Recycling of asphalt



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New set of rules and standards shows the way forward

Parallel arum

Surge bin





Drying drum

Recycling of asphalt

asphalt

Publisher

dav

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Recycling of asphalt

New set of rules and standards shows the way forward

Preface

Asphalt has been systematically recycled in Germany on an industrial scale since 1978. In 1988, the state of the art was presented for the first time in the series of DAV publications entitled "Asphalt – <u>der</u> Baustoff für die Wiederverwendung" (Asphalt – <u>the</u> recyclable building material), in 1997 a revised version entitled "Asphalt – <u>der</u> Baustoff zum Wiederverwenden" (Asphalt – <u>the</u> building material for recycling).



Since the last guideline appeared, asphalt recycling processes have been subject to ongoing development. Quantitatively, advances have been made in terms of increasing the recyclable quantities in the various types of asphalt, and qualitatively, value has been placed on achieving an extremely high level of quality in the process of recycling reclaimed asphalt. In addition to the significant advances made over a decade mostly due to increasing experience in the handling of reclaimed asphalt, it has become necessary to release a new version for the following reasons

- new legal foundation,
- new insights gained as a result of research

and

new construction regulations, especially the Technical Supply Conditions for Reclaimed asphalt (TL AG-StB 06),

the Technical Supply Conditions for Asphalt Mixtures Used in the Construction of Pavements (TL Asphalt-StB 07) and

the Technical Supply Conditions for Aggregates Used in Road Construction (TL Gestein-StB 07). This guideline differentiates between the terms **"Utilisation"** or "utilising", **"Use"** or "using" and **"Recycling"** or "recycle" as follows:

> **"Utilisation"** describes the requirement of the Closed Substance Cycle Waste Management Act (KrW-/AfG) to return excavated asphalt to the closed substance cycle, i.e. normally by transporting it to an asphalt mixing plant.

> The reclaimed asphalt ceases to be waste as soon as it arrives at the plant. The reclaimed asphalt is then stored, treated and processed, i.e. **used**, at the asphalt mixing plant together with other (fresh) construction materials such as aggregates and bitumen.

> **"Recycling"** is defined as reuse of a material/product for the same purpose, i.e. when using reclaimed asphalt to manufacture asphalt mixture.

"Recycling of asphalt" therefore reflects the highest level of recycling, i.e. the reprocessing of asphalt to obtain (hot) asphalt, and therefore demonstrates on the one hand compliance with the requirement of the Closed Substance Cycle Waste Management Act (KrW-/AfG) to achieve an **extremely high quality** of utilisation and on the other the technical and qualitative homogeneity of the product thus obtained.

1. General



Approximately 40 m tonnes of asphalt mixture were produced annually in the Federal Republic of Germany until the reunification in 1990 (Figure 1.1). Production reached its peak in 1994 with 69 m tonnes, and 57 m tonnes of asphalt mixture were produced in 2006. The quantity of reclaimed asphalt recycled in the production of asphalt mixture rose from 0.3 m tonnes in 1982 to roughly 11.5 m tonnes in recent years.

The quota of recycled reclaimed asphalt used in hot asphalt mixture rose from roughly 40% in 1987 to 82% in 2006. The is essentially due to the following:

- improvements made in separate recovery (milling, possibly recrushing and storage),
- improved technologies for increasing quantities added,
- increasing focus on recycling in rules and standards and construction contracts,
- comprehensive distribution and improvement of reclaimed asphalt feeding technologies.

In 1993, nearly 60% of reclaimed asphalt was recycled to make asphalt base course material. Owing to the shift in road construction activities from new construction to maintenance construction measures, the need for **asphalt base courses** will continue to fall and, as a result, recycling for the purpose of obtaining **asphalt binder course** and **asphalt wearing course** mixtures will increase in significance.

In order to be able to continue to utilise the accumulating quantities of reclaimed asphalt to a high standard of quality and as fully as possible, more stringent requirements must exist in relation to the reclaimed material. Initially, the only requirement in relation to aggregates – namely that their quality is to be monitored during initial use – is no longer sufficient. In fact, the properties of aggregates and quality parameters of the binding agents now have to be established both individually and jointly and they must be evaluated so the reclaimed materials can also be used specifically to make the mixtures for asphalt binder and asphalt wearing courses.



Figure 1.1: Asphalt production and recycling in Germany in m tonnes from 1982 to 2006



These changing requirements to be met by reclaimed material have been accommodated by revising the "Technical Supply Conditions for Reclaimed asphalt", Edition 2006 (TL AG-StB 06) and by incorporating the regulations for addition amounts from the "Code of practise for utilisation of reclaimed asphalt", Edition 2000, into the 2007 edition of the TL Asphalt-StB 07. The mandatory application of these rules and standards which has been now introduced ensures that reclaimed asphalt satisfies the requirements for adding large quantities when manufacturing hot mixtures for asphalt base courses and also adding asphalt binder and asphalt wearing courses, without adversely affecting the quality of the material properties in the asphalt mixture thereby obtained.

Of course it goes without saying that high-quality utilisation of reclaimed asphalt in asphalt binder and asphalt wearing courses requires precise and conscientious **"management of reclaimed asphalt"**, between the recovery point and asphalt mixing plant. As only asphalt reclaimed from asphalt wearing courses can be used for newly manufactured **asphalt wearing courses** for example, it must be ensured that the material is removed in layers, separated out and stored separately at the recovery point directly. This requirement can then only be met with certainty if the technical specification states from the outset that the asphalt must be removed in layers. In order also in future to recycle asphalt responsibly, it is indispensable for this topic to be regularly examined and re-examined by working and research committees. This will for example make it possible to use greater quantities of asphalt in low temperature construction methods. With these methods, speciallymodified bitumen or additives are used for which little recycling experience exists and a general solution for the contractual handling (e. g. definition of the tolerance for the ring-and-ball softening point) has not yet been found. The DAV guideline for temperature reduction, to be released at the start of 2009, will contain further information.

In summary, it can be concluded that the objectives of the Closed Substance Cycle Waste Management Act on one hand and the need for efficient handling on the other are the defining elements in ensuring the highest possible quality in relation to the use of reclaimed asphalt and that also continue to apply with the highest possible addition quantities – taking the relevant quality criteria into consideration.

When recycling asphalt, not only constructional aspects must be taken into account, environmental legislation must also be complied with.

2.1 Closed Substance Cycle Waste Management Act

General

The **Closed Substance Cycle Waste Management Act (KrW-/AbfG)** came into force in Germany in 1996 and superseded the 1986 Waste Management Act. Identical or similar laws exist in all German federal states.

This law, which was created in the context of harmonisation of national state regulations to form a Europewide waste legislation, is so general in meaning that construction specifications were necessary for the relevant branches of industry. The law does not contain individual regulations for the recovery/recycling of waste/reclaimed materials. These are formulated as ordinances, using the KrW-/AbfG as the legal basis.

In addition to the KrW-/AbfG and its ordinances, the "Requirements for recycling mineral-based residual materials/waste – technical rules" published by the Federal state community for waste in Germany **(LAGA)** form the basis of federal state regulations when recycling/reusing asphalt.

The LAGA technical rules can be viewed as a link between waste legislation and construction materials recycling, as it states the requirements of the KrW-/AbfG in relation to mineral-based residual materials/waste. The basic notion the two rules and standards have in common is that residual materials or waste are to be fed back into the closed substance cycle and utilised.

The KrW-/AbfG adopted the European definition of waste and therefore put an end to the confusion that previously existing surrounding the terms "waste", "commodity", "resource", "residual material", "residue" and "secondary raw material".

Implementation of the KrW-/AbfG means there are only two types of waste: **"Waste for utilisation"** and **"Waste for disposal"**. Furthermore, it means that **waste avoidance** takes precedence over waste utilisation.

Multiple usability with technical longevity was the introduction to recycling management, and will also assume a decisive influence in future. Apart from continuing with clear prioritisation of waste avoidance, "waste for utilisation", i. e. waste that can harmlessly and correctly recycled should be retained in the economic cycle. This especially applies for asphalt. Accordingly, "waste for disposal" is waste that cannot be utilised correctly and harmlessly and must be disposed of.

The KrW-/AbfG rigorously pursues the path taken by the 1986 Waste Management Act in Germany towards placing more responsibility on the economy itself for the avoidance, utilisation and disposal of waste arising as a result of production and consumption. The purpose of the polluter-pays principle and introduction of basic obligations for the producer and owner of waste (§§ 4ff. KrW-/AbfG: waste avoidance, waste utilisation and waste disposal obligation) is to urge the economy and consumer to move away from thinking in terms of "waste".





Construction sector

The KrW-/AbfG also has a significant influence on the construction sector.

§ 3, Paragraph 1 KrW-/AbfG (definition of terms): "Waste in the sense of this law is all movable objects that belong to the groups listed in Appendix 1 and which the owner disposes of, wishes to dispose of or must dispose of. Waste for utilisation is waste that is utilised; waste which is not utilised is waste to be disposed of."

It follows from the appendix to KrW-/AbfG that, in addition to the list of products listed, materials and residues of all production or consumption residues not described in more detail are waste. According to the law, reclaimed asphalt is waste – and are therefore subject to the KrW-/AbfG.

In several German federal states, regulations exist whereby the characteristic "waste" ceases to apply if the material is utilised correctly and not in a manner that endangers health or the environment and is also subject to independent quality monitoring. This is the case with reclaimed asphalt.

The LAGA technical rules follow the definitions of the KrW-/AbfG. On a positive note, these technical rules define "Recycling" as "reusing a material/product for the same intended purpose".

The general LAGA requirements include the following basic principle:

"The residual material/waste to be utilised must perform the function of a primary raw material in order to satisfy the technical requirements to the maximum possible extent. Justifiable deviations are permissible. The technical requirements are to be specified by the relevant user, by the highway authority or by the mining authorities."

In the road construction sector, this is achieved with contractual terms, guidelines and codes of practise developed in collaboration with the road construction industry associations.

