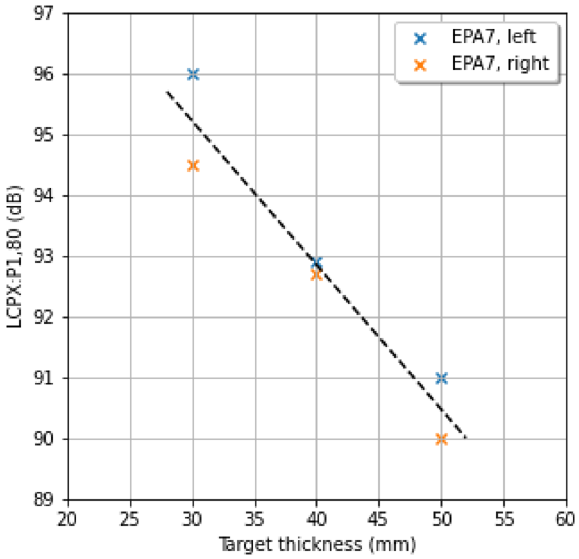

Figure 7. Target layer thickness to $L_{CPX:P1,80}$ relationship from the thickness trial.

PLANNED TRIALS

The high voids trial sections revealed a potential trade-off between macrotexture and voids. While porosity is generally considered necessary for a “low-noise” road surface, the optimal air voids content is not yet known and it may be possible to achieve lower tyre/road noise with slightly reduced air voids if there is a corresponding reduction in macrotexture. Porous asphalt surfaces with reduced air voids have higher strength than standard porous asphalt mixes, so there is also an engineering benefit from a slight reduction in air voids [9].

Several trial sections are planned on the Christchurch Northern Corridor to investigate the effects of reduced air voids. These trials are expected to be constructed in early 2022. Details of the sections currently planned are included in Table 1.

Table 2. Porous asphalt trial results. Average of all measurement sessions to date.

Trial	Mix	Target thickness	$L_{CPX:P1,80}$ (dB)	
			Left lane	Right lane
High voids trial	EPA10 30 mm	30 mm	95.8	94.4
	EPA10HV	30 mm	97.3	95.9
	EPA14 30 mm	30 mm	99.8	97.7
Small chip trials	EPA7	30 mm	94.2	93.8
		40 mm	93.6	91.4
Thickness trial	EPA7	30 mm	96.1	94.2
		40 mm	92.9	92.5
		50 mm	91.6	90.6

NZ LOW-NOISE SURFACE

Prior to these focussed porous asphalt trials a PA10 surface (nominally 20-25% air voids) was the standard "low-noise" road surface used on NZ State highways, with a high-voids version (PA10HV) or a twin-layer surface preferred in particularly noise sensitive environments.

The thickness of the PA10 / PA10HV surfaces was nominally 30 mm, but in practice was chosen by the project team and ranged between 25 mm and 40 mm (nominal thickness).
The results of the Christchurch trials to date have led to the adoption of a 40 mm thick PA7 surface as the preferred "low-noise" surface, with a 50 mm thick version being preferred in particularly noise sensitive environments. Projects already underway before these findings may still be using the older advice due to contractual restrictions, but where possible these projects are being moved over to a PA7 surface.

Research continues into optimising porous asphalts in New Zealand, but at least for now, 50 mm PA7 is the state of the art in low noise road surfaces.

ACKNOWLEDGMENTS

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