NCAT Report 08-01

SYNTHESIS OF NCAT LOW-NOISE HMA STUDIES

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André de Fortier Smit

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277 Technology Parkway Auburn, AL 36830

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André de Fortier Smit
Research Engineer
National Center for Asphalt Technology
Auburn University, Auburn, Alabama

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INTRODUCTION

The Federal Highway Administration (FHWA) sponsored a study (AU4-C2) at the National Center for Asphalt Technology (NCAT) to evaluate different low noise HMA pavement solutions. The study involved the construction and testing of 12 low noise hot-mix asphalt (HMA) pavement structures at the NCAT Test Track.

Five structures comprising coarse and fine, single and double layered open graded friction course asphalt mixtures were paved on the north-tangent at the Test Track in November 2005. NCAT Report 07-02 (*1*) reports on the design and testing of these structures. Construction of an additional seven structures on the south tangent at the test track was completed during the reconstruction efforts undertaken for the Phase 3 experiment at the Test Track late in 2006. These structures comprised a variety of HMA mixtures including dense-graded Superpave and stone-matrix asphalt (SMA) with varying nominal maximum aggregate sizes, as well as a microsurfacing and a propriety mixture donated by East Alabama Paving, the contractor on the Test Track Phase 3 reconstruction project. NCAT Report 07-03 (*2*) reports on the design and testing of these south-tangent structures.

The purpose of this report is to synthesize the findings previously reported to provide an overview of the study and to draw conclusions regarding the relative performance of the different low-noise HMA structures evaluated.

The HMA mixtures selected for evaluation as part of the study were identified based on past experience in Europe and the United States recognizing these mixtures as potential low-noise alternatives for quieter pavements. As indicated in NCAT Report 07-02 (*1*) it has been shown that modification of pavement surface type and/or texture can result in significant tire-pavement noise reductions. European highway agencies have found that the proper selection of the pavement surface can be an appropriate noise abatement procedure. Specifically, they have identified that a low noise road surface can be built at the same time considering safety, durability and cost using one of the following approaches (*3*):

1. A porous surface, such as an open-graded friction course (OGFC) with a high air void content.
2. A surface with a smooth surface texture using small maximum size aggregate.
3. A pavement-wearing surface with an inherent low stiffness at the tire-pavement interface.

The three approaches as listed above are based on underlying principles to counter noise generation at the source i.e. the tire-pavement interface. A pavement surface that is porous serves to dissipate the sound energy radiating from the source (tire-pavement contact patch) as the sound waves are reflected and hence attenuated within the pores of the surface mix. Reducing the stone size and hence the macrotexture of the surface mix would reduce the contact forces between the tire and pavement surface and the excitation of the tire. A smaller stone size could also reduce noise generated as a result of friction and adhesion contact at the tire-pavement interface. A pavement with a lower stiffness would further serve to dampen the forces applied to it.

It is generally agreed that the degree to which noise at the tire-pavement interface may be reduced ranks in the order of the approaches as listed i.e. a more significant noise reduction may be obtained by using a porous pavement than that achieved by reducing surface macrotexture. This perception was confirmed in the current study. The practical significance of reduced pavement stiffness on road noise is still unclear. The noise reduction benefits of using asphalt rubber in asphalt mixtures are well known. Asphalt rubber is manufactured by blending crumb rubber from shredded tires with asphalt binder in the so called wet- or McDonald-process. While asphalt rubber mixtures are not necessarily less “stiff” than mixtures manufactured with conventional asphalt binders, the product may be more compliant and resilient. For the current study, the emphasis was on investigating the noise reduction benefits resulting from porous pavements and those with reduced macrotexture. The benefits of reduced pavement stiffness were not investigated.

LOW NOISE PAVEMENT DESIGN

Details of the mix-design and construction of the asphalt mixtures evaluated as part of the study are included in NCAT Report 07-02 (*1*) and NCAT Report 07-03 (*2*). Table 1 shows the structure and mixtures paved on the north tangent at the NCAT Test Track. These pavement structures consisted of single and double layer porous asphalt mixtures. Sections N5 and N9 consisted of a single layer of Open-Graded Friction Course (OGFC) and Porous European Mixture (PEM) respectively, compacted to a thickness of 1.25 in. over the existing dense-graded asphalt (DGA), which was milled. The other sections consisted of double layer systems of the OGFC and PEM mixtures both with thicknesses of 1.25 in.