According to § 37 KrW-/AbfG, all authorities of the German federation and legal entities under public law supervised by the German federation are obliged to conduct themselves in a manner that promotes recycling management in order to preserve natural resources and ensure that waste is disposed of in an environmentally-sound manner. A similar obligation has been set out in Article 2, Paragraph 1 of the Bavarian Waste

Management Law (BayAbfG), for example, which states that reclaimed asphalt and reclaimed road construction materials containing tar or pitch must, fundamentally and where economically feasible, be brought to a suitable facility for processing, in order to satisfy the requirements for recycling of the highest possible quality in an environmentally-sound manner. Utilisation is considered to be economically feasible where the associated costs are not disproportionate when compared to the disposal as waste (§5(2)-(4) KrW-/AbfG).

Within the meaning of KrW-/AbfG the treatment of asphalt therefore means:

that highway authorities must satisfy the contractual and technical prerequisites to ensure that reclaimed asphalt is utilised to the **greatest possible extent**. This has been implemented in the last two decades across the Federal Republic of Germany.

All highway authorities are required by law as a matter of priority to promote recycling of reclaimed road construction materials; this also includes the separation of reclaimed asphalt and other reclaimed road construction materials.

The fundamental prerequisite for recycling reclamed asphalt is its constructional suitability.



2.2 Ordinances on the Closed Substance Cycle Waste Management Act

At the time of implementation of the KrW-/AbfG in the autumn of 1996 the German Government issued seven ordinances that have since been partially withdrawn, replaced and modified.

On 1 February 2007 new waste legislation regulations came into force in the form of a new law and a corresponding ordinance introduced to simplify monitoring of compliance with waste legislation. The objective of both sets of rules and standards is to reduce the administration workload of the waste authorities as well as the industry concerned and also boost the efficiency of monitoring compliance with waste legislation.

In Article 1 (revision of KrW-/AbfG) of **"Law for simplification of the monitoring of waste legislation"** dated 15 July 2006 the following are defined and regulated:

- new concepts (hazardous and non-hazardous waste),
- EC legally prescribed waste register,
- structure and general obligations for keeping of records,
- reduction in operational waste management concept and balance sheet obligations,
- monitoring rights privileges of Qualitymanagementsystems,
- monitoring rights privileges of product responsibility,
- power to issue statutory instruments for introduction of electronic communication techniques.

This means that in particular the Ordinance on Waste Management Concepts and Waste Balance Sheets in Germany (AbfKoBiV) of 13 September 1996 and the Ordinance on the Codification of Waste for Recovery Requiring Supervision in Germany (Bestü-VAbfV) of 10 September 1996 have been superseded. Furthermore, the following were modified (among others):

- Environmental Impacts Assessment Act,
- Ordinance on Installations Subject to Licensing,
- Waste Catalogue Ordinance,
- Ordinance on Transport Licences,
- Landfill Ordinance.

The **"Ordinance for Simplification of Monitoring of Compliance with Waste Legislation"** of 20 October 2006 contains the necessary fleshing out of details of the new regulations required for implementation. The **"Ordinance on the Codification of Waste for Recovery Requiring Supervision"** (Ordinance on Waste Recovery and Disposal Records – NachwV) of 10 September 1996 has been fully revised in Article 1 of this ordinance. This new version particularly affects the necessary fleshing out of details in relation to the form and content of the waste catalogue. Article 2 and subsequent articles of the Ordinance for Simplification of Monitoring of Compliance with Waste Legislation contain the necessary follow-up amendments in other statutory regulations.

An **"Implementation aid for amended legislation on waste recovery and disposal records"** (final version of 26 January 2007) has been developed for the new regulations within the scope of federal/state work group "Simplification of procedure for monitoring of compliance with waste legislation".

It is understood as an informative and expert commentary on the new statutory provisions regarding waste recovery and disposal records. It's purpose is to provide assistance with questions and problems arising from implementation of the new legislation. It is not legally binding in any manner whatsoever; experience has shown however that administrative practise frequently complies with it. Following the constitutional order of competencies, this is an opportunity for the federal states responsible for implementation of the amended legislation for waste recovery and disposal records to decide whether, to what extent and how the implementation aid for amended legislation on waste recovery and disposal records is introduced within their area of responsibility. Relevant information is available from the authorities responsible in accordance with federal state law for implementation of legislation for waste recovery and disposal records.

2.3 Contractual regulations



Since as early as 1988 in Germany, the **General technical terms of contract for construction services** (ATV) in the **General regulations for construction work** (ATV DIN18299) contained in the Contracting rules for award of public works contracts (VOB)/Part C

The **client** must pay particular attention to following points according to **ATV DIN 18299**, 2006 Edition when drawing up the specification: envisage the recycling of used materials and components. Used materials and components that satisfy the relevant quality requirements are of the same value as unused materials.

With regard to recycling, the **contractor** is bound by the provisions of **ATV DIN 18299** and **ATV DIN 18317**, October 2006 version respectively, and the **"Additional technical contract conditions and guidelines for the construction of road surfaces using asphalt"**, 2007 Edition (ZTV Asphalt-StB 07) and the **"Technical supply conditions for asphalt mixtures used in the construction of pavements"**, 2007 Edition (TL Asphalt-StB 07) as follows:

- According to Section 0.1.20, the type and scope of pollution, e.g. of the soil, water, air, the materials and components must be stated below the information provided on the building site.
- According to Section 0.2.9, statements regarding the use or additional use of recycled materials must also be provided below the information provided on implementation.
- According to Section 0.2.10, requirements to be met by recycled materials and components must be described.
- According to Section 2.3.1 of ATV DIN 18299, the materials and components supplied and installed by the contractor, i. e. incorporated into the structure, must be unused. Recycled materials are equal to those unused, if they are suitable for the relevant purpose and are also mutually compatible (also see Section 2.1.3 of ATV DIN 18299).
- According to Section 2.1.4.1 of ATV DIN 18317, the contractor can determine the composition of the mixture. In doing so, he must take the



2. Basic legal principles

2.3 Contractual regulations

The **client**

The contractor

customer's specifications on purpose, traffic volumes and types, climatic factors and local conditions into consideration. According to Section 2.1.3 of this ATV, reclaimed asphalt recovered from reclaimed asphalt must also be used, providing the aggregates satisfy the requirements of the **Technical supply conditions for aggregates used in road construction** (TL Gestein-StB). The binder mixture of the asphalt obtained using reclaimed asphalt must be suitable.

According to Section 2.3.2 of ZTV Asphalt-StB 07, the contractor must verify the suitability of the construction materials and mixtures to be used. The proof of suitability must therefore provide the following information on the composition and the tests performed within the scope of the initial type test according to TL Asphalt-StB 07 with additional use of reclaimed asphalt: type and quantity as M.-%, the ring-and-ball softening point of the binder recovered from the reclaimed asphalt and the ring-and-ball softening point on the binder mixture obtained using the reclaimed asphalt.



It has already been pointed out that the road maintenance authority is obliged to use used construction materials (§ 37 KrW-/AbfG) where technically and environmentally compatible materials of equivalent value are available. For this reason the Federal Minister for Traffic, Construction and Urban Development (BMVBS) as issuer of the **"Manual for the award and execu**tion of works in road and bridge construction" (HVA B-StB) states the following in Part 1 "Guidelines for compilation of contractual documents" in the tender conditions/E2 (Sample 1.0-1, Version dated: March 2006) as addendum to paragraph 5 **"Alternative tenders"**:

- Alternative tenders with negative prices will only be recognised if the relevant Position is quoted as a lump sum.
- Alternative tender detailing more affordable or environmentally-compatible proposals for waste avoidance, recycling, recovery or disposal in accordance with KrW-/AbfG are expressly requested.
- **3.** If the solution for utilisation or disposal of waste in the tender is different to the one stated in the specification, the tenderer must verify as a minimum requirement that
 - the plant to be used is licensed to utilise, dispose of and accept the waste and the operator provides legally-binding confirmation that he will accept the waste,

- confirmation by the waste management authority has been provided,
- the costs of utilising the waste have been factored into the unit prices,
- the necessary transport permit (§ 49 Para. 1 No. 2 KrW-/AbfG) has been granted.

The fees incurred for disposing of the waste to be paid by the customer directly must be stated. The declarations and certificates must be presented with the alternative tender.

In conclusion, the new contract conditions provide a range of options that allow the standards of the legislative authority as well as the quality expectations and economic requirements of the customer, the contractor and mixture manufacturer to be met. As the new sets of rules and standards have been harmonised, their application is inevitable and the use of reclaimed asphalt has become state-of-the-art not only when manufacturing mixtures for asphalt base courses, but also for asphalt binder and asphalt wearing courses.

3. Status of research

Research continues to support further developments in the recycling of reclaimed asphalt in practise. Scientific research ensures that the types and grades of mixtures manufactured using reclaimed asphalt are not adversely affected in terms of suitability and useful life.

An important objective behind investigations into the use of reclaimed asphalt is homogeneity of the resulting mixture. This generally concerns the composition/properties

- of the new aggregates,
- of the new binder,
- of the reclaimed asphalt and

how lack of homogeneity in terms of performance characteristics can be avoided.



Figure 3.1: Principle of cryogenic (cooling-dependent) tensile stress, tensile strength and tensile strength reserve as a function of asphalt temperature

3.1 Recycling in asphalt base courses

As early as 1988, the effects of using reclaimed asphalt on the long-term behaviour of asphalt base courses were investigated at the Institute for Road and Railway Engineering at the University of Karlsruhe. During these investigations, asphalt base course mixture containing 30 M.-% of reclaimed asphalt from asphalt binder and asphalt wearing courses was compared with a reference mixture containing 100 M.-% of new construction materials. The behaviour at low temperatures ($< -20^{\circ}$ C) was determined by performing cooling tests. The fracture temperature of the asphalt base course containing reclaimed asphalt was slightly lower with higher cryogenic (cooling-dependent) tensile stress than a mixture that did not contain reclaimed asphalt. It may be concluded from this that reclaimed asphalt does not adversely affect the behaviour of asphalt base courses at low temperatures. Figure 3.1 contain an example showing the determination of tensile strength reserve by carrying out cold tests.

