5 RECYCLED ASPHALT PAVEMENT

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Abstract
The recycling of old asphalt has gained ground over the past few years. There are several methods to reuse reclaimed asphalt during road maintenance and reconstruction works. Despite being in situ or in plant, it is possible to have “hot-mix” recycling or “cold-mix” recycling. Evidently the recycling of asphalt has many advantages. However, some limitations need to be considered. Reclaimed asphalt should therefore be subjected to a rigid inspection before being reused.

5.1 INTRODUCTION
Tremendous amounts of “reclaimed asphalt” are available from maintenance works on asphalt road pavements. Reclaimed asphalt (RA) comprises asphalt reclaimed by milling of asphalt road layers, by crushing of slabs ripped up from asphalt pavements, lumps from slabs, and asphalt from reject and surplus production [1].

With the principles of durable development in mind, and urged by economic and ecological factors, the recycling of old asphalt has gained ground over the past few years. This is mainly due to the relatively high cost of bitumen (a by-product of oil refining) and the advances in technologies making high-quality recycling of old asphalt into new bituminous mixtures possible.

In situ recycling of asphalt pavements made its appearance in the year 1975. The technology was used on several works over the next ten years or so, without being able to force a major breakthrough. The principal reason why this technique did not continue as a success was the development of another form of asphalt recycling in the eighties: in-plant recycling, which has a wider field of application than in situ recycling. In view of sustainable development the use of these recycling technologies must increase because reuse of reclaimed asphalt accounts only for about 7% of the total road rehabilitation work [2].

5.2 TECHNOLOGY OF ASPHALT RECYCLING
There are several methods to reuse reclaimed asphalt during road maintenance and reconstruction works. Figure 1 diagrammatically represents the various possibilities. Despite being in situ or in plant it is possible to have “hot-mix” recycling or “cold-mix” recycling according to the temperature operated on the reclaimed asphalt material.
Recycling of old asphalt

<table>
<thead>
<tr>
<th>Recycling of old asphalt</th>
<th>Hot in plant</th>
<th>Cold in plant</th>
<th>Hot in situ</th>
<th>Cold in situ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot</strong></td>
<td>• added cold in batch mixing plant</td>
<td>• mixed with sand and cement (cement-bound crushed asphalt)</td>
<td>• reforming</td>
<td>• mixed with underlying base material and cement</td>
</tr>
<tr>
<td></td>
<td>• added hot through parallel-flow drum</td>
<td>• mixed with emulsion (cold-mix asphalt)</td>
<td>• repaving</td>
<td>• mixed with sand and cement (cement-bound crushed asphalt)</td>
</tr>
<tr>
<td></td>
<td>• in drum mixer</td>
<td>• remixing</td>
<td></td>
<td>• mixed with emulsion (cold-mix asphalt)</td>
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<tr>
<td><strong>End product</strong></td>
<td>asphalt mix for base course and wearing course</td>
<td>bound base material</td>
<td>asphalt mix for wearing course</td>
<td>bound base material and asphalt mix for base course</td>
</tr>
</tbody>
</table>

Figure 1: Asphalt recycling

“Hot-mix” recycling is a high-grade method, as the RA is used as a constituent in a material with properties equivalent to those of an asphalt mix produced exclusively with new materials. The original properties of the old bitumen – which enable it to act as a binder – are fully reused.

“Cold-mix” recycling is used in lower-grade applications in which the crushed or milled asphalt only replaces the cheaper materials (stone and sand). The intrinsic properties of the residual bitumen are not utilized; only the “aggregate” aspect is addressed. There are, however, some studies concerning the use of bitumen emulsions with a rejuvenating agent in cold recycling, in order that the new bitumen added to the RA combines with the old one.

5.2.1 Hot-in-plant recycling

The highest-grade reuse of RA is in new asphalt mixes. Processing old asphalt into a material that has the same properties as a comparable asphalt mix manufactured with new raw materials is called “asphalt regeneration”. The product of this process is referred to as “recycled hot mix (RHM)”, that is, a plant-produced asphalt mix prepared with a given percentage of old asphalt. The percentage of new binder to be added depends on the proportion of old asphalt in the RHM. Starting from the measured characteristics of the old binder – such as ring-and-ball softening point, penetration or viscosity – and the proportions of old and new binder, the type of new binder required to produce a given quality of blend binder can be calculated with a few simple rules or read from nomograms, as the ones that can be found in [3]. Other methods may be applied on the design of hot recycled bituminous mixtures [4].

If the old binder has reached an advanced stage of ageing, the additional use of a
rejuvenating agent is to be recommended. This liquid admixture strongly reduces viscosity by acting on the chemical structure of the bitumen, which results in a softer material.

Several techniques are available for recycling asphalt in bituminous mixing plants. The differences between variants lie in the heating process of the RA that dictate the technological adaptations to the conventional mixing plant and determine the maximum percentage of reuse. There are, in principle, three methods of plant recycling and the allowed RA percentage to be used depends on them [5]:

- no preheating of the old asphalt – 10 to 30 % of RA;
- addition in the drum mixer in the continuous process – 10 to 50 % of RA; and
- preheating of the RA in a parallel-flow drum – 10 to 70 % of RA.

Factors such as water content, the grading of the RA, and possible ageing of the reused binder play a part as well when choosing the appropriate method. The technologies of preheating the reclaimed asphalt in a parallel-flow drum dryer gives the best value for asphalt recycling; it is the technique most used for high-quality asphalt recycling.

5.2.2 Hot-in-situ recycling

This regeneration process consists in improving the top 2 to 4 cm of asphalt surfacing on site. Heating, after which the softened asphalt is scarified, softens the upper few centimetres and a treatment is performed to smooth away the existing defect. Depending on the nature of this treatment, a distinction is made between:

- reforming – the scarified material is shaped to the desired profile by means of spreading screws and a levelling beam, and precompacted with a finishing screed. Final compaction is performed with conventional rollers. This technique only modifies the shape of the road surface and possibly the voids content, but not the actual composition of the mix;
- repaving – after the scarified old asphalt has been levelled, a new asphalt-wearing course is laid over it, and the old and fresh material are compacted together. So in this technique the old asphalt does not change in composition either, but it is now overlaid with a thin asphalt surfacing; and
- remixing – is a development of repaving, in which the old asphalt is mixed with fresh material in a mixer. The fresh material may be a new asphalt mix or just bitumen or a rejuvenating agent, depending on the correction required. This technique definitely changes the composition of the mix.

In all these techniques, a long array of infrared or hot air heaters is used to heat the upper few centimetres of the surfacing to 100-140 °C, while avoiding thermal damage to the bitumen (oxidation). The heating unit can operate as a separate machine or be incorporated in the asphalt pavers. Immediately after heating, the softened material is mechanically scarified by means of steel cutting tools.

5.2.3 Cold-mix recycling

Processed RA can be reused as a sub-base material or a road base material by binding it with cement, a bitumen emulsion, or foamed bitumen.

When using RA as a sub-base material the reclaimed asphalt mix is usually composed of processed RA, new aggregates (most of the cases sand), cement, and water. After compaction, a sub-base layer is obtained with the characteristics of a sand-cement layer. Technically speaking, it does not matter whether the old binder in the RA contains tar or bitumen.
When using RA as a road base material generally bitumen emulsion or foamed bitumen is used as binder [6, 7]. The materials used in the production of the cold recycled mixture are processed RA, bitumen emulsion or foamed bitumen and water. Other materials such as lime, cement or new aggregates are also often used (for example, for adjusting the grading of the mixture). The cement intends mainly to improve initial performance of the cold mixture in order to shorten the time of road reopening to traffic [8].

5.3 ADVANTAGES AND LIMITATIONS OF RECYCLING

5.3.1 Hot-in-plant recycling
As explained before, the percentage of RA that can be allowed in RHM depends on the equipment of the coating plant, but naturally also on the quality and homogeneity of the old asphalt itself. That is why the percentage of reuse of RA has been limited in most countries. Improved understanding of the environmental hazards of the high concentrations of polycyclic aromatic hydrocarbons (PAHs) in tar has changed the public attitude towards tar-containing products. The problems raised by PAHs, both for the environment (e.g. emissions) and for the health of workers, are critical when heating tar-contaminated asphalt. For that reason, hot recycling of tar-containing materials is now prohibited in Belgium. It should be clarified what concentrations of tar in old asphalt are hazardous to worker health and the environment in hot-mix recycling. This would enable policy-makers to set a maximum tar content that can be allowed in hot asphalt regeneration.

5.3.2 Hot-in-situ recycling
The technique of in situ recycling is difficult to master where road surfacing change too often in composition along a given route. In addition, it requires bulky and very expensive machines, which are only cost-effective on major works. Finally, it must not be forgotten that hot-in-situ recycling only affects the wearing course – heating is effective only to a depth of about 5 cm – and is, therefore, inadequate to remove rutting caused by flow in the underlying layers or by poor structural design (insufficient thickness of courses). The concern about PAHs also applies to this technology.

5.3.3 Cold-mix recycling into a bound base material or base course
As mentioned before, the cold-mix recycling leads to low-grade applications. Nevertheless binder’s combination may envisage its application in wearing course of low traffic roads [8].

The technique of stabilization with a bitumen emulsion or with an emulsion and cement, which is used in a number of countries, is worth mentioning [9, 10, and 11].

Cold-mix in situ presents several advantages such as preservation of the environment, the health of the operators and actual cost savings. However mix design and design aspects such as compactive effort, wetting conditions among others must be better specified [9].

Cold-mix recycling into a bound base material may be a solution for tar-contaminated RA. Binding with cement or an emulsion reduces the leaching of environmentally hazardous substances such as PAHs. With emulsion stabilization, possible contact with water and, consequently, leaching may be expected to be even less than with cement stabilization, owing to the hydrophobic properties of the emulsion. This remains to be verified by experiment.
5.3.4 Assessment of the recyclability of RA in asphalt mixes

Before being reused, RA should be subjected to a rigid inspection. The checks and investigations made, allow a first assessment of recyclability and – if the result is favourable – an evaluation of the allowable percentage of reuse of old asphalt and the most appropriate method (cold- or hot-mix recycling). The following checks and investigations are desirable:

- in situ preliminary study of the asphalt pavement to be reclaimed;
- inspection of the freshly reclaimed material upon delivery; and
- qualitative evaluation of the RA for recycling in asphalt mixes.

Further checks and laboratory tests will guarantee that the RA meets the requirements for homogeneity. The following characteristics are determined: grading, the percentage of fines, the nature of the stone fraction, binder content, the ring-and-ball softening point and penetration of the recovered binder. Limits are set to each of these characteristics, to assess whether a given lot of RA can be considered as homogeneous or not.

Most countries have set requirements to be met by a bituminous mix design before the mix can actually be produced [12]. As far as RA is concerned, the requirements most often relate to the maximum percentage of reuse. In this respect, a distinction is made according to:

- the function of the layer: wearing course or base course;
- the group of asphalt mixes;
- the homogeneity of the RA; and
- the recycling technique (cold or hot addition).

At the European level, CEN working group TC227/WG1 “Road Materials – Bituminous Mixtures”, is developing product standards for seven groups of asphalt mixes, which set the European requirements for bituminous mix designs, and, in addition, they contain specific requirements for RHM mixes.

The amount of RA to be used in bituminous mixtures may be specified or agreed between the parties involved. However some requirements in the standards constitute or could constitute a restriction to the nature of the reclaimed asphalt or the amount to be used. Generally it is described that the mix group from which the reclaimed asphalt was derived, and the mix group in which it may be utilized, may be specified. The requirement that the amount of reclaimed asphalt may be specified is applicable for all mix groups.

5.3.5 Future research needs and remaining issues

Reclaimed asphalt in hot bituminous mixtures is increasingly used in most of the European countries especially for base and binder courses or for low traffic roads. The percentages are often still limited in case of top layers or for highly trafficked roads, mainly because of lack of knowledge about the performance of bituminous mixes with RA. To increase the percentage of reclaimed asphalt implies that machinery and techniques exist to produce these mixes adequately and lay them in place properly. It should be investigated to what extend a further increase of the percentage of RA is possible from its practical viewpoint.

Concerning mix design and performance of the mix lot of issues indeed need further research:

- Restrictions to the use of certain types of RA only for identical types of asphalt mixes. For instance gap graded mixes, such as porous asphalt (PA), could only incorporate RA coming from graded mixes.
- Limits, if any, for “rejuvenating oils” in order to improve the adhesion properties of the
old binder.

- Performance of aged polymer modified binders (PMB) from RA and its compatibility with normal paving grade binders on new mixes.
- Impact of fluctuations of RA characteristics on the performance of new mixes.
- Legitimacy of applying rules relating the “final” binder properties (i.e. penetration and Ring and Ball temperature) with those of the new and old binder for special binders (i.e. highly modified binders).
- Allowance of RA containing tar in new mixes and in what percentages.

It is also necessary to take a look into the structural design of bituminous mixes with RA to evaluate how their properties will vary with time. Lifetime assessment may be very different compared to mixes without RA. The structural design rules that are applied for mixes without RA may no longer hold for mixes with RA, because they vary differently with time. This could have a considerable impact on the lifetime of the road structure.

Research around the features above mentioned must be done keeping in mind the performance of asphalt mixtures and not the establishment of empirical relations.

REFERENCES