Table 1. Pavements Sections Constructed On The NCAT Track North Tangent

Section	N5	N6	N7	N8	N9
Layer 1 (1.25 in.)	OGFC	OGFC	OGFC	PEM	PEM
Layer 2 (1.25 in.)	DGA	OGFC	PEM	PEM	DGA

The OGFC mixture had an aggregate gradation identical to that of the Arizona Asphalt Rubber Friction Course (ARFC) but did not include asphalt rubber as a binder. The PEM mixture is a porous mixture used extensively in Georgia. Both mixtures comprised Georgia granite and a PG76-22 SBS polymer modified asphalt binder. The OGFC and PEM mixtures included a fiber stabilizer at 0.3 percent by mass of total mix.

Of particular interest was the relative performance of the so called twin layer system consisting of the finer-graded OGFC over the coarser PEM mixture. Reports are that these twin layer open-graded systems are significantly quieter than convention dense-graded systems and single layer porous systems based on European experience. Furthermore, the double layer concept is based on the idea that the finer-graded upper layer will serve as a sieve or filter preventing clogging of the underlying layer and thus extending the performance and serviceability of the system.

Seven different pavement sections were constructed on the south tangent of the NCAT Test Track including three with stone-matrix asphalt (SMA) and two with dense-graded Superpave mixtures with varying nominal maximum aggregate sizes. A micro-surfacing and a proprietary OGFC donated by the East Alabama Asphalt Plant (EAP) were also paved. Table 2 shows the south tangent structures and mixtures.

Table 2. Pavements Sections Constructed On The NCAT Track South Tangent

Section	S2	S4	S5	S6	S7	S8	S9
Layer 1 (2 in.)	EAP	4.75 DGA	9.5 DGA	<4.75 SMA	4.75 SMA	9.5 SMA	Micro
Layer 2	Existing Track						

These mixtures were paved to a thickness of 2 in over an existing DGA that was milled. All of the mixtures comprised a PG76-22 SBS polymer modified asphalt binder with Georgia granite.

As indicated in NCAT Report 07-03 (*2*), the design gradations of the study mixtures were developed based on experience using Georgia aggregates. For the 4.75 mm SMA, there was not an aggregate size that would provide, or could be blended to provide, the desired gradation. Therefore available aggregate sizes were blended to get as close as possible to the desired gradation without having to special crush and size material. These particular gradations are therefore different to those recommended for 4.75 SMA mixtures in a previous NCAT Report (*4*) – the design and gradation used for an asphalt mixture will be influenced by the materials used.

After paving of the mixtures on the south-tangent at the Test Track it was clear from visual assessments that the surfaces of the mixtures paved on sections S4, S5, S6 and S7 appeared flushed with very low macrotexture. It was confirmed from cores taken from these sections that the as-built gradations of these mixtures varied significantly from those as designed – the as-built pavements having dust or filler contents that were 3-6 percent higher than designed. Consequently, the noise performance of the finer 4.75 and 9.5 mm DGA and the 4.75 and <4.75 mm SMA mixtures as tested do not necessarily reflect those as designed. This shortcoming, although unfortunate did provide evidence indicating the noise performance of asphalt mixtures with very low macrotexture. Table 3 shows the macrotexture of the mixtures from the various sections at the Test Track determined using the circular-texture meter (CTM) expressed in mean profile depth (MPD) in units mm.

Table 3. Surface Macrotexture (MPD, mm) Of Noise Sections Using The CTM

Section	N5	N6	N7	N8	N9	S2	S4	S5	S6	S7	S8	S9
Mean, mm	0.83	0.83	0.83	1.54	1.54	1.19	0.11	0.12	0.10	0.15	0.58	1.04
Stdev, mm	0.20	0.20	0.20	0.31	0.31	0.26	0.02	0.02	0.05	0.03	0.15	0.25

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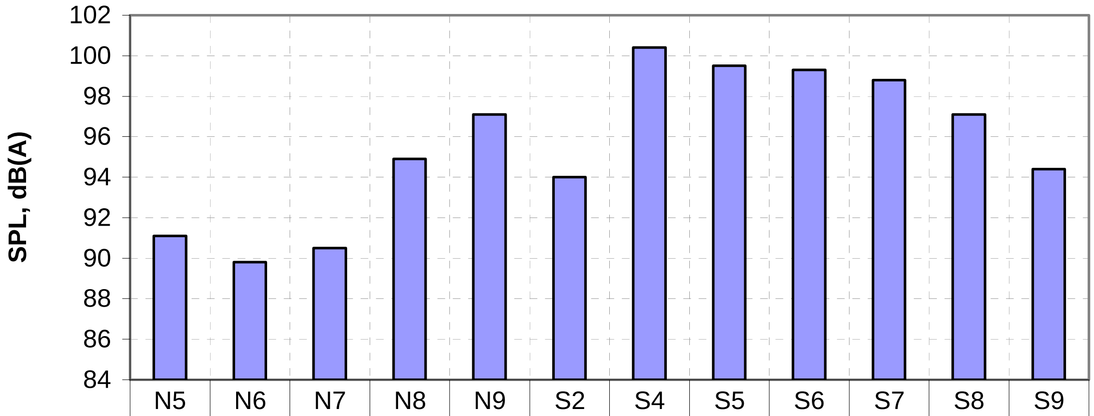
Details and results of the noise testing done on the sections are reported in NCAT Reports 07-02 (*1*) and 07-03 (*2*), for mixtures on the south- and north-tangents at the Test Track respectively.

Figure 1 summaries the global sound pressure levels as measured on the various Test Track sections. These sound pressure levels were measured with the close-proximity NCAT noise trailer at a speed of 60 mph using the new Michelin Standard Reference Test Tire (SRTT).



	N5	N6	N7	N8	N9	S2	S4	S5	S6	S7	S8	S9
SPL	91.1	89.8	90.5	94.9	97.1	94.0	100.4	99.5	99.3	98.8	97.1	94.4

Track Section

Figure 1. Summary Of SPL Measured On Track Sections

The figure indicates the relative noise performance of the mixtures on the different sections. Overall there is about a 10 dB(A) difference between the quietest and noisiest section tested. The best performers were the double layer OGFC mixture on section N6, the twin layer structure on section N7 and the single layer of OGFC on section N5 – all of which comprised open-graded or porous asphalt mixtures. Impedance tube measurements were done to ascertain the degree of sound absorption of the respective mixtures. As expected, each of the porous mixtures indicated significant levels of sound absorption, whereas the DGA and SMA mixtures offered negligible sound absorption. Furthermore it was seen in the impedance tube measurements as well as in the frequency-spectra plots of the sound levels measured on the double layer porous asphalt mixtures that these structures tended to absorb sound levels within the frequency range spanning from 800 to 1,200 Hz. This range is critical given the sensitivity of the human ear to these frequencies and the well-known peak in sound levels at a frequency of 1,000 Hz that is typically evident on dense-graded asphalt pavements.

The worst performers of those evaluated were the mixtures on sections S4 through S7 that had particularly low surface macrotexture. This illustrates clearly the noise reduction benefits of porous pavements and the negative influence of too low a surface macrotexture that may lead to air pumping beneath passenger vehicle tires.

An interesting noise response was found when comparing sound intensity measurements of passenger and truck tires on the surfaces with very low surface macrotexture. When truck tires were used, the pavements with very low surface macrotexture were relatively quieter than the other surfaces tested. This finding was contrary to the results when passenger vehicle tires were used. It is believed that this is as a result of the wider and deeper tire treads on the truck tires that would alleviate or reduce air pumping beneath these tires.

The findings of the study indicated that while too low a surface macrotexture led to increases in noise levels for passenger vehicle tires, a reduction in macrotexture did decrease the noise levels for the porous mixtures when comparing the sound levels measured on the OGFC mixtures relative to the PEM mixtures.

Layer thickness appears to have a significant influence on noise levels, particularly for the coarser PEM mixtures when comparing the difference in noise levels as measured on section N8 with the double PEM layer and N9 with the single PEM layer. The same was true, albeit to a lesser extent, when comparing the noise levels for the single and double layer OGFC mixtures on sections N5 and N6. This finding suggests that the influence of layer thickness on noise reduction should be considered when designing porous mixtures as low-noise alternatives.

Unfortunately, given that the as-built gradations of the DGA and SMA mixtures as-tested were not as-designed, no inferences can be drawn regarding the noise influence of nominal maximum aggregate size.

CONCLUSIONS AND RECOMMENDATIONS

The findings of the low-noise HMA study clearly indicated the noise attenuating properties and benefits of porous asphalt pavements. Furthermore, consideration should be given to the layer thickness of these pavements, which appeared to significantly influence tire-pavement noise. While not the original objective of the study, the negative impact on road noise of too low a surface macrotexture for DGA and SMA mixtures was well illustrated. Other than this finding, no conclusions can be drawn regarding the noise performance of these mixtures given the difference in the gradations of the as-built and as-designed mixtures. It is recommended therefore that the experiment on these mixtures be repeated to further investigate the influence of nominal maximum aggregate size and macrotexture on tire-pavement noise. It is further recommended that the influence of mixture stiffness be evaluated – one of the low-noise pavement approaches not investigated in the present study.

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