Noise Reducing Thin Asphalt Layers in an Urban Environment: a pilot study in Antwerp

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ABSTRACT
The City of Antwerp has initiated a pilot project on thin noise reducing asphalt layers in an urban environment. The aim is to investigate the behaviour of the asphalt layers from a noise perspective with respect to urban (lower speed) traffic without neglecting the mechanical durability.

Five thin asphalt layers are selected, and compared with a reference section. The laying has been followed extensively by visual inspection and surface and internal temperature measurements during laying and compaction. Sampling of bulk materials of the distinct sections serves for a granulometry check and laboratory ravelling tests on sample specimens.

Periodically the test sections are monitored by texture, CPX and rolling resistance measurements. At the acoustically best performing test sections, an initial reduction of 4 up to 5 dB(A) is detected by the CPX method using P1 tyre at 50 km/h. Also lower MPD and rolling resistance values are measured on the thin asphalt layers.

The major concern in the STOLA project is to learn about a good balance between the noise reducing capacity of the chosen thin asphalt layers, a limited degradation of the noise performance during its lifetime and a good mechanical performance delaying ravelling and texture changes as long as possible.

Keywords: Road traffic noise, Thin asphalt layers, Low noise pavement

1. INTRODUCTION

Within the context of the European Noise Directive 2002/49/EC, member states are forced to establish not only noise maps, but also action plans. One of those actions is to deepen the knowledge about noise friendly road surfaces. Noise reducing road surfaces are considered as a cost-efficient measure for traffic noise abatement, and especially in an urban environment where noise barriers from a practical perspective are (most likely) not an option.

One of the incentives for this pilot study, with acronym STOLA, was the experience and knowledge gained within a previous pilot project with noise reducing asphalt layers installed in 2012 on the road network of the Flemish Road Authorities in Kasterlee, with the objective of integrating noise friendly bituminous wearing courses in the Flemish road surface tender specifications.

The City of Antwerp intends with this pilot project to demonstrate that thin noise-reducing asphalt layers – practically, according to the Flemish tender specifications, thin asphalt layers (TAL) with a maximal nominal thickness of 30 mm - can also reduce noise in an efficient way in an urban environment.

The acoustical quality of the asphalt surfaces is monitored in time by Statistical Pass-By (SPB) and Close-ProXimity (CPX) measurements. Texture measurements performed with laser profilometer are linked to the noise measurement results.

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The focus of the project is on the noise viewpoint, although also mechanical performance is taken into account in the overall assessment. An important performance characteristic of TALs is the ravelling sensitivity. The ravelling performance was not only an indicator in the tendering, but is also checked via laboratory tests and will be monitored by periodic visual inspection.

The STOLA project of testing and analysing the global performance of the thin noise-reducing asphalt layers is carried out by the consortium consisting of University of Antwerp (UA) and the Belgian Road Research Centre (BRRC).

2. CHOICE OF THIN ASPHALT LAYER TEST TRACKS

2.1 Lessons learnt from test tracks in Kasterlee

The STOLA project presented in this paper relies on experience gained in a previous pilot project regarding the acoustical quality and durability of thin noise reducing asphalt layers. Ten test sections were installed in May 2012 on the N19, a regional road in Kasterlee (Belgium) with the objective of integrating noise friendly bituminous wearing courses in the Flemish road surface policy in a later stage.

Eight test sections were paved with hot laid, bituminous wearing courses with a thickness of maximum 30 mm and a maximum content of accessible voids of 18 %. The other two sections consisted of a double layer porous asphalt (PA) and a stone mastic asphalt (SMA10) (reference section).

The acoustical quality of the asphalt surfaces was followed up in time. Statistical Pass-By and Close-ProXimity measurements were performed according to ISO 11819 within certain time intervals to follow up the evolution. Texture measurements performed with laser profilometer according to ISO 13473 were linked to the noise measurement results. Also other important factors, like durability, were studied. Resistance to ravelling and adhesion to the base course were studied in the laboratory and linked to the evolution on site and to the evolution of the noise measurement results, as reported by Bergiers et al. (1)(2)(3).

The findings of the Kasterlee project were useful for the STOLA project. The acoustical durability in Kasterlee was disappointing. While at the beginning noise reductions of 1 to 7 dB(A) with respect to SMA10, after four years almost no noise reduction is left for most TALs. The TALs showed noise increases of 0.05 to 0.20 dB(A) per month with CPX measurements while other research, e.g. from Denmark (4) showed increases of only 0.05 to 0.06 dB(A) per month. In the QUESTIM project a noise evolution of 0.03 and 0.06 dB(A) per month is reported for a semi open TAL in Dutch and French research respectively (5). Noise increase can be related to ravelling, besides other factors such as clogging of voids and texture changes. Ravelling is clearly linked to the composition of the mixtures and the high void content. The results indicate that it is difficult to realize excellent noise reduction and durability at the same time. The best compromise between these goals should be sought. A well thought choice should be made based on the characteristics of the construction site. TALs are not applicable at urban road crossing or where vehicles exert high shear forces on the surface layer. Extra attention is given to this in the STOLA project. The construction is also crucial to guarantee a long lifetime. Care should be taken as TALs are very sensitive to weather conditions during paving. Rain during construction in Kasterlee led to the early failure of certain TALs.

As the construction is crucial to guarantee a good durability, the paving of the test sections within STOLA has been followed up closely. By doing so it will be possible to relate problems which show up at a later stage with difficulties encountered during construction.

The experience gained with monitoring in Kasterlee is used to establish the measurement program for STOLA.

Roads in an urban environment are more subject to shear forces and raveling than regional roads. Therefore asphalt mixes were chosen with a not too high void content. The TALs which started to ravel at an early stage in Kasterlee were avoided for Antwerp. Additionally the test locations were carefully selected.

The city of Antwerp intended to realize five different TALs. To be able to compare noise and mechanical performance results between TAL sections under the same traffic conditions, they are
realized consecutively on a stretch, similar as in the Kasterlee pilot project, in sections of ~150 to ~220 m.

2.2 Tendering process

In order to address the widest TAL choice and best practice in the tender process, city of Antwerp opted not for a classical lowest bid procedure, but for a two stage tender process.

In a first step of the tender process, contractors were asked to prove their experience with laying of TALs. In a second step, a limited number of contractors were selected and could deliver a final offer. This offer was then assessed by multiple criteria:

- Diversity of proposed noise reducing thin asphalt layers
- Quality of the proposed TALs, related to noise reducing capacity and raveling sensitivity (laboratory test proven)
- Proposed plan of action for the construction of the TALs. Built-in measures (such as automated compaction follow up) to ensure the best laying conditions
- Price

As a good balance between noise and mechanical performance is envisaged, an option would have been to require the values as stated in the new tender specifications from the Flemish Road Administration (6). However, as noise as well as raveling performance is expressed sometimes differently, especially in Belgium compared to Holland, it is chosen to allow in this second step of the tendering any proof of noise and mechanical durability of the TALs, without explicit numeric requirements.

For the STOLA projects, finally two test locations for the TALs are chosen, Zandvliet and Wilrijk. For both test site locations there is a reference section. All TALs are applies on both test locations, to make sure periodic comparison between TALs at one test location is not biased by differences in traffic load. In Zandvliet this is a SMA10 with a modified binder. The reason to choose this reference originates from the current practice at the city of Antwerp to use SMA as wearing course for renovations nowadays. In Wilrijk the existent wearing course was still in good condition to be used as reference section. There, the reference is a DAC10, a dense asphalt with maximal 10 mm aggregate size.

All selected TALs have a lower maximal aggregate size of 5.8 to 6.3 mm and void contents between 5% to 6.6%.

Other considerations, among others, to take into account in the choice of the test locations were:

- Typical urban street, representative for a situation where noise reducing pavements are considered in the city of Antwerp
- Special care to limit heavy mechanical impact on the TALs. Locations with frequent bus stops and many heavy vehicles are excluded.
- Speed limit 50km/h. The Mobility Plan of Antwerp forsees to limit the maximum speed to 30km/h at some locations. Knowing that below 30 to 50km/h (depending on other parameters) engine noise becomes predominant for passenger cars, reducing tyre pavement noise is only useful when the speed limit is 50 km/h, the maximal speed in Flanders in an urban environment.
- Practical considerations to limit nuisance (such as traffic diversion) for residents during constriction.

The first test site is located at the Zandvlietse Dorpstraat in Zandvliet (Figure 1), in a northern district of Antwerp. It concerns a street with mainly detached houses and low traffic of cars, and a very limited number of heavy vehicles passes.
The second test site is located at the Kleine Doornstraat in Wilrijk (Figure 2), a southern district of Antwerp. This street with two separate lanes contains mostly terraced or semidetached houses, has a higher traffic intensity and a larger number of heavy vehicles.

The road works are awarded to three different contractors, posing together eight different TAL sections in totally ten test sections. COLAS VBG (Belgium) applied sections with Rugosoft, Microville and the reference SMA10 section, Dura Vermeer (the Netherlands) applied sections with Micropave and Nobelpave and Rasenberg (the Netherlands) applied sections with Decipave.
Table 1  TAL summary at test locations

<table>
<thead>
<tr>
<th>Test location</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zandvliet (location A)</strong></td>
<td></td>
</tr>
<tr>
<td>TAL-A1</td>
<td>164</td>
</tr>
<tr>
<td>TAL-A2</td>
<td>153</td>
</tr>
<tr>
<td>TAL-A3</td>
<td>167</td>
</tr>
<tr>
<td>SMA-A</td>
<td>147</td>
</tr>
<tr>
<td><strong>Wilrijk (location B)</strong></td>
<td></td>
</tr>
<tr>
<td>TAL-B1</td>
<td>211</td>
</tr>
<tr>
<td>TAL-B2</td>
<td>206</td>
</tr>
<tr>
<td>TAL-B3</td>
<td>201</td>
</tr>
<tr>
<td>TAL-B4</td>
<td>212</td>
</tr>
<tr>
<td>TAL-B5</td>
<td>222</td>
</tr>
<tr>
<td>DAC-B</td>
<td>212</td>
</tr>
</tbody>
</table>

3. REALISATION OF LOW NOISE TEST TRACKS

3.1 Visual inspection during construction

The construction of all TALs took place the first week of October 2016, by the contractors COLAS VBG (from Belgium), Dura Vermeer and Rasenberg (from the Netherlands).

The laying of the TALs has been extensively followed by a combination of visual inspection and temperature measurements. Following tasks were done by the asphalt division of BRRC:

- Follow-up of the paving works
- Infra-red surface temperature measurements after the asphalt finisher passage
- Thermo-couple temperature measurement from the moment of laying till the completely cooled down TAL.
- Sampling of bulk asphalt for laboratory granulometry and bitumen contents control
- Laboratory ravelling tests on test plates compacted from site bulk material, by the Darmstadt Scuffing Device (7).

3.2 Temperature measurement during construction

With the infrared camera the homogeneity of the temperature just behind the finisher is detectable. As an example, the surface temperatures are shown just after a passage of the asphalt finisher (Figure 3). Temperature differences can be detected in Figure 3(left), and are caused by the presence of colder asphalt chunks in the finisher hopper. Figure 3(right) clearly shows the effect of a standstill of the finisher, possibly resulting in a weak spot for durability.

During the visual monitoring, possible decrease in durability in the future will also be checked with the events observed during the TAL construction.

![Figure 3 IR surface temperatures after finisher passage](image)
Monitoring of the cooling of the asphalt after laying and during compaction, gives input on the available time frame for optimal compaction, based on the current air temperature and wind, and asphalt bulk temperature. Measurements show that the time frame between laying and an asphalt temperature -measured with a thermocouples at the middle of the thickness of the TAL- lower than 90 °C, is divergent, ranging from 4 to 16 min. When considering the time frame till a temperature lower than 50 °C, the range varies from 16 min to 55 min. This implies that climatological conditions have to be ideal to leave enough time for an ideal compaction. More data can be found in the project report (8).

![Thermo couple at mid-thickness of TAL](image)

### 3.3 Laboratory tests

Bulk material of all TALs are tested to check granulometric characteristics and bitumen contents (more info in (8)), but also test specimens were fabricated for laboratory ravelling tests. The test equipment used at BRRC for the ravelling test is the DSD (Darmstadt Scuffing Device) (Figure 5). This device measures the mass loss of a specimen of 26 cm² after a specified number of movements of a loaded pneumatic tyre on the specimen (moving with a combination of translations and rotations), and simulates the mechanical effect of turning, braking or accelerating vehicles (7). Results are to be compared with visual inspection data in the future of the TAL’s durability.

![Darmstadt Scuffing Device at BRRC](image)
4. MONITORING OF LOW NOISE TEST TRACKS

4.1 Noise measurements

4.1.1 Close proximity measurements

Standard ISO 11819-2 (9) describes the CPX or Close-Proximity method. Tyre/pavement noise is measured by driving over the road surface with a trailer. The main purpose of the CPX-method is to evaluate the noise production and homogeneity of the road surface over a certain distance. The CPX trailer of BRRC is used in this study. Two times two microphones are mounted close to the tyre/road contact in two acoustic isolated chambers which are attached to the trailer. Measurements are performed at reference speed 50 km/h and additional speed 30 km/h with two different reference tyres, namely Standard Reference Test Tyre (P1) and Avon AV4 (H1) according to ISO/TS 11819-3 (under preparation), representative for car and truck tyres respectively. The speeds were chosen as they are typical speeds in the city. Three runs are performed for each test section, reference tyre and speed. As a result the noise levels of 20 m road sections and the noise level of the total test section \( L_{CPX,tyre,speed} \) including noise spectra are obtained.

All results are corrected for temperature to a reference temperature of 20°C. A temperature correction coefficient of -0.10 dB(A)/°C is used by Bühlmann et al. (10)(11). No surfaces are considered to be porous. The air temperatures range lies between 12 and 21 °C.

The noise levels of all sections are shown in Figure 6 for one and six months after construction. The acoustical quality during the first six months remains stable for all TALs. Only for the reference SMA 1dB(A) difference is noticed, but the measurement driving direction at test location A was different at 6 months and also texture differences between both driving directions were noticed for SMA.

At 50 km/h initial noise reductions of 2.4 to 5.4 dB(A) are obtained for the TALs with P1 tyre and 1.8 to 4.1 dB(A) with H1 tyre with respect to the SMA reference. It is seen that for tyre P1 the reduction for TAL-1 (both at location A and B) has the lowest reduction compared to the reference, also confirmed by texture measurements. The lower texture dependency of tyre H1 compared to P1 can be observed.

At 30 km/h similar initial noise reductions are obtained for the TALs. The CPX speed of 30 km/h is not present in standard ISO 11819-2 because of possible parasitic effects due to background noise, but is carried out anyhow to verify the tendency at a lower speed.

4.1.2 Statistical Pass By measurements

Standard ISO 11819-1 (12) describes the Statistical Pass By (SPB) method. Following the standard the speed and the maximum sound pressure level of minimum 100 cars and 80 heavy vehicles are measured. The measurement is performed during their passage in front of a microphone which is installed next to the road surface of which the acoustic quality has to be assessed.

However at both test locations the proximity of houses is problematic to fulfil the conditions of the ISO Standard. In Zandvliet the houses are built so close to the road that it is not possible to respect the 7.5 m distance between microphone and vehicle which is required to perform SPB measurements according to the standard. In Wilrijk SPB measurements have been carried out using a backing board.
according to ISO/PAS 11819-4 (13) to eliminate the influence from acoustic reflections from the rear of the measurement position. However, it should be noted that even with the backing board measurements do not fulfil true free-field conditions, but only serve to confirm the CPX measurements.

SPB measurements were performed by a master student from UA with the equipment from and under the guidance of a researcher from BRRC. The results are reported in (14). Noise reductions between 3.8 to 5.2 dB(A) are measured for cars compared to the original road surface DAC for a reference speed of 50 km/h.

### 4.2 Texture measurements

Texture is measured with the dynamical laser profilometer of BRRC following standard ISO 13473 (15). The laser combines a high sampling frequency (78 kHz) with a small diameter of laser beam (0.2 mm). The laser profilometer has a vertical measuring range of 64 mm and consists of a 16-bit system. The vertical resolution is 1 μm. Tests for this study were performed at a low speed in the right wheel track with a step size of 0.2 mm.

In Figure 7 the texture spectra results of the measurements one month after construction are shown. No significant differences are found between the same TAL mixes which are constructed at the two test locations (e.g. between TAL-A1 and TAL-B1). Therefore here only the average values are shown for the various mixes. No significant change is measured six months after construction so these results are not shown here. The texture spectrum of TAL-1 is clearly deviating from the other TALs.

![Figure 7 Texture spectra of various TALs and reference surfaces one month after construction](image)

In Figure 8 the MPD values are presented. The old reference DAC has very low MPD values, while the new reference SMA has the highest value. One TAL type lies close to SMA at the two test locations, namely TAL-A1 and TAL-B1. CPX values using P1 tyre also showed the lowest reduction with respect to the reference, for TAL-1 (see Figure 6). All the other TALs have similar MPD values which are lower.
4.3 Periodic surveys of residents

Besides the previously discussed measurements, another research task includes the assessment (and measurement) of the change of nuisance for the residents due to perceived noise after the change towards a noise reducing pavement. It may be clear that not only the measured values but also other factors interfere. For the psychological assessment of the noise measures with residents and the polling techniques used for this purpose, is referred to (15).

4.4 Rolling resistance measurements

Rolling resistance measurements are performed with the BRRC trailer, see Figure 19 (left). The trailer is designed as a quarter-car with a common car-suspension. It is connected to the measurement vehicle with bolts and has a fixed and a movable frame. At the end of the movable frame the extra load is attached. The total vertical force exerted on the tyre by the trailer is 2 kN.

The principle of these measurements is shown in Figure 9 (right). The tyre can lean backwards and forwards thanks to the hinged connection with the fixed frame. During the measurements the tyre is pulled backwards as a result of the rolling resistance force (R). This results in the angle \( \theta \) which is measured. The rolling resistance coefficient \( C_r \) is the proportion of the horizontal force (rolling resistance force, R) to the vertical force (vertical load, \( F_z \)). This corresponds to the tangent of the measured angle \( \theta \) which may be approximated by \( \theta \), itself expressed in radians as it is a small angle.

The trailer has an enclosure that can prevent the tyre air drag from affecting the results. It is equipped with several sensors to register different parameters during the measurement, e.g. inclination \( \theta \) of the wheel carrier with respect to the frame of the trailer, inclination of the frame of the trailer with respect to the horizontal plane, inclination between the trailer and the towing vehicle, …

Measurements are performed at 30 and 50 km/h in Wilrijk with H1 tyre, the same reference tyre type as used for the CPX measurements. In Zandvliet only measurements at 30 km/h with H1 tyre were performed because of safety reasons in the narrow street under traffic and the difficulty to close down
the street. Three runs are performed and an average value for the whole test section is calculated. The results for the measurements in Wilrijk at 50 km/h are shown in Figure 10. The $C_r$ of DAC is similar to the one measured in Zandvliet on SMA. It is not shown in this figure because the measurements were performed at 30 km/h in Zandvliet.

The references have the highest rolling resistance. It is clear that all TALs have lower rolling resistance. TAL-B1 is followed by TAL-B4 and TAL-B2. Tal-B3 and TAL-B5 have a similar rolling resistance which is the lowest. The results are closely related to the MPD results (see Figure 8). There also for the TAL the highest MPD of TAL-B1 was followed by TAL-B4 and TAL-B2, while TAL-B3 and TAL-B5 showed the lowest MPD. SMA yields the highest MPD and also the highest $C_r$. Only the result of DAC is inconsistent with a low MPD value and a high $C_r$. As it is an older pavement, perhaps unevenness may have caused the measured high rolling resistance.

![Figure 10](image)

Figure 10 Rolling resistance results with P1 at 50 km/h for the test sections in Wilrijk

5. FINAL REMARKS

The pilot project envisages to learn more on the behavior of noise reducing thin asphalt layers in a typical urban environment, where speed is rather low. After a two-stage tendering process, contractors with experience in laying TALs where selected and special attention was made to facilitate the best laying of the TALs. The construction has been followed extensively, and shortly after the construction the baseline measurements took place.

The expected noise reductions with respect to the reference sections were reached, even knowing the SMA reference section is silent with respect to average measured values on similar SMA sections. Texture spectra gave similar results for all but one thin asphalt layer. Measured rolling resistance showed a good correlation with MPD values.

The first periodic monitoring after six months did not show changes in obtained results, what is promising, though the follow-up has just started. Texture and CPX values stay stable. Every half year the noise performance as well as the mechanical durability will be assessed by measurements, in order to be able to give recommendations on how thin asphalt layers can aid to reduce noise in a durable way in an urban environment.

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REFERENCES

study the acoustical quality of thin noise reducing asphalt layers”, Internoise 2014, Melbourne, Australia, 16-19 November 2014


6. Standaardbestek 250 versie 3.1, Agentschap Wegen & Verkeer, Flemish tender specification from Flemish Road Administration