The behaviour at 20 °C was determined by carrying out the dynamic bending tensile strength test. The results of the test indicate that the useful life of the material containing reclaimed asphalt is longer compared to a asphalt base course containing 100 M.-% of new materials. Dynamic creep tests on core samples were carried out in the higher temperature range at 45 °C with the same results for both types of base course.

The uniform distribution of the reclaimed asphalt and possible double coating of reclaimed asphalt pieces with binder in the resulting mixture was evaluated using an an optical mineralogical procedure. These tests were able to demonstrate that although reclaimed asphalt pieces do not dissolve when added cold but they are still fully bonded with the new construction materials and are uniformly distributed. The pattern of the fracture zones arising as a result of the dynamic bending tensile test has no direct correlation with the distribution of the reclaimed asphalt in the specimen, see Figure 3.2.





Figure 3.2: The fracture zone in the specimen has no direct correlation with the distribution of the reclaimed asphalt – the basalt comes from the reclaimed asphalt; moraine and limestone are new aggregates

It was established that when higher quantities are added, apart from the suitability and homogeneity of the reclaimed asphalt, the greater the impact of the method used to heat the reclaimed asphalt has on the resulting mixture.

Whether these conclusions drawn from laboratory tests actually reflect reality and then to what extent was unclear. The objective of the research project "Verifying the performance of asphalt structures with high percentages of reclaimed asphalt" was therefore to clarify uncertainties using existing roads on which traffic has been travelling for at least 5 years containing large amounts of reclaimed asphalt in asphalt base courses. According to the white paper published in 1998, practical investigations of the results obtained in the laboratory have confirmed that mixtures to which reclaimed asphalt has been added can have the same value as mixtures containing exclusively new construction materials providing sufficient care is taken when choosing the reclaimed asphalt and the new construction materials.

3.2 Recycling in asphalt binder courses and asphalt wearing courses

Based on the positive results of the tests carried out to determine the long-term behaviour of reclaimed asphalt in asphalt base courses, similar investigations of asphalt binder and asphalt wearing courses were subsequently carried out in 1989 at the Institute for Road and Railway Engineering at the University of Karlsruhe. The effect of adding cold and heated reclaimed asphalt on homogeneity and mechanical properties was at the centre of these investigations. The addition amounts were 25 M.-% and 20 M.-% for for asphalt binder mixture and asphalt concrete mixture respectively. To ensure that a link with the real-life conditions was established, all asphalts tested were manufactured in a mixing plant and installed in a test section of a road.

The mechanical behaviour at low temperatures was tested by analysing the tensile strength and cryogenic tensile stresses and remained more or less the same when reclaimed asphalt was added in the cold or preheated state. In the displacement-controlled dynamic reversed bending test, no differences were identified in either the asphalt binder courses or the asphalt wearing courses as a result of adding reclaimed asphalt.

During the mineralogical investigations, it was established when comparing the reclaimed asphalt with the new mixture that both were extensively homogeneous in all variants tested. In this case too, with asphalt binder courses and asphalt wearing courses, the fracture zones arising during the reverse bending tests had no direct correlation with the distribution of the reclaimed asphalt. In terms of their homogeneity and mechanical behaviour, the variants where the reclaimed asphalt was preheated were not eva-luated any more positively than variants where the reclaimed asphalt was added cold.

The effects of **"High quantities of reclaimed asphalt in asphalt wearing courses"** were subsequently comprehensively investigated in 1992/1993 at the TU Braunschweig Road Research Institute at laboratory scale, on a semi-industrial scale and on an industrial scale. The main conclusions drawn from these investigations are:





Two separate feed units when manufacturing asphalt mixture, one for the addition of reclaimed asphalt for asphalt base courses and one for asphalt binder and asphalt wearing courses

- During and after manufacturing of asphalts using reclaimed asphalt there was no evening out of the viscosity of the binders involved. This kind of evening out, the result of which would be a resulting bitumen, can only be expected if softer and harder bitumens are mixed or when carrying out tests in the road engineering laboratory.
- There was no systematic correlation between the maximum size of the pieces of the reclaimed asphalt ("U" in EN 13108-8) and the homogeneity of the resulting asphalt mixture.
- Where a greater proportion of reclaimed asphalt was added this made the compaction of asphalt concretes significantly easier
- The risk of cracking in asphalt concretes due to low temperatures has been reduced by using a softer bitumen as additional bitumen.

The research study entitled **"Effectiveness of the addition of reclaimed asphalt on the mechanical properties of asphalt wearing courses"** was structured by the TU Braunschweig Road Engineering Institute so it could perform performance-oriented tests – selectively using an asphalt concrete 0/11 S – during which the following factors were varied:

- Reclaimed asphalt hardness (ring-and-ball softening points: 56 °C, 69 °C),
- Proportion added (ratios: 20 M.-%, 40 M.-%),
- Addition method (warm feed, cold feed),
- Post-mixing time (times: 30 s, 90 s, 180 s)
- Moisture content of reclaimed asphalt (natural water content, 3% moisture)

The results were published in 2004 and demonstrate that additional use of reclaimed asphalt in asphalt concrete wearing courses is possible without adversely affecting quality. This not only applies for the conventionally definable parameters, namely composition and void characteristics. The performance-oriented systematically-implemented tests

- Compactability by determining the compaction resistance,
- Deformation resistance when exposed to heat using wheel tracking tests and dynamic creep tests, cracking behaviour when exposed to cold using tensile and cooling tests and
- fatigue characteristics ascertained by performing tensile/swelling tests

show that the use of reclaimed asphalt does not bring about a one-sided shift in the performance characteristics "to the cold or hot side" depending on the hardness of the reclaimed asphalt. It is much more evident that the addition of hard reclaimed asphalt in fact has a positive effect on the cold and fatigue behaviour. The double coating of aggregates which occurs may influence these results. A further reason why the property of the mixture is positively affected is without a doubt also the affinity of the old bitumen on the aggregates.

The research study also revealed that the duration of the post-mixing time is of particular significance. Although the technology available in the lab cannot be compared with an industrial-scale mixing plant, the greatest of care must still be taken to ensure an appropriate post-mixing time and corresponding homogenisation in the mixing plant. The above particularly applies when heating the reclaimed asphalt by the hot aggregates.

3. Status of research

3.2 Recycling in asphalt binder courses and asphalt wearing courses

The objective of the research study "Effect of adding reclaimed asphalt to asphalt binder mixture with PmB 45" was to find out how adding reclaimed asphalt with or without PmB affects the mechanical properties of a compacted asphalt binder mixture 0/16 S with PmB 45. For the purpose of this study, the asphalt binder courses were manufactured using two PmB 45 A by different manufacturers which were chosen so that the entire range of properties of standard PmB 45 A was covered. The subjects of the systematic variations were the quality of the reclaimed asphalt (with PmB on the one hand, and with paving grade bitumen on the other), addition ratios, addition temperatures and post-mixing times. 36 asphalt binder variants in total were manufactured at laboratory scale using twin-shaft pugmills. The testing instruments used were compaction tests to determine compaction resistance, indirect tensile tests to test the adhesion properties, wheel tracking tests and dynamic punch penetration tests to determine the deformation characteristics, tensile tests at different temperatures and cooling tests to test flexibility at low temperatures and mono-axial dynamic tensile tests to assess resistance to fatigue.

The results were published by the TU Braunschweig Road Research Institute in 2007 and were as follows:

- No conclusions could be drawn regarding the quality of the reclaimed asphalt used or the mechanical properties of the asphalt obtained, based on the properties of the binder extracted from the asphalt binder variants. Both the ring-and-ball softening point and the elastic recovery of the extracted binder satisfy the required values in TL PmB, Edition 2001 in combination with ZTV Asphalt-StB. The elastic recovery is more than 50%, even if the re-claimed asphalt is used with paving grade bitumen as binder.
- There is no indication that the test results are adversely affected by adding large quantities of reclaimed

asphalt, on the contrary, both the deformation behaviour and the low temperature and fatigue properties are favourably affected when a large quantity (30 M.-% as opposed to 15 M.-%) is added.

- The post-mixing time was identified as a dominant influence on the mechanical properties of the asphalt mixture obtained. The deformation, low temperature and fatigue properties were positively affected by extending the post-mixing time, to the extent that more or less equivalent and sometimes even more favourable properties were obtained than when using asphalt binder mixture without adding reclaimed asphalt. This was also determined when using reclaimed asphalt with paving grade bitumen, irrespective of the addition temperature.
- When using reclaimed asphalt with PmB, flexibility at low temperatures was adversely affected if the post-mixing times were too short.

On the whole, the results of all research studies quoted show that reclaimed asphalt fractions can be added to the mixture for asphalt binder courses and asphalt wearing courses. In practise, reclaimed asphalt fractions of up to 50 M.-% have been used successfully when manufacturing mixtures for both courses.

The prerequisites for this are

- careful sourcing,
- effective receiving inspection,
- separate storage,
- extensive initial type tests and
- machine- and process-specific requirements to be met by the mixing plant.

4. Reclaimed asphalt



Breaking up a layer package using the drag shovel

Asphalt that is reclaimed for road construction is to be reused during the course of road construction measures. The highest quality type of material utilisation that must fundamentally be aimed at is use in the manufacturing of new asphalt mixtures, as this is the only possible way to use the binder it contains, bitumen, as the binder again.

To do so, the reclaimed asphalt must be classified in accordance with the **"Technical supply conditions** for reclaimed asphalt", 2006 Edition (TL AG-StB 06). TL Asphalt-StB 07 defines how to determine the maximum possible addition quantities. The **"Code of Practice for the Utilisation of Reclaimed asphalt**", 2000 Edition (M VAG) gives further guidance; this code of practise, to which reference has already been made in this guideline – e. g. in the nomograms, is due to be revised in 2008.

The terms used in the recycling of asphalt are defined in the TL AG-StB 06 as follows:

- Asphalt is an industrially-manufactured mixture containing paving grade bitumen or binders containing bitumen and aggregates, and also possibly other additives. Asphalt also occurs naturally on its own in nature in a particular composition.
- Asphalt comes in the form of milled asphalt or demolition asphalt (slabs, lumps) back to the Asphaltplant.
- Milled asphalt is been obtained by milling asphalt layers to a small size.

- The **maximum piece size U** of the reclaimed asphalt corresponds to the nominal width of the testing sieve through which the larger pieces are just able to pass.
- The piece size distribution is the composition of the reclaimed asphalt which is categorised in size fractions. It does not describe the particle size distribution of the aggregate mixture in the reclaimed asphalt.
- The size fraction of aggregates and pieces in reclaimed asphalt is identified by the lower (d) and upper (D) mesh size as d/D. (Note: Both the aggregates in the reclaimed asphalt and the distribution of piece sizes in the reclaimed asphalt itself (e. g. for utilisation in unbound layers) are identified in this manner.
- The biggest particle diameter D of the aggregate mixture extracted from the reclaimed asphalt is the larger of the two values below:
 - mesh width M/1.4 (M is the smallest mesh width with 100 M.-% passing) or
 - the smallest mesh width with at least 85 M.-% passing..
- A category is the characteristic level for the characteristics of a construction material, expressed as a range of values or as a limit value.
- **Demolition asphalt** is obtained by breaking/lifting up a layer package in slabs (see illustration above).
- Reclaimed asphalt is recovered in pieces by milling (possibly followed by further comminution) or by breaking up/lifting up slabs in pieces which are subsequently crushed and processed. Note: In this English translation the term "Reclaimed Asphalt" is reserved for the processed, assessed and ready to be used material. The literal translation of the german term would be "Asphalt Granulates", but according to EN 13108-8, "Reclaimed Asphalt" is used for the constituent material/product.

Milling of an asphalt pavement structure



4. Reclaimed asphalt

4.1 Recovery and storage



Comminution of asphalt slabs in the crusher

Reclaimed asphalt is either recovered by lifting up in slabs or ideally by milling, then processed and assessed. When lifting up in slabs it is subsequently necessary to crush the asphalt until the required piece size is obtained.



Separate recovery and storage of reclaimed asphalt is the prerequisite for high-quality utilisation

The "Code of practise for the milling of asphalt pavements" (M FA) regulates the removal of asphalt courses by milling. Milling in layers is the preferred method of recovery, as this enables the reclaimed asphalt to be stored and processed separately. The reclaimed asphalt thus selectively recovered should be stored separately according to its intended use (manufacturing of asphalt mixtures, manufacturing of construction material mixtures for unbound base courses ders or base courses with hydraulic binders). Furthermore, separate storage of milled asphalt obtained from asphalt wearing courses and asphalt binder courses and also milled asphalt obtained exclusively from asphalt wearing courses is necessary. Asphalt reclaimed from mastic asphalt or special types of mixtures must also be stored separately.

When recovering or preparing reclaimed asphalt, internal changes in the aggregate mix (e. g. due to particle fragmentation) are unavoidable. The relationship between coarse and fine aggregate may not be the same as it was originally in the asphalt mixture.

Whenever possible, the reclaimed asphalt to be used in the near future should be stored dry. Although in principle open-air storage is possible, the energy costs for manufacturing asphalt mixture increase signi-ficantly as the moisture content of the reclaimed asphalt increases. A warehouse is an ideal and frequently economical dry storage solution. If this is not available, the reclaimed asphalt can also be kept dry using other suitable measures, by covering it with tarpaulins for example.



4.2 Recycling in asphalt mixtures



4.2.1 Suitability

When manufacturing asphalt mixtures via hot plant mixing, exclusive use of reclaimed asphalt is permissible. This means that the material must correspond to the utilisation class A as per the German **"Guidelines for environmentally-clean utilisation of reclaimed materials with typical tar/pitch constituents and for utilisation of reclaimed asphalt in road construction"** (RuVA-StB). In addition, the reclaimed asphalt must be classified in accordance with TL AG-StB (see Section 4.2.2).

Reclaimed asphalt whose binder has an average ringand-ball softening point $(T_{R\&B})^*$ of no more than 70 °C (individual values of up to 77 °C are possible) is normally suitable for use in asphalt mixture. With higher $T_{R\&B}$ softening points, the effectiveness of the binder in the mixture must be tested based on appropriate technological characteristics (e. g. behaviour at low temperatures) as part of separate investigations and taken into account as required when compiling the initial type test. To do this, it must be compared with the technological characteristics of a mixture manufactured exclusively using new construction materials.

This particularly applies if special binders that already have high TR&B softening points in their initial state are used. These kind of binders can for example be modified bitumen, such as the bitumens used to lower the manufacturing and laying temperature of asphalt or to assist with laying and processing. A general upper limit value for the T_{R&B} softening point with a view to effectiveness of the binder should not be defined. The DAV guideline for Warm Mix Asphalts, to be released at the start of 2009, will contain further information.

Table 4.1 shows the range of options for adding reclaimed asphalts to the various types of asphalt mixtures.

	Addition options for asphalt mixture for								
Reclaimed asphalt from	Mastic asphalt	Rolled asphalt wearing course	Asphalt binder course	Asphalt base course	Combined asphalt base and wearing course	Asphalt foundation course			
Mastic asphalt	++	Ο	0	+	Ο	Ο			
Rolled asphalt wearing course	-	++ ¹⁾	++	+	+	+			
Asphalt wearing ²⁾ and binder course	-	O ³⁾	++	+	+	+			
Asphalt binder course	-	O ³⁾	++	+	+	+			
Asphalt base course or combined asphalt asphalt base and wearing course	-	-	-	++	ο	+			
Asphalt foundation course	_	_	_	ο	_	++			

Table 4.1: Options for addition of reclaimed asphalt to the asphalt mixture types (as per M VAG)

++ = priority (highest value-added step)

- = possible, but without fully exploiting the technical characteristics and cost effectiveness

O = possible with some reservations following special testing

- = not possible ¹) as per TL Asphalt-StB ²) normally not from mastic asphalt ³) following separate processing

4. Reclaimed asphalt

4.2 Recycling in asphalt mixtures

4.2.2 Classification

Reclaimed asphalt is classified according to TL AG StB which states that the individual properties and characteristic values of the reclaimed asphalt and its constituents are to be classified based on parameters.

The following can be used to determine these parameters:

- Information on the origin of the reclaimed asphalt and the materials in the asphalt when used for the first time and also passing of a quality monitoring test carried out within the scope of initial use,
- Results from the time the asphalt was manufactured and layed (e.g. results of previous type tests, self-monitoring tests or contractual testing),
- Results of tests on samples of the pavements or courses to be reclaimed or
- Results of tests carried out on the reclaimed asphalt itself.

The parameters required to determine the homogeneity of the reclaimed asphalt are excluded from this. These must always be defined by carrying out tests on the reclaimed asphalt itself. The homogeneity of reclaimed asphalt to be used for the manufacturing of asphalt mixtures is assessed based on the following characteristic values:

- binder content,
- ring-and-ball softening point T_{R&B},
- particle fractions
 - 0 to 0.063 mm and
 - 0.063 to 2 mm and
 - > 2 mm
 - at the relevant extracted aggregate mixture.

Note: When recycling reclaimed asphalt for unbound layers, hydraulically-bonded layers and bitumen-bound base courses in cold processing, the homogeneity of the fractions of piece sizes 0 to 0.063 mm, 0.063 to 2 mm and > 2 mm must be determined.

In doing so, the homogeneity of the reclaimed asphalt in the stockpile is described by the range of corresponding consistent (i. e. outlier-free*) measured values of these characteristic values.

* see "Code of practise for statistical evaluation of test results – Part 2: identifying and dealing with outliers"



A sample must be taken for every 500 tonnes of the stockpile, or part thereof, which is used. This means for example that at least 9 samples must be tested with a stockpile of 4200 tonnes and 5 samples must be tested with a stockpile of 1200 tonnes.

If demolition asphalt and/or milled asphalt recovered from different sources is to be jointly reused, testing of the reclaimed asphalt must only be carried out following comminution and mixing as only then will the results be representative. This excludes testing of the environmental compatibility of the reclaimed asphalt (testing of tar/pitch-typical constituents) which must always be clarified or tested upon delivery. Other individual characteristics are verified according to the intended purpose and this is regulated by TL AG-StB.

Annex 3.1 of this guideline contains a printout of a form which is used for classification purposes, taking TL AG-StB 06 and Appendix A of TL Asphalt-StB 07 into account. It is different to the form in Appendix 4 of TL AG-StB 06 in that the lines that deal with the aggregate properties C, PSV and F take the new TL Asphalt-StB 07 specifications into account. In addition, the ECS line and the line where the method used to test the density in the raw state is stated have been omitted.

Annex 3.2 contains an example of classification for reclaimed asphalt which is suitable for addition to a mixture used in asphalt binder courses.





4.2.3 Determining the maximum possible addition amounts

The maximum amount of reclaimed asphalt which can be added when manufacturing asphalt mixtures depends on

- the suitability of the reclaimed asphalt for the designated asphalt mixture (mix design),
- the homogeneity of the reclaimed asphalt and
- the mechanical prerequisites of the relevant asphalt mixing plant (cp. Section 5),

whereby the smallest of the three values is to be used as the basis for the amount added.

Mix Design

With "mix design" (i. e. when compiling and optimising the composition of the asphalt mixture prior to initial type testing) it must of course be ensured that the resulting asphalt mixture satisfies all requirements of TL Asphalt-StB 07. The ratio of fine aggregates or the ring-and-ball softening point of the binder in the reclaimed asphalt respectively may for example already determine the maximum possible addition amount alone.

Die TL Asphalt-StB 07 schreiben vor, dass der rechnerische Erweichungspunkt Ring und Kugel des resultierenden Bindemittels mit folgender Formel (4.1) zu ermitteln ist: $T_{R\&Bmix}$ must then be within the grade range of the required (specified) bitumen. A bitumen with the same specification as the required bitumen or a paving grade bitumen that is (at the most) one grade softer than the required bitumen can be used for this. A softer bitumen than 70/100 must not be used – with the exception of combined asphalt base and wearing course mixture.

For asphalt **base** course mixtures, Section 3.4.3 of ZTV Asphalt-StB 07 rules that when using reclaimed asphalt and a paving grade bitumen 70/100 or 50/70 is requested (i.e. specified) the contractor can, as opposed to the binder grade specified in the invitation to tender, also state a resulting ring-and-ball softening point ($T_{R\&Bmix}$) that corresponds to the nearest harder grade. This grade then counts as the requested (specified) binder grade for the asphalt mixture.

4. Reclaimed asphalt

4.2 Recycling in asphalt mixture

Homogeneity

In order to determine the value for the maximum possible addition amounts arising from the homogeneity, TL Asphalt-StB 07 contains corresponding formulas that, depending on the type of asphalt mixture concerned, state the maximum permissible range of characteristics as a function of the amount added. The maximum possible addition amount can be very easily determined depending on the range of the corresponding characteristic value by simply changing these formulas around.

Asphalt base courses, combined asphalt base and wearing courses and asphalt foundation courses

When recycling reclaimed asphalt to manufacture asphalt mixtures for asphalt base courses, combined asphalt base and wearing courses and asphalt foundation courses ("Code of practise for hot-laid asphalt foundation courses" (M AFS-H)), the maximum permissible range of the individual characteristic is **half** of the (contractual) permissible overall tolerance of this characteristic in accordance with ZTV Asphalt-StB 07 (see Tab. 4.2 of this guideline), divided by the addition amount (Formula 4.2)

$$a_{\max} = \frac{0.5 \cdot T_{perm}}{Z_{poss}} \cdot 100$$
 Formula 4.2

with

- *a*max Maximum permissible range of corresponding characteristic
- **T**_{perm} Permissible (contractual)overall tolerance of the characteristic in accordance with ZTV Asphalt-StB 07
- **Z***poss* Maximum possible reclaimed asphalt addition amount in M.-%

Following the changeover, formula 4.3 is produced and the addition amount is half of the permissible overall tolerance for the corresponding characteristic divided by the range of the characteristic determined by the tests.

$$Z_{poss} = \frac{0.5 \cdot T_{perm}}{a_{max}} \cdot 100$$

Formula 4.3

Table 4.2: Overall tolerances T_{perm} of relevant characteristics as a function of asphalt mixture type (corresponds to Table D.1 of TL Asphalt-StB 07)

		T _{perm}					
Characteristic	A: co	sphalt mixture for asphalt wearing courses, asphalt binder courses and ombined asphalt base and wearing courses	Asphalt mixture for asphalt base courses				
Softening point [°C Ring-and-ball]	8	8				
Binder content [M	I%]	1,0	1,2				
Particle fraction < 0.063 mm [M	I%]	6,0	10,0				
Particle fraction 0.063 to 2 mm [M	I%]	16,0	16,0				
Particle fraction > 2 mm [M	I%]	16,0	18,0				





The maximum addition amount arising from the homogeneity of the reclaimed asphalt is then the smallest of the values determined for the five characteristics (binder content, ring-and-ball softening point and the corresponding particle fractions 0 to 0.063 mm, 0.063 to 2 mm and the particle fraction > 2 mm at the extracted aggregate mixture).

With the introduction of TL Asphalt-StB 07 and ZTV Asphalt-StB 07 came a new development in that ZTV Asphalt-StB 07 now also documents the particle fraction 0.063 to 2 mm for asphalt **base** courses with a

tolerance (± 8.0 M.-%). Accordingly, in contrast with the process detailed for example in the 2000 edition of the "Code of conduct for utilisation of reclaimed asphalt", this characteristic must **also** be taken into account for the asphalt base courses.

The maximum possible addition amount can also be determined graphically as a function of the range of the characteristics using the nomogram (Figure 4.1). The additional characteristic referred to above (particle fraction 0.063 to 2 mm) has been incorporated into Figure 4.1 with its own abscissa.



Range of the characteristic values of the reclaimed asphalt

Reclaimed asphalt addition amount [M.-%]

Figure 4.1: Nomogram for determining the maximum possible reclaimed asphalt addition amount in asphalt mixture for asphalt base courses, combined asphalt base and wearing courses and asphalt foundation courses with reference to the five characteristics of the reclaimed asphalt (based on M VAG)

4. Reclaimed asphalt



4.2 Recycling in asphalt mixture

Asphalt wearing courses and asphalt binder courses

When using reclaimed asphalt to manufacture asphalt mixture for asphalt wearing courses and asphalt binding courses, the maximum permissible range of the characteristics is **one third** of the (contractual) permissible overall tolerance in accordance with ZTV Asphalt-StB 07

(see Tab. 4.2 of this guideline), divided by the addition amount.



Formula 4.4

An **exception** in this case is the characteristic value **ring-and-ball softening point** for which **the half** of the permissible overall tolerance applies.

Following the changeover which corresponds to the procedure followed for asphalt base courses, Formula 4.5 is produced and the addition amount is one third of the (contractual) permissible overall tolerance for

the corresponding characteristic divided by the range of the characteristic determined by the tests. (with exception of $T_{R\&B}$).

$$Z_{poss} = \frac{0,33 \cdot T_{perm}}{a_{max}} \cdot 100$$

Note: Does not apply for the Formula 4.5 ring-and-ball softening point

Here too, the maximum addition amount arising from the homogeneity of the reclaimed asphalt is also the smallest value of those calculated for the five characteristics.

The maximum possible addition amount can also be determined graphically in this case as a function of the range of the five characteristics using the relevant nomogram (Figure 4.2).



Reclaimed asphalt addition amount [M.-%]

Figure 4.2: Nomogram for determining the maximum possible reclaimed asphalt addition amount in asphalt mixture for **asphalt** wearing courses and asphalt binder courses with reference to the five characteristics of the reclaimed asphalt (based on M VAG)

Range of the characteristic values of the reclaimed asphalt



Example for calculating the maximum possible reclaimed asphalt addition amount with reference to the homogeneity of the reclaimed asphalt characteristics

In this example, the reclaimed asphalt is to be used to manufacture asphalt mixture for asphalt binder courses. It has the characteristics listed in Table 4.3 below

The ranges of the individual characteristic values are entered in the nomogram at the corresponding ordinate (Figure 4.3). The highest range of a characteristic that lies on the ordinates from which the lowest reclaimed asphalt addition amount can be read off is decisive for determining the maximum possible amount of reclaimed asphalt to be added with reference to homogeneity.

Table 4.3: Example for characteristics of reclaimed asphalt which is suitable for addition to asphalt binder mixture

Characteristic	Softening point Ring-and-ball (T _{R&B}) [°C]	Binder content [M%]	Particle fraction < 0,063 mm [M%]	Particle fraction 0,063 mm bis 2 mm [M%]	Particle fraction > 2 mm [M%]
Sample no. 1 Sample no. 2 Sample no. 3 Sample no. 4 Sample no. 5	68,6 64,0 64,8 68,0 66,4	5,8 5,8 5,2 4,7 5,1	9,8 11,3 9,2 6,7 12,1	27,7 25,2 19,8 21,5 23,8	62,4 63,5 70,9 71,8 64,1
Mean value	66,4	5,3	9,8	23,6	66,5
Range	4,6	1,1	5,4	7,9	9,4

In this example, when manufacturing asphalt binder mixture, a maximum addition amount of 30 M.-% is obtained based on the homogeneity of the reclaimed asphalt. In this case, the range of the binder content is crucial (or the limiting characteristic). For this amount to be added, the asphalt mixing plant must on the one hand have suitable mechanical equipment and the moisture content of the reclaimed asphalt must be low (cp. Section 5) and a suitable mix design must be used on the other hand to ensure the resulting mixture satisfies the requirements to be met by the asphalt binder mixture. Range of the characteristic values of the reclaimed asphalt



Figure 4.3: **Example** ffor determining the maximum possible reclaimed asphalt addition amount for an asphalt binder mixture with reference to the homogeneity of the reclaimed asphalt characteristics

4.2 Recycling in asphalt mixture

Plant-specific conditions

When determining the maximum addition amount that can be used in practise, next to the maximum addition amount calculated with reference to the characteristic value ranges the maximum addition amount found in the mix design as well as the specific conditions of the designated asphalt mixing plant must also be taken into account. For more information refer to Section 5.

4.2.4 Initial Type Testing and proof of contractual suitability

An initial type testing must be carried out for each asphalt mixture composition. This type test is carried out to verify that the requirements of TL Asphalt-StB have been satisfied and for the purposes of CE marking. This must be carried out prior to initial use and incorporates the tests specified in TL Asphalt-StB 07. To this end, section 4.2.3 of this guideline describes the procedure used to calculate the resulting $T_{R\&BMix}$ softening point.

A certificate of contractual suitability (which becomes an integral part of the contract) is drawn up on the basis of these values and states that the asphalt mixture is suitable for the purpose (project) intended.

In addition, when reclaimed asphalt is used manufacturing the mixture

- the particle size distribution of the aggregate mixture in the reclaimed asphalt and
- the binder content and
- the softening point ring-and-ball of the binder in the reclaimed asphalt

must be determined (by carrying out a test, i.e. "test once again").

In addition, the

density of the reclaimed asphalt in its raw state

must be determined.

For this characteristic value (in contrast to the three other characteristic values) the results of the classification in accordance with TL AG-StB, i.e. the information from the form used for classification, can be used.



4.3 Using in unbound, hydraulically-bound or bitumen-bound (cold processed) mixtures

As well as the preferred addition of reclaimed asphalt to hot asphalt mixture, reclaimed asphalt can also be used to manufacture

- courses without binders in accordance with the "Technical supply conditions for construction material mixtures and soils used in road construction to manufacture courses without binders" (TL SoB-StB),
- base courses with hydraulic binders in accordance with the "Technical supply requirements for construction materials and construction material mixtures for hydraulically-bound base courses and concrete toppings" (TL Beton-StB 07) or
- cold-process bitumen-bound base courses in accordance with "Code of practise for utilisation of road construction materials containing tar and reclaimed asphalt in bitumen-bound base courses by means of cold-processing in mixing plants" (M VB-K)

providing the requirements defined in these rules and standards for the construction material mixtures are met.

Deformation may occur in courses without binders containing high reclaimed asphalt ratios, as a result of traffic-related post-compaction at high temperatures which is why the construction material mixture must in general not contain more than 30 M.-% of reclaimed asphalt. Higher amounts can also be added and processed providing this is verified, e.g. by trial compaction. The installation of reclaimed asphalt in noise barriers or in the substructure of traffic zones should generally be avoided as this kind of use does not satisfy the requirements of the Closed Substance Cycle Waste Management Act.





5. Plant engineering

5.1 Batch mixing plants

As a basic rule, reclaimed asphalt should always be used as aconstituent material for asphalt mixes, as this is the only way to reuse the binder, the bitumen it contains. Different plant technologies are available for this.

Reclaimed asphalt is normally

- heated (batchwise or continuously) by the hot aggregates
- together with the aggregates or
- in separate facilities.

Due to the diversity of the mixture grades and types and the fact that often only small amounts of asphalt are required, in Germany asphalt mixture is predominantly manufactured using batch mixing plants. There are very few continuous mixing plants in operation because it only makes sense to use these if larger amounts of mixtures are produced without changing the grade or type (e.g. new building or basic reconstruction of main roads).

Figure 5.1: Batch mixing plant – heating reclaimed asphalt with

Aggregates, binders and possibly additives are weighed in in batch mixing plants according to the size of the mixer. Reclaimed asphalt can be fed to the mixer in different ways.

5.1.1 Batchwise addition of reclaimed asphalt

The reclaimed asphalt is fed to the mixer via a surge bin and aggregate scale (1) or via a separate batch scale (2) (Figure 5.1). **Heating** takes place (in the mixer) **by the hot aggregates.**

As the temperature of the mixture has a significant influence on laying and compaction, the mixture temperature limit values defined in the contractual conditions must not be undercut. (These are normally the temperatures defined in Table 3 of TL Asphalt-StB 07.) The thermal energy required to heat the reclaimed asphalt is drawn from the unused aggregates, which

hot aggregates, batchwise addition

1 Addition to aggregate scale

2 Addition to mixer



Addition of (cold) reclaimed asphalt to the mixer via a batch scale

means that these must be heated to an appropriate higher temperature. The moisture in the reclaimed asphalt must be evaporated. The values in Figures 5.2 and 5.3 can be used for heating the unused aggregates, depending on the amount to be added and the moisture content of the reclaimed asphalt.

30 M.-% of reclaimed asphalt at the most is normally added and this amount is determined by the moisture content of the reclaimed asphalt and the required temperature of the hot aggregates..

When heat is transferred from the hot aggregates to the reclaimed asphalt, the moisture it contains evaporates and water vapour is suddenly produced which must be drawn off via suction devices or overpressure flaps.

The hot aggregates are first premixed with the cold reclaimed asphalt to counteract the hardening of the new binder. Once the surplus heat in the aggregates has dissipated during which time the reclaimed asphalt has been dried and heated, the new binder is added.

The screening and metering of the unused aggregates from the hot silos is not adversely affected. Figure 5.2: Required temperature of aggregates at specified mixture temperature as a function of the amount of reclaimed asphalt added



Figure 5.3: Required increase in temperature of aggregates as a function of the reclaimed asphalt moisture content; the highlighted area should be avoided (critical area)

Addition amount	Moisture content of reclaimed asphalt in M%								
of reclaimed	1	2	3	4	5	6			
asphalt in M%		Temperature adjustment in ^o C							
10	4	8	12	16	20	24			
15	6	12	18	24	30	36			
20	8	16	24	32	40	48			
25	10	20	30	40	50	60			
30	12	24							

5.1 Batch mixing plants

5.1.2 Continuous addition of reclaimed asphalt

Another way to **heat reclaimed asphalt by the hot aggregates** is to add (Figure 5.4)

- into the outlet of the drying drum or into the hot elevator or
- Into the screen bypass.

With drying drums that operate according to the counter-flow principle (which is normally the case), the reclaimed asphalt can be added via a central feed system or via a device at the drum outlet (Figure 5.5). In this case the reclaimed asphalt is **heated together** with the aggregates.

With both processes, amounts of up to approx. 40 M.-% can be added. The extended heating time means that water vapour does not form instantly as the reclaimed asphalt is continuously added. The addition of reclaimed asphalt is controlled via belt scales.

Hot screening of mixtures consisting of aggregates and reclaimed asphalt would cause clogging of the sieves which therefore excludes addition amounts greater than 10 M.-%. The mixture is therefore directed through the screen bypass (Figures 5.4 and 5.5). The granulometric composition of the resulting aggregate mixture is therefore determined exclusively by the homogeneity of the aggregates and the reclaimed asphalt as well as the setting of the cold feed dosing units. Subsequent adjustment (as described in Sections 5.1.1. or 5.1.3) is no longer possible. Figure 5.4: Batch mixing plant – heating of reclaimed asphalt by the hot aggregates, continuous addition

Figure 5.5: Batch mixing plant – heating of reclaimed asphalt together with the aggregates, continuous addition



- 1 Addition to drying drum outlet
- 2 Addition to hot elevator
- 3 Addition to screen bypass



- 1 Drying drum central feed system
- 2 Addition to drying drum via front wall on burner side (e.g. slinger conveyor)

5. Plant engineering

5.1 Batch mixing plants

5.1.3 Heating in separate devices

Parallel drums (Figure 5.6) have proven to be effective as devices in which the reclaimed asphalt can be heated separately; amounts of up to approx. 80 M.-% can be added when manufacturing asphalt base course mixtures, and when manufacturing asphalt foundation course mixtures this can even be as much as 100 M.-%. During this process, the reclaimed asphalt is heated to a maximum temperature of 130 °C in order to preserve its binder and to limit emissions.



Parallel drum for gentle drying and heating of reclaimed asphalt – elevated so that the heated (and therefore glutinous) reclaimed asphalt cannot adhere to or clog downstream conveyors.



Parallel drum – elevated with connected reclaimed asphalt hot silos (silver), via which heated reclaimed asphalt can be added at short notice and also when producing small amounts

The larger the proportion of reclaimed asphalt added, the greater the effect this has on the composition of the new mixture. In terms of its composition and homogeneity therefore, it is particularly important that the reclaimed asphalt satisfies the designated purpose (cp. Section 4).

Figure 5.6: Batch mixing plant – heating of reclaimed asphalt in separate device (parallel drum)



1 Addition to aggregate scale

2 Addition to mixer

In these plants the unused construction materials are mixed continuously in a drum (Figure 5.7) or in a downstream continuous mixer (Figure 5.8). Therefore it follows that the reclaimed asphalt is also added continuously during this process.

The homogeneity of the mixture's composition largely depends on the homogeneity of the aggregates and the reclaimed asphalt and cannot be changed once discharged from the cold feed dosing units. The reclaimed asphalt is **heated** continuously **together with the aggregates** and added either with the cold aggregates or close to the centre of the drum (Figure 5.7). Unused aggregates and reclaimed asphalt are weighed separately using belt scales, dried and heated together in the drum and mixed with additional binder in one operation. With both processes, amounts of up to approx. 50 M.-% can be added.

Figure 5.7: Continuous mixing plant – heating of reclaimed asphalt together with aggregates



1 Addition together with aggregates

2 Separate addition in centre of drum mixer

5. Plant engineering

5.2 Continuous mixing plants

In continuous mixing plants, the reclaimed asphalt can also be heated **in a separate device** (parallel drum, Figure 5.8), although the temperature must not be higher than 130 °C in order to preserve the binder and to limit emissions. As with the batch mixing plants, large quantities can be added (up to roughly 80 M.-% when manufacturing asphalt base course mixtures, and even as much as 100 M.-% when manufacturing asphalt foundation courses).

Figure 5.8: Continuous mixing plant – heating of reclaimed asphalt in a separate device (parallel drum) – addition in downstream continuous mixer



6. Recycling in-situ

6.1 Reshaping

Apart from using stationary mixing plants and mixing plants that have only been provisionally set up (mobile), asphalt can also be lifted, mixed and then reinstalled directly on-site (in situ), i. e. by self-propelled machines on the building site in a hot process (reshaping) or in a cold process (cold recycling in situ), using the processes listed below.

Only asphalt courses that have been manufactured exclusively using bitumen or bitumen-based binders are suitable for the reshaping application and therefore must correspond to utilisation class A as specified in the **"Guidelines for environmentally-clean utilisation of reclaimed materials with typical tar/pitch components and for the utilisation of reclaimed asphalt in road construction"**, Edition 2001, Version 2005, (RuVA-StB 01) (cp. Annex 1).

Depending on the requirement, reshaping can be performed with, or without, mixing in additional materials such as asphalt mixture, binder, additives or aggregates. Reshaping produces an asphalt course which can be

- subsequently be built on top of later,
- driven directly over or
- be built on top of directly with asphalt using hot-on-hot construction methods.

Depending on the objective of the construction maintenance measures, different construction methods can be selected:

- a) Reshape Reshaping without changing the composition of the asphalt
- b) Remix
- Reshaping and changing the composition of the asphalt
- c) Remix compact Reshaping with change in the asphalt composition combined with installation of a new wearing course with additional paver screed plate.

With the **Reshape** construction method, the course to be worked on is heated gently using infrared heaters or other indirect heating appliances down to the specified depth so that the asphalt material can be loosened, lifted up and mixed in the mixer. The asphalt is then distributed crosswise with a spreading auger and precompacted according to the required profile using the paver screed plate. Finally, the reshaped course is compacted.

> Remixer beim Rückformen einer Asphaltdeckschicht

6. Recycling in-situ

6.1 Reshaping

The **remix** construction method follows a similar procedure to the reshape construction method. The difference between the two is that additional materials such as specially composed supplementary mixture and/or binders are added and mixed with the lifted asphalt in the mixer to change the mixture composition and the properties, depending on the requirements, to obtain a modified asphalt in terms of its composition. This is followed by laying and compaction as with the reshape construction method.



With the **remix compact** construction method, a new course consisting of plant-mixed asphalt mixture is installed on top of the reshaped course according to TL Asphalt-StB "hot-on-hot" in compliance with the requirements of ZTV Asphalt-StB. The course to be worked on is initially treated in accordance with the remix construction process. Both courses are compacted. On the whole, this construction method makes it possible to install a thinner asphalt wearing course.

Table 6.1: Selection	of the	construction	method	for	reshaping	based	on	characteristic	groups
(according to M RF)									

Characteristic group	Physical characteristic	cal characteristic Appearance/Cause		Reshaping according to construction method			
			(a)	(b)	(c)		
Evenness	Evenness in longitudinal direction	Deformation	_ 1)	0	0		
Evenness	Evenness in transverse direction	Deformation	0	+	+		
Roughness	Skid resistance	Binder enrichment	-	+	+		
		Polished aggregate surface	O ²⁾	+	+		
	Alligator	-	O ³⁾	O ³⁾			
Substance deficiency	Leaning due to and loss of coa	-	+	+			
	Ravelling (Pa	rticle popout)	-	Ο	+		

+ = suitable O = partially suitable - = not suitable

1) however, only partially suitable with short-wave and/or periodic unevenness (with mixture composition that satisfies the requirements)

2) only temporary improvement

3) suitable if binder content is too low

Table 6.1 provides a summary of the application criteria which reflects the **"Code of practise for reshaping of asphalt courses"**, 2002 Edition (M RF) and also in general the information in the **"Additional technical conditions of contract and directives for structural maintenance of traffic areas – asphalt constructions"**, 1998 Edition/2003 Version (ZTV BEA-StB 98/03).

The construction methods used for reshaping can be applied with repair construction measures for the characteristic groups **"Evenness"**, **"Roughness"** and **"Substance deficiency"** (cp. Table 6.1).

The characteristic group **"Evenness"** is further broken down into the physical characteristics **"Evenness in longitudinal direction"** and **"Evenness in the transverse direction"**. Unevenness in the longitudinal direction cannot be repaired or can only be repaired to a limited extent using the reshape construction method. Unevenness in the transverse direction can generally be repaired using the reshape construction method. However, the application scope of the reshape construction method is limited because the causes of deformation in the transverse direction generally cannot be permanently eliminated without changing the composition of the asphalt mixture.

The **"Roughness"** characteristic group is identified by the physical characteristic "Skid resistance". For this, the **"Binder enrichment"** and **"Polished aggregate surface"** are to be analysed as Appearance/ Cause. Both causes of skid resistance deficiency can be eliminated by changing the mixture composition using the Remix construction method or by installing a new asphalt wearing course using the Remix compact construction method. Here too, the Reshape construction method is only suitable for restoring the skid resistance with polished aggregate surfaces to a limited extent. The characteristic group **"Substance deficiency"** is characterised by the visual appearance "Alligator cracking", "Leaning" and "Ravelling". The Reshape construction method cannot be applied for all substance deficiencies stated. If alligator cracking is caused by low binder content, the asphalt course can be permanently repaired by adding suitable supplementary materials using the Remix or Remix compact construction method.

Leaning in the form of mortar loss and loss of coarse aggregates can only be repaired by adding suitable supplementary materials. The Remix and Remix compact construction methods can be used for this. In the event of ravelling due to serious deficiencies in the mixture composition, tests must be carried out when applying the Remix and Remix compact construction method to determine whether it is possible to manufacture an asphalt mixture that satisfies the requirements by adding the technically feasible amounts of supplementary material.

6. Recycling in-situ

6.1 Reshaping



Joint remixer renovating a damaged centre joint (60 cm)

The **"Code of practise for reshaping of asphalt courses"**, 2002 Edition (M RF) also deals with two further special cases of the construction method (c), Remix compact:

In the first special case, Reshaping with a change of asphalt composition in conjunction with the installation of a new wearing course with the same machine (Remix plus) can also be used, in which case supplementary material from aggregates of less than 12 kg/m² is added by laying it on the relevant preheated course using suitable distribution machines. The required binder addition for the supplementary material is dosed in the mixer and should not exceed 0.5 kg/m². The machine is equipped with two laying fixtures. The first laying fixture – consisting of spreading auger and paver screed plate - places the reshaped mixture. The plant-mixed asphalt mixture for the new asphalt wearing course is placed on the hot subsurface by the machine's receiving hopper via the longitudinal conveyor device above the mixer and the first laying fixture in front of the second laying fixture. The second laying fixture - consisting of spreader auger and paver screed plate - performs the transverse spreading and installation of the new asphalt wearing course according to the required profile. Both courses are therefore installed together "hot-on-hot".

In the second special case, the **reshaping without modification of the asphalt composition in combination with installation of a new wearing course with the same machine (Repave)** can be used. In this case the course to be worked on is initially treated according to the Reshape construction method. The asphalt is lifted and mixed, then spread crosswise with spreader augers via an initial laying fixture according to the required profile. The plantmixed asphalt mixture for the new asphalt wearing course is transported and installed in the same way as described in the first special case.

The construction methods named above are normally carried out using machines with a variable width between 3.0 and 4.5 m. Machines with widths that can be

varied between 1.5 and 2.5 m are available. Due to their compact size, only the remix or reshape method is possible with these machines.

Special machines referred to as joint remixers with working widths of between 30 cm and 60 cm have been developed for the renovation of damaged centre joints. These machines and their possible applications are described in detail in the **"Information on closing and repair of cracks and damaged joints and gap joints in asphalt traffic areas"** (H SR).

In summary, the following must be observed when applying the reshape construction method:

- These construction methods can only be used if the courses to be worked on have a homogeneous composition.
- The line routing and road installations may limit the application of the construction methods.
- Asphalt courses with mesh/grid inlays cannot be reshaped for engineering reasons.
- The maximum loosening depth is generally re-stricted to 5 cm.
- Isolated repair-patches made of cold or hot mixture or of mastic asphalt must be removed beforehand.
- Marking films must be removed.
- In order to restore transverse evenness, the processing depth must be selected so that the course is picked up at least 1 cm below the lowest point of the unevenness in the transverse profile.
- Reshaping methods should only be used when the weather is warm and dry.
- If the road surface is wet, or if it is windy or cold, it is considerably harder to heat the course to be worked on.
- These construction methods should not be applied at air temperatures below <u>10 °C.</u>
- Courses with materials containing tar/pitc cannot be processed hot for occupational health and safety reasons (see Appendix 1).

6.2 Cold recycling in-situ



Cold recycler for the manufacturing of predominantly bituminous KRC course

The cold recycling methods vary depending on where the construction material mixtures are manufactured (KRC mixtures); "in plant" or "in situ". With the "inplant" method, KRC mixtures can be manufactured in stationary or mobile cold mixing plants. These methods are not dealt with in this guide (also cp. Appendix 1).

Cold recycling in situ, i. e. directly at the construction site, was developed from the use of milling/recycling machines or stabilisers that loosen the existing carriageway to a depth of 22 cm, turn it into granulate, prepare it with binder and reinstall it. This produces base courses whose characteristics generally depend on the type of binder used (bituminous and/or hydraulic) and the composition of the construction materials mix.

The mixtures of construction materials (KRC mixtures) can then be subdivided into predominantly bituminous and predominantly hydraulic binder types, depending on the binder combination and the elastic moduli it can achieve. The binder combination selected is based on the composition of the granulate mix and the load-bearing capacity of the subsurface. If large fractions of reclaimed asphalt are used, it is possible for example that a predominantly bituminous KRC mixture is produced, even if a large amount of hydraulic binder is added.

Bitumen emulsions are used as bituminous binders in accordance with the **"Technical supply conditions for bitumen emulsions in road construction"** (TL BE-StB). Foam bitumen manufactured from grade 50/70 or 70/100 paving grade bitumen according to DIN EN 12591 and water, can also be used, providing its suitability has been proven. The bitumen foam is produced in an expansion chamber by adding water under pressure to the hot flowing bitumen and at the same time injecting air. The machines used as standard to manufacture KRC courses in situ can be subdivided into two groups according to their salient features:

- 1. Milling machine with constant working width (2.0 m or 2.5 m), that also performs mixing function (milling/recycling machine and stabiliser).
- Milling machine with variable working width and twin-shaft pugmill and laying fixture consisting of spreader auger and paver screed plate (cold recycler and mix-paver).

Cold recyclers and mix-pavers have become more widespread than milling/recycling machines and stabilisers in recent years because they produce far more homogeneous mixtures. The variable laying and installation width also avoids several longitudinal seams. As a rule, course thicknesses should not exceed 20 cm (or 22 cm in exceptional cases) for compactibility reasons. KRC mixtures should not be manufactured and installed at temperatures below 5 °C.

Experience to date and the requirements to be met by this construction method are summarised in the **"Code of practise for cold recycling of road surfaces in situ"**, 2005 Edition (M KRC).

7. Outlook



The recycling of asphalt has an exemplary function when compared to the recycling quotas in other areas of the national economy. For a long time now, manufacturers of asphalt mixtures and construction companies have seen their methods confirmed in the implementation of the Closed Substance Cycle Waste Management Act.

In addition to further increasing of the recycling rate, high-quality utilisation of reclaimed asphalt will continue to increase in significance. The amounts of suitable reclaimed asphalt used in the manufacturing of asphalt binder and asphalt wearing course mixtures



must be increased in order to compensate for the reduced demand for asphalt base course mixtures. To do so, the existing path must consistently be followed:

- separate recovery and storage of removed asphalt courses according to their properties,
- careful preparation with gentle heating of reclaimed asphalt to obtain asphalt mixtures that satisfy the requirements as well as
- using asphalt mixtures manufactured with use of reclaimed asphalt for all courses which, in terms of thier characteristics, in any manner whatsoever, do not fall short of asphalt mixtures manufactured using fresh construction materials only.

The removal and utilisation of particularly valuable courses – such as asphalt wearing courses made of porous asphalt or asphalt coatings manufactured using modified binders bring further new challenges but with them also new opportunities.

Annex

1	Recycling reclaimed road construction materials containing tar or pitch 40
2	_ Rules and standards and chronological list of references
3 3.1 3.2	Classification of reclaimed asphalt
4	Additional DAV/DAI guidelines and publications 46 Overview of publications currently available from DAV/DAI (brochures, guidelines and research reports).

1. Recycling reclaimed road construction materials containing tar or pitch

Tar/pitch and bitumen are so similar in terms of their effectiveness as binders for aggregate mixtures, that previously it was not necessary from a building engineering viewpoint to differentiate greatly between the two.

In terms of their chemical composition however, road pitch and bitumen are different. Road pitch is produced by coking (pyrolysis) of coal followed by distillation of the crude tar. It consists more or less entirely of aromatic hydrocarbons with high **concentrations of polycyclic aromatic** hydrocarbons (PAH) as well as phenolic compounds. These ingredients make road pitch a construction material that is critical for the environment and endangers health.

Bitumen, a product obtained from the distillation of crude oil on the other hand, consists of hydrocarbons that only contain a very low fraction of polycyclic aromatic hydrocarbons.

Only once binders containing tar/pitch had long been replaced by bitumen in road construction for economic reasons the harmful effects of the binder containing tar/pitch were fully established through research in the medical and ecological fields. The use of binders containing tar/pitch in Germany has been banned since the introduction of the 1993 edition of the **technical rules for hazardous substances "Pyrolysis products made from organic material"** (TRGS 551). Before this, water engineering requirements in specific German states to be met by industrial by-products and recyclable materials used in road construction had excluded the use of binders containing tar/pitch before that date. The **Recycling of** reclaimed road construction materials containing tar/pitch on the other hand is not excluded either by TRGS 551 or the various regulations in individual German states, providing the method summarised in the following four points is observed:

1. Leaving materials containing tar/pitch in the pavement structure

Providing road materials containing tar/pitch are integrated into the pavement, adverse effects on soil water and ground water are not expected. If these bound substances containing tar/pitch are allowed to remain in the pavement, this therefore cannot be objected to. If preliminary investigations made when carrying out construction measures and/or the available documentation shows that these kinds of substances are present in the pavement structure, the construction design can be revised by modifying the gradient and possibly lateral inclination with the aim of leaving the courses containing tar/pitch in the pavement structure.

2. Removal of materials containing tar/pitch

Examples of construction measures where courses containing tar/pitch cannot be overbuilt are:

- replacement of pavement in conjunction with work on supply lines,
- removal of roads,
- smoothing out of curved sections and other gradient improvements,
- specified carriageway heights due to existing building developments in through streets and other gradient constraint points.

In doing so, reclaimed road construction materials containing tar/pitch that accumulate must be recycled in an environmentally-clean manner. Utilisation as a construction material is in harmony with the legal requirements and has proved to be significantly more cost-effective than consignment to landfill.



Mobile cold mixing plant

3. Identification of harmful ingredients

Providing records on the pavements and binders used are still available to the authorities preparing the construction work, the environmental compatibility can be verified by referring to the documentation. If the use of binders containing tar/pitch cannot be excluded, the PAH and phenol content of these materials must be determined. According to the General technical terms of contract (ATV) of VOB, Part C DIN 18299, this proof must be provided by the client who must also authorise the taking of samples and must carry the costs of the analysis. The qualitative proof of PAH according to EPA (Environmental Protection Agency – environmental authority in USA) and/or elutable phenols can initially be obtained using fast-track methods that are described in Working document no. 27/2 "Testing of reclaimed road construction materials for binders of carbon origin - fast-track methods". This working document deals with, among other things, methods that can de-tect PAH using fluorescence under UV light with little effort and phenols in environmentallyrelevant concentrations through colour reactions in the materials that have been removed (cores, slabs and milled material). The methods are used as a priority to carry out on-site testing and perform checks on incoming material.

For the purposes of quantitative determination in accordance with working document no. 27/3 "Testing of reclaimed road construction materials for binders of carbon origin - quantitative determination", the loose reclaimed materials and specimens manufactured in the laboratory from bonded reclaimed materials are eluted in accordance with the "Technical testing instructions for aggregates in road construction", (TP Ge-stein-StB) Teil 7.1.2 (trough method). Cores must not be used for this test. The PAH content in the eluate according to the EPA is determined according to DIN 38407-F18. The PAH content in the eluate according to the EPA is deter-mined according to DIN ISO 13877 or using the gas chromatographic method. The phenolic index is determined using the high-performance liquid chromatographic (HPLC) method according to Heimer or according to DIN 38409-H16-2.

Quantitative determination of the selected PAH and determination of phenol must be carried out as a minimum requirement as the basis for grading of the reclaimed road construction materials into different utilisation classes.

The utilisation class in turn determines the possible recycling method.

4. Allocation to utilisation classes

In addition to being suitable from a constructional standpoint, if there is evidence that the materials to be removed and recycled contain typical tar/pitch constituents, they must primarily be evaluated in relation to occupational health and safety, soil protection and water protection. The PAH and phenol content must be analysed to determine occupational health and safety aspects. The evaluation is carried out based on the overall PAH content according to the EPA. Phenols essentially escape with water vapour if this is released during heating. In addition to the "Recommendations of the union and institution for occupational health and safety" (BG/BIA re-commendations), TRGS 551, TRGS 900, TRGS 901 and TRGS 905 must be observed.

The quantity of PAH according to the EPA and the quantity of phenols eluted with water are of significance for soil and water protection.

Depending on the PAH content in the solid according to the EPA and the phenolic index of the eluate, the material is assigned to one of three utilisation classes in accordance with Table A1. Where a value for utilisation class A of up to 25 mg/kg PAH according to the EPA is stated, this corresponds to a binder in a construction material mixture that is free of ingredients requiring labelling. The reason this limit value is used to separate reclaimed asphalt from reclaimed materials with typical tar/pitch constituents is explained in the Appendix to the "Guidelines for environmentally-clean utilisation of reclaimed materials with typical tar/pitch constituents and for the utilisation of reclaimed asphalt in road construction", 2001 Edition, 2005 Version (RuVA-StB 01).

RuVA-StB 01 deals with reclaimed road construction materials for which the requirements of the German Working Group of the Federal States on Waste Issues (LAGA) apply. These have been defined in LAGA notification 20 as technical rules and the provisions of RuVA-StB 01 were compiled taking these technical rules and the definitions of the TRGS stated above into account and differentiate, by defining three utilisation classes, between reclaimed asphalt and reclaimed materials with typical tar/pitch constituents.

Utilisation class	Typ reclaim constructio	e of ed road on materials	Background 1)	Total content in solid of PAH according to the EPA mg/kg	Phenol index in eluate mg/l
Α	Reclaime	ed asphalt	AS, BS, GS	≤ 25 ²⁾	≤ 0,1 ²⁾
В	Reclaimed materials with	Predominantly hard coal tar-typical	AS, BS, GS	> 25	≤ 0,1
С	pitch/tar constituents	Predominantly lignite tar-typical	BS, GS	Value must be stated	> 0,1

Table A1: Utilisation classes for reclaimed road construction materials

(correspond to Table 1 in RuVA-StB 01 (2005 version) and TL AG-StB 06 respectively)

1) AS = occupational health and safety, BS = soil protection,

2) Certificate not required if proven beyond doubt in each individual case,

that only bitumen or binders containing bitumen have been used.

GS = water protection

With higher PAH contents the LAGA technical regulations and revised RuVA-StB 01 (2005 version) only envisage bonding of reclaimed construction materials containing tar/pitch through application of the cold mix method with addition of binders and do not state a maximum value.

tar/pitch in this case has the following effect:

- minimises the percentage of voids in the finished
- prevents the ingress of water and therefore
- ensures that harmful ingredients in the reclaimed materials are incorporated effectively and perma-

The following are used as binders for cold mixtures:

- special bitumen emulsions,
- Schaumbitumen,
- foamed bitumen,
- special hydraulic binders and combinations of

Reclaimed road construction materials in all utilisation classes can be utilised by applying the cold mix method with binders according to Table A1. However, these methods are only permitted for utilisation classes B and C if it has been verified during the scope of type tests that through bonding with the binder in the eluate of the test specimen the PAH according to the EPA is less than 0.03 mg/l and the phenol index in utilisation

class C is less than 0.01 mg/l. With this method, a differentiation can be made between use in stationary and mobile mixing plants and building site mixing methods.

However, from the point of view of road administration, classification in utilisation classes as well as the limit values of RuVA-StB 01 (2005 version) are not suitable for grading of reclaimed materials for waste legislation purposes. This concerns among others the classification of reclaimed road construction materials with respect to the requirements for monitoring of waste set out in the Waste Register Ordinance (AVV). From the point of view of waste legislation, materials must be assessed as defined in KrW-/AbfG and the sub-statutory rules and standards and that is the responsibility of the waste authorities responsible in the German states.

Depending on the binder used, the "Code of practise for utilisation of reclaimed asphalt and reclaimed road construction materials in base courses with hydraulic binders" and the "Code of practise for utilisation of reclaimed road construction materials containing pitch and reclaimed asphalt in bitumenbound base courses by means of cold processing in mixing plants" (M VB-K) must be observed. The rules set out in the "Code of practise for utilisation of reclaimed asphalt" (M VAG) for the storage of reclaimed road construction materials apply irrespective of the recycling method used.

2. Rules and standards and chronological list of references



- Arbeitspapier zur Pr
 üfung von Stra
 ßenausbaumaterial auf carbost
 ämmige Bindemittel Ouantitative Bestimmung, Ausgabe 2004, FGSV-Nr, AP 27/3
- Hinweise für das Schließen und die Sanierung von Rissen sowie schadhaften Nähten und Anschlüssen in Verkehrsflächen aus Asphalt, Ausgabe 2003 (H SR), FGSV-Nr. 777
- Merkblatt f
 ür Asphaltfundationsschichten im Hei
 ßeinbau, Ausgