RE-USE OF RECLAIMED ASPHALT WITH HIGH ADDED VALUE

M. Wistuba, J. Grönniger, and P. Renken
Braunschweig Pavement Engineering Centre, TU Braunschweig, Germany
m.wistuba@tu-bs.de, j.groenniger@ tu-bs.de, p. renken@ tu-bs.de

ABSTRACT

Bitumen, which is used as binding agent in asphalt roads, is derived from crude oil through distillation process. Today, availability of crude oil is decreasing and with bitumen for road asphalts, there will soon be a raw material and price problem. On the other hand, the development of alternative binding agents from other (renewable) raw materials is not an alternative at the moment. Thus, it is favourable that bitumen is reclaimed from old asphalt roads and is used again for new asphalt mixes. In some countries the re-use of bitumen has been common practice for some time: In some European countries, up to 80 % of the milled road asphalt is used again in new asphalt binder courses and base courses. Even re-using reclaimed material in new asphalt surface courses, i. e. at the highest level of added value, is both technically feasible and advisable. This paper summarizes results of a recent study conducted at Braunschweig Pavement Engineering Centre, Germany. From comprehensive laboratory analysis it was concluded, that reclaimed asphalts from porous asphalt layers (which meet highest requirements of quality and are therefore most expensive) can effectively be re-used in new asphalt binder courses and in new asphalt surface courses. For this purpose, asphalt concretes and stone mastic asphalts were produced in the laboratory by adding reclaimed porous asphalts in different amounts and at different temperatures. In order to compensate the hardening of the binder of the reclaimed asphalt different fresh polymer-modified binders were added. It was than verified to what extent the addition of reclaimed asphalt to the new asphalt mix effects mayor performance characteristics of the resulting asphalt mix, such as deformation behaviour, low-temperature behaviour, fatigue behaviour and bonding. It was found, that neither the asphalt mix tests nor the binder tests indicated negative effects on the performance of the new asphalt mix. Quite on the contrary, some important positive effects were observed. The results of this research study and the developed methodology for adding reclaimed asphalt to asphalt binder and surface course materials form a solid basis for future developments in re-utilization of bitumen.

1. INTRODUCTION

In Europe, materials reclaimed from asphalt roads are generally recycled, required technologies are widely known. In particular, research initiatives under the umbrella of the European Union – e.g. the ALT-MAT [1] and SAMARIS [2] projects, and also projects that are still underway, like DIRECT-MAT [3] and RE-ROAD [4] – have contributed a great deal to improving the technology transfer in Europe. Nevertheless both the recycling rates and the strategies differ considerably from one country to another. This can be explained by differences in availability of reclaimed materials and in official regulations, or by the fact that certain countries prefer specific technologies due to long-term practical experience. In Germany, the re-utilisation of reclaimed asphalt in the form of granulated asphalt (produced by milling) in the new asphalt mixture is favoured. Granulated asphalt recycling is possible without any significant loss in quality and has been state-of-the-art technology for many years (cf. [5] to [10]). Consequently the recycling rate has gone up from approx. 40 % to more than 80 % in the past 20 years. This is primarily due to the constant improvement of reclaiming, preparation and processing techniques, as well as the permanently updated documentation of the available experience in national rules and regulations. High-quality asphalt can only be produced when certain conditions are complied with. These include careful production of reclaimed asphalt ("selective" milling of layers), its separate storage, and a number of requirements that production plants have to meet. For mixing the granulated asphalt into the asphalt matrix during asphalt production, separate heating of the granulated asphalt in parallel drums has proven to be a successful method, as this ensures that all components are uniformly heated and the granulated asphalt will be sufficiently decomposed in the produced asphalt mixture. Only with separate heating maximum addition rates can be achieved. The maximum addition rate for production of a new asphalt mixture is defined after the homogeneity of the granulated asphalt has been determined. A crucial factor is also the span of specific (conventional) characteristics, such as binder content and softening point ring and ball. Addition rates of up to 100 wt % have become acceptable for asphalt road bases or asphalt base/surface courses. This is why granulated asphalt is nowadays primarily used in new asphalts for binder and base courses. At present a maximum addition rate of 50 wt % applies to the upper pavement courses. However, the regulations in some countries permit higher maximum addition rates for asphalt surface and binder courses, in order to push developments towards higher addition rates.

2. RE-USE OF MILLED ASPHALT FROM POROUS ASPHALT SURFACE COURSES

2.1. Background

In general, aggregates and binders used in porous asphalt (PA) surface courses have to meet stringent requirements and are therefore costly materials. Increase of PA recycling rate is therefore desirable. However, little experience is available with re-utilisation of asphalt reclaimed from PA. Recent research conducted at Braunschweig Pavement Engineering Centre concluded that it is technically feasible and without any drawbacks to re-use asphalt reclaimed from PA for new asphalt binders and stone mastic asphalts [9].

2.2. Research programme

Research focused on effects that the addition of granulated asphalt from PA has on properties of resultant asphalt mixtures for binder courses and stone mastic asphalt courses. Aspects covered in this context were quality of the milled material (e. g. milling depth), properties of bitumen contained in the milled material, possible addition rates, grade of added fresh-bitumen, effects of hardened bitumen on resultant bitumen, and effects on mechanical asphalt properties.

2.2.1. *Selection of granulated asphalt and added binder*

Granulated asphalt was obtained from different roads by milling. For laboratory testing, five variations of granulated asphalt were selected considering the binder product (and content) they contained, the particle size distribution, and the degree of hardening characterised by the softening point ring and ball ($T_{R\&B}$) that was determined for the reclaimed bitumen. Hence, a broad range of granulated asphalts were considered for the research study (Table 1).

Table 1 - Properties of the granulated asphalts selected for laboratory testing

<table>
<tr><th colspan="2" rowspan="2">attribute</th><th rowspan="2">unit</th><th colspan="5">asphalt variant</th></tr>
<tr><th>V1</th><th>V2</th><th>V3</th><th>V4</th><th>V5</th></tr>
<tr><td colspan="2">binder content (B)</td><td>wt %</td><td>6.7</td><td>5.1</td><td>5.5</td><td>7.8</td><td>6.5</td></tr>
<tr><td colspan="2">softening point ring and ball ($T_{R\&B}$)</td><td>°C</td><td>87.6</td><td>89.5</td><td>107.4</td><td>84.5</td><td>79.6</td></tr>
<tr><td colspan="2">filler content [%]</td><td>wt %</td><td>7.0</td><td>5.4</td><td>5.0</td><td>7.3</td><td>5.3</td></tr>
<tr><td rowspan="4">aggregate [mm]</td><td>2.0 – 5.0</td><td>wt %</td><td>23.0</td><td>16.2</td><td>18.1</td><td>17.7</td><td>15.3</td></tr>
<tr><td>5.0 – 8.0</td><td>wt %</td><td>47.1</td><td>65.9</td><td>60.7</td><td>44.3</td><td>51.3</td></tr>
<tr><td>8.0 – 11.2</td><td>wt %</td><td>5.7</td><td>5.1</td><td>5.2</td><td>7.6</td><td>11.0</td></tr>
<tr><td>> 11.2</td><td>wt %</td><td>0.7</td><td>0.1</td><td>0.0</td><td>2.6</td><td>7.0</td></tr>
</table>

In order to produce most realistic conditions in laboratory, always the same "fresh" binder was used for one type of asphalt, irrespective of hardness of added granulated asphalt. The corresponding "zero" version was produced with a fresh binder of a higher viscosity. For an overview of the added binders, see Table 2.

Table 2 - Added binders for the production of asphalt mixtures of stone mastic asphalt SMA 8 and asphalt concrete AC 16

	added binder (irrespective of the resultant softening point)	
	for "zero" versions	with the addition of granulated asphalt
SMA 8	25/55-55 A	45/80-50 A
AC 16	10/40-65 A	25/55-55 A

2.2.2. *Asphalt mixtures and variation*

Granulated asphalt obtained from PA was added to stone mastic asphalt of the type SMA 8, and to asphalt binder mixture of the type AC 16. The following variations were made (cf. Table 3):

- type (hardening) of granulated asphalt (in five steps),
- addition rate (15 wt % and 30 wt %), and
- temperature at which the granulated asphalt was added (20 °C to simulate addition in cold state, and 100 °C to simulate addition in hot state).

In order to determine viscosity effect of "fresh" binder, the binders were varied in three steps for "hardest" granulated asphalt mixture (V3) (see Table 3). For this purpose, the following types of polymer (elastomeric) modified bitumen were used:

- 10/40-65 A,
- 25/55-55 A and
- 120/200-40 A.

In this way, a total of 36 versions of asphalt mixtures (with addition of granulated asphalt) and two zero versions of asphalt mixtures (without granulated asphalt) were produced for further laboratory analyses (Table 3).

Table 3 – Asphalt mix variations for laboratory testing

<table>
<tr><th colspan="2">version</th><th colspan="6">stone mastic asphalt SMA 8</th><th colspan="6">asphalt concrete AC 16</th></tr>
<tr><td colspan="2">addition rate [wt %]</td><td colspan="2">0</td><td colspan="2">15</td><td colspan="2">30</td><td colspan="2">0</td><td colspan="2">15</td><td colspan="2">30</td></tr>
<tr><td colspan="2">V1</td><td colspan="2">SO</td><td colspan="2">S11</td><td colspan="2">S21</td><td colspan="2">BO</td><td colspan="2">B11</td><td colspan="2">B21</td></tr>
<tr><td colspan="2">V2</td><td colspan="2"></td><td colspan="2">S12</td><td colspan="2">S22</td><td colspan="2"></td><td colspan="2">B12</td><td colspan="2">B22</td></tr>
<tr><td rowspan="3">V3</td><td>added binder 1</td><td colspan="2"></td><td colspan="2">S14</td><td colspan="2">S24</td><td colspan="2"></td><td colspan="2">B14</td><td colspan="2">B24</td></tr>
<tr><td>added binder 2</td><td colspan="2"></td><td colspan="2">S14b</td><td colspan="2">S24b</td><td colspan="2"></td><td colspan="2">B14b</td><td colspan="2">B24b</td></tr>
<tr><td>added binder 3</td><td colspan="2"></td><td colspan="2">S14c</td><td colspan="2">S24c</td><td colspan="2"></td><td colspan="2">B14c</td><td colspan="2">B24c</td></tr>
<tr><td colspan="2">V4</td><td colspan="2"></td><td colspan="2">S15</td><td colspan="2">S25</td><td colspan="2"></td><td colspan="2">B15</td><td colspan="2">B25</td></tr>
<tr><td colspan="2">V5</td><td colspan="2"></td><td colspan="2">S17</td><td colspan="2">S27</td><td colspan="2"></td><td colspan="2">B17</td><td colspan="2">B27</td></tr>
<tr><td colspan="2">addition temperature [°C]</td><td colspan="12">100</td></tr>
<tr><td colspan="2">addition rate [wt %]</td><td colspan="3">15</td><td colspan="3">30</td><td colspan="3">15</td><td colspan="3">30</td></tr>
<tr><td colspan="2">V3</td><td colspan="3">S34</td><td colspan="3">S44</td><td colspan="3">B34</td><td colspan="3">B44</td></tr>
<tr><td colspan="2">V5</td><td colspan="3">S37</td><td colspan="3">S47</td><td colspan="3">B37</td><td colspan="3">B47</td></tr>
</table>

Reclaimed binder was subjected to conventional and rheological binder testing, including determination of force-ductility curve, dynamic shear rheometer (DSR) and bending beam rheometer (BBR) analyses.

All asphalt mix variations were tested in laboratory for mechanical performance-related properties, such as

- deformation behaviour,
- fatigue behaviour,
- low-temperature behaviour, and
- bonding.

Multiple variance analysis was used as statistical tool for evaluating effects of variations (hardness of granulated asphalt, addition rate, addition temperature and grade of added bitumen) on the resultant asphalt mix properties. These analyses served to quantitatively determine the effects that several factors have on the overall variability of a specific asphalt property as well as on the interaction between the factors.

2.3. Test results

2.3.1. *Effect of viscosity of added binder*

Viscosity of added binder has immediate effect on resultant binder viscosity, as illustrated in Figure 1 for granulated asphalt V3 (with $T_{R\&B}$ = 107 °C). Changes in viscosity are evident from conventional binder characteristics such as penetration (Pen), softening point ring and ball, Fraas brittle point and elastic recovery all established for the reclaimed binder. In the Figure, limits are given applied to added binder in accordance with the German regulations for reclaimed binders. It is possible to find a bitumen grade for added binder so that the characteristics of resultant binder compare with the zero version.

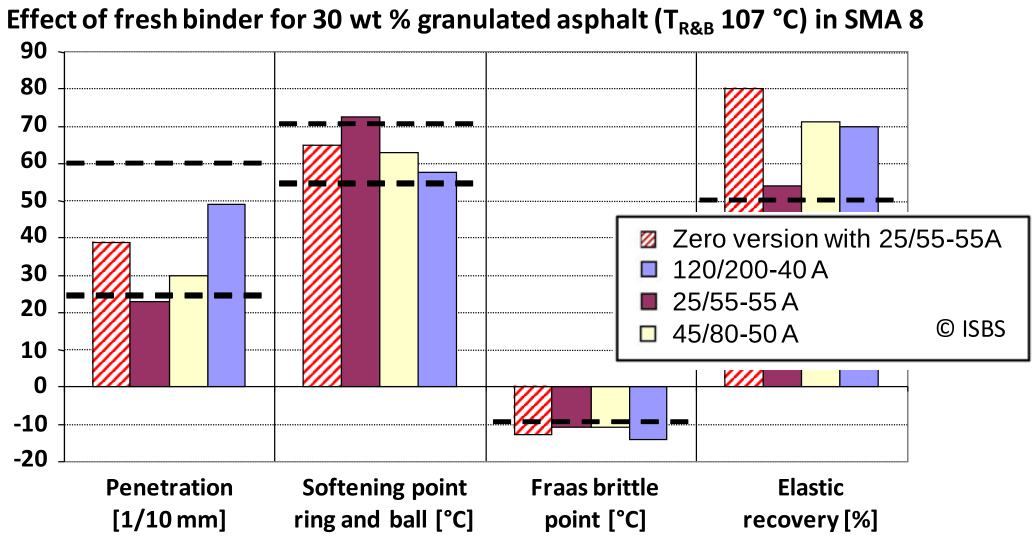

Figure 1 - Stone mastic asphalt SMA 8 with 30 wt % granulated asphalt of V3 version (with $T_{R\&B}$ = 107 °C): changes in conventional binder characteristics due to influence of the added binder.

As hardness of the granulated asphalt increases, viscosity of resultant binder goes up, penetration decreases, and softening point goes up. This effect is the more distinct, the higher the percentage of the added granulated asphalt is (it is therefore more marked at an addition rate of 30 wt % of granulated asphalt, cp. Figure 2).

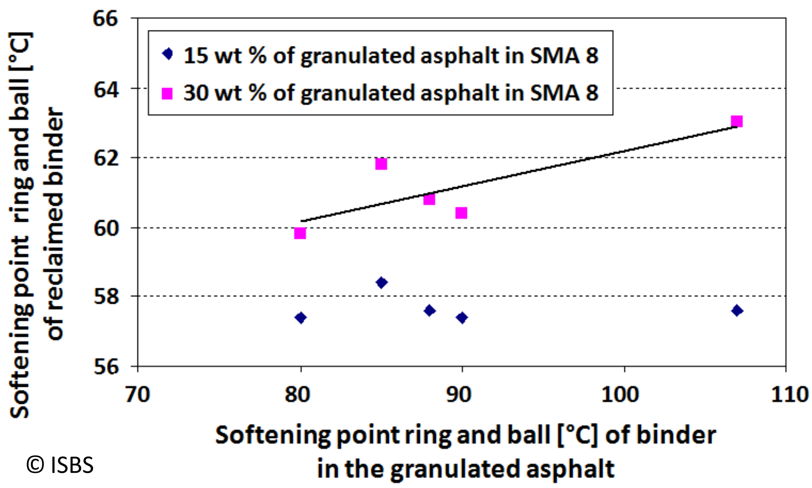

Figure 2 - Stone mastic asphalt SMA 8 with 15 / 30 wt % of granulated asphalt: relationship between softening point ring and ball of the binder in the granulated asphalt and the softening point ring and ball of the resultant (reclaimed) binder.

2.3.2. *Granulated asphalt addition and its effect on the resultant asphalt properties*

2.3.2.1. Deformation behaviour

Deformation behaviour of asphalt mixtures modified with granulated asphalt was examined in laboratory through the wheel tracking test and dynamic indenter test (200/80 mm, T = 50 °C). Figure 3 represents SMA 8 version with V3 granulated asphalt ($T_{R\&B}$ = 107 °C) as an example to demonstrate the effect of added binder viscosity on the resultant rut depth. Rut depth decreases as viscosity goes up. Thus, addition of hard granulated asphalt has favourable effect on deformation resistance.

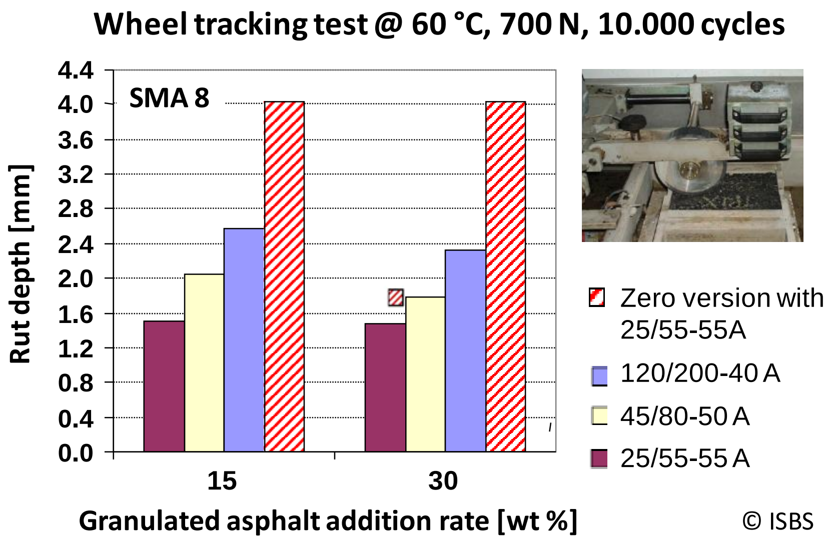

Figure 3 - SMA 8 with version V3 granulated asphalt ($T_{R\&B}$ = 107 °C): effect of added binder viscosity on rut depth determined in wheel tracking test (rubber wheel, air, T = 60 °C).

2.3.2.2. Low-temperature behaviour

Low-temperature behaviour of asphalt mixtures modified with granulated asphalt was tested in laboratory through cooling and uni-axial tension tests at four temperature levels (+20 / +5 / -10 / -25 °C). Added binder viscosity significantly influences all characteristics determined in these tests – fracture temperature, maximum tensile strength and corresponding temperature (see Figure 4 for fracture temperature determined in TSRST).

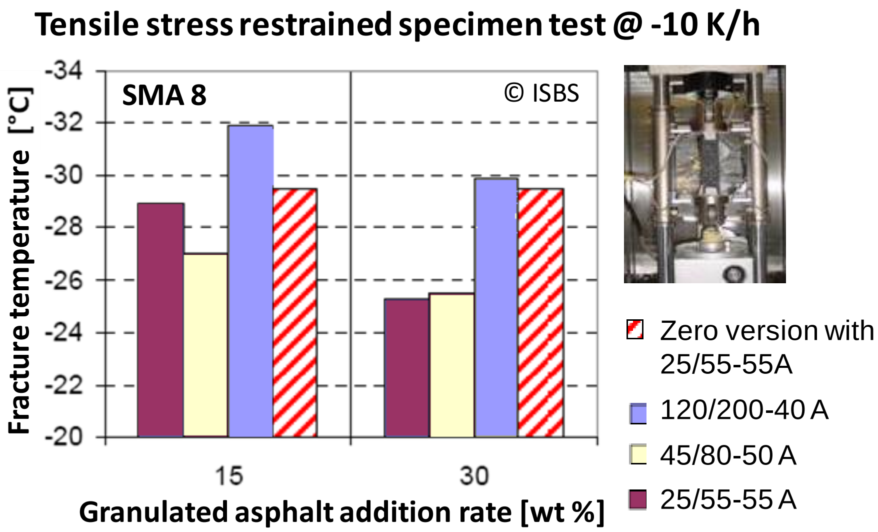

Figure 4 - Effect of added binder viscosity on fracture temperature determined in tensile stress restrained specimen test (TSRST).

In general, low-viscosity binders have favourable effect on low-temperature behaviour, also at high granulated asphalt addition rate, which is due to the higher resistance against cracking in the presence of low-temperatures. Adverse effects, which were observed in some cases, could be compensated in the course of a test programme with a softer added binder so that low-temperatures properties compared with those of zero versions. A factor of mayor influence on low-temperature behaviour, in addition to added binder grade, is the addition rate of granulated asphalt. A high rate results in less favourable (higher) fracture temperature.

2.3.2.3. Fatigue behaviour

To assess fatigue behaviour, prismatic asphalt mix specimens were subjected to uni-axial cyclic indirect tensile stress tests. Fatigue resistance was determined with load cycles applied up to the point of failure (number of failure load cycles). Figure 5 shows the number of failure load cycles for SMA 8 version and a test temperature of -10 °C. In this case, the addition of granulated asphalt has favourable effect on fatigue resistance.

2.3.2.4. Water sensitivity

Water sensitivity (bond behaviour) was tested in laboratory with asphalt mix specimens by assessing indirect tensile strength at a temperature of 15 °C after the specimen had been stored in water. It turned out that the addition of granulated asphalt does not have a negative effect on water sensitivity, irrespective of whether the granulated asphalt addition rate, the addition temperature or the added binder viscosity were varied.

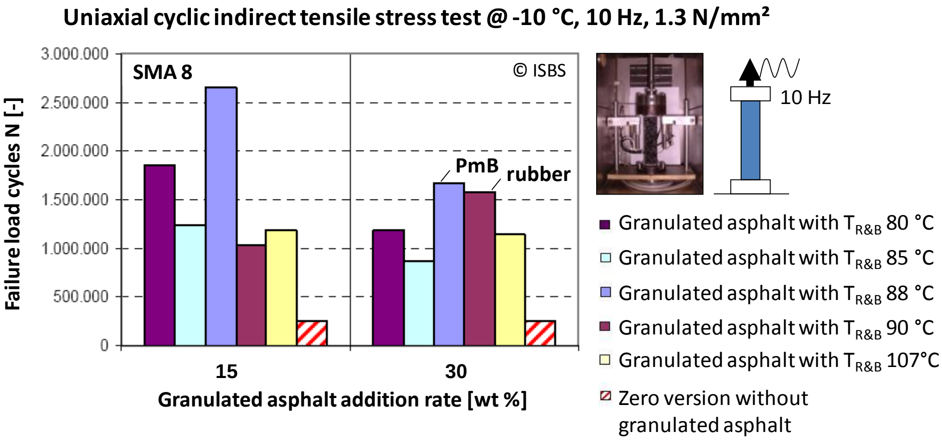

Figure 5 - Stone mastic asphalt SMA 8: effect of hardness and granulated asphalt addition rate on the number of failure load cycles determined in uni-axial cyclic indirect tensile stress test.

3. SUMMARY

This study focuses on the possibility of re-using material reclaimed by milling from porous asphalt surface courses – which are subject to highly demanding requirements regarding their composition and components and are therefore expensive to produce – in new binder courses of asphalt concrete and in surface courses made from stone mastic asphalt. The results of the project can be summarised as follows:

- Blending the hardened binder in the added granulated asphalt with fresh virgin binder does not have an adverse effect on resultant binder properties when compared with zero version properties (without granulated asphalt).
- Granulated asphalt containing highly aged (hardened) binders, too, can be used for production of stone mastic asphalt SMA 8, and of asphalt concrete AC 16 used for asphalt binder courses, without any decisively adverse effects on the properties of the resultant binder.
- Thorough selection of the added fresh binder is an important factor, because its viscosity significantly influences resultant asphalt properties. Low-viscosity binders tend to have a favourable effect on low-temperature behaviour, and, to lesser

degree, on deformation behaviour. Therefore fresh binder viscosity has to be adapted to the hardness of the granulated asphalt.

- In this study, addition of granulated asphalt obtained from porous asphalt surface courses had practically no adverse effect on the properties of any of the tested asphalt mixtures. (Partially) improved were compaction, deformation, low-temperature, and fatigue characteristics.

It can be concluded that granulated asphalt reclaimed from porous asphalt surface courses can be re-used in asphalt binder course material and SMA mixtures without any loss in quality, provided a number of basic conditions are observed. Addition rates of up to 30 wt % to SMA 8 and AC 16 can be recommended without having to expect any adverse changes in performance characteristics. Care should however be taken when extremely hard granulated asphalt is added at high rates. This could adversely affect fatigue properties.

Additional research is required for further investigate the influence that the added fresh binder has on granulated asphalt of different degrees of hardness. Results might then be used for recommending optimal added binder grades for specific combinations of granulated asphalt hardness and addition rates.

Another aspect that remains to be clarified is whether higher granulated asphalt addition rates (> 30 wt %) would be feasible under large-scale production conditions. The potential effects of mixing and proportioning conditions, which tend to vary in practice, on the asphalt quality have not been determined yet.

Acknowledgements

Special thanks go to German Federal Ministry of Transport, Building and Urban Development and the German Federal Highway Research Institute for funding the underlying research project.

REFERENCES

1. CORDIS (1999). ALT-MAT, Alternative materials in road construction. Final report, research project as part of the Transport RTD Programme of the European Union, http://cordis.europa.eu/transport/src/alt-mat.htm.
2. FEHRL, Forum of European National Highway Research Laboratories (2003). SAMARIS, Sustainable and Advanced Materials for Road Infrastructures. Final report, research project as part of the 5th Framework Programme of the European Union, http://samaris.zag.si/documents/sam_ge_de03.pdf.
3. DIRECT-MAT – Dismantling and recycling techniques for road materials – sharing knowledge and practices; Bringing together best practice across Europe on the dismantling and recycling of road materials – Introductory article. Current research as part of the 7th Framework Programme of the European Union, http://direct-mat.fehrl.org.
4. FEHRL, Forum of European National Highway Research Laboratories. RE-ROAD – End of Life Strategies of Asphalt Pavements. Current research project as part of the 7th Framework Programme of the European Union, http://re-road.fehrl.org/?m=1.
5. Arand, W. & Renken, P. (1994). Verwendung größtmöglicher Ausbauasphaltanteile im Straßenbau (in german). Final report, research project commissioned by the Federal Ministry for Transport, FA Q 148669, Institut für Straßenwesen - Braunschweig Pavement Engineering Centre, Technische Universität Braunschweig, Germany.
6. Leutner, R. & Dröge, C. (2000). Ermittlung von Einsatzgrenzen für die Zugabe von Ausbauasphalt in Asphaltdeckschichten anhand von Erprobungsstrecken (in German). Final report, research project commissioned by the Federal Ministry for Transport, FV 148104, Institut für Straßenwesen - Braunschweig Pavement Engineering Centre, Technische Universität Braunschweig, Germany.

7. Renken, P. & Lobach, T. (2004). Wirksamkeit der Zugabe von Asphaltgranulat auf die mechanischen Eigenschaften von Asphaltdeckschichten (in German). Final report, research project commissioned by the Federal Ministry for Transport, FA 07.194/2001, Institut für Straßenwesen - Braunschweig Pavement Engineering Centre, Technische Universität Braunschweig, Germany.
8. Renken, P. & Lobach, T. (2006). Einfluss der Zugabe von Ausbauasphalt ohne und mit PmB auf die Eigenschaften von Asphaltbindervarianten bei Verwendung von PmB 45 (in German). Final report, research project commissioned by the Federal Ministry for Transport, FE 07.205/2003/BGB, Institut für Straßenwesen - Braunschweig Pavement Engineering Centre, Technische Universität Braunschweig, Germany.
9. Grönniger, J., Renken, P. & Wistuba, M. (2009). Verwendung von Fräsasphalt aus Offenporigen Asphaltdeckschichten auf möglichst hohem Wertschöpfungsniveau (in German). Final report, research project commissioned by the Federal Ministry for Transport, FE 07.0212/2006/CGB, Institut für Straßenwesen, Technische Universität Braunschweig, Germany.
10. Wistuba, M., Grönniger, J. & Renken, P. (2010). Asphaltwiederverwendung auf hohem Wertschöpfungsniveau (in German). Proc., Deutscher Straßen- und Verkehrskongress 2010, 16. Sept. 2010, Mannheim, Germany.

RE-UTILISATION D'ASPHALTE A HAUTE VALEUR AJOUTEE

M. Wistuba, J. Grönniger et P. Renken
Braunschweig Pavement Engineering Centre, TU Braunschweig, Germany
m.wistuba@tu-bs.de, j.groenniger@ tu-bs.de, p.renken@ tu-bs.de

RESUME

Le bitume, qui est employé comme liant dans des enrobés bitumineux, est dérivé du pétrole brut dans un processus de distillation. Aujourd'hui, la disponibilité de pétrole brut est décroissante et avec le bitume, il y aura bientôt un problème de disposition et de prix. Actuellement, le développement des liants alternatifs d'autres matières premières (renouvelables) n'est pas une alternative. Les ressources sont limitées et il est donc nécessaire de conserver les matériaux bitumineux aussi longtemps que possible. Ainsi, il est essentiel que le bitume soit repris de vieilles routes et est employé encore pour de nouveaux enrobés bitumineux. Les technologies actuelles pratiqués dans quelques pays nous permettent d'en réutiliser des quantités respectables: Dans quelques pays européens, environ 80 % de l'asphalte fraisé de route est récupéré dans de nouveaux couches de liaison et couches de base. Même la réutilisation du matériel dans de nouvelles couches de roulement, c'est-à-dire au de plus haut niveau de la valeur ajoutée, est techniquement faisables et recommandés, comme des résultats de la recherche récents montrent. Dans le cadre d’une étude entreprise à Technische Universität Braunschweig, Allemagne, on l'a prouvé, que les asphaltes repris des couches poreuses d'asphalte (ou les conditions de qualité sont les plus élevées et sont donc les plus chères) peut effectivement être réutilisé dans des nouvelles couches de liaison et dans de nouvelles couches de roulement. Ainsi, des mélanges de béton d'asphalte et de Stone Mastic Asphalt ont été produits dans le laboratoire en ajoutant les asphaltes poreux aux montants différents et aux températures différentes à l’asphalte frais. Pour compenser le raidissement du bitume des liants polymère-modifiés fraîches différents ont été ajoutés. Au moyen d'essai laboratoire on a vérifié comment l'incorporation de l'asphalte recyclé dans l'asphalte nouveau effectue le comportement de déformation, le comportement à température basse, le comportement de fatigue et la liaison du mélange. On n’a pas constaté une influence négative, au contraire, on a observé quelques effets positifs importants sur la performance. Ainsi, les résultats de cette recherche et la méthodologie développée sont une bonne base pour des développements suivants dans le domaine du recyclage des matériaux routiers.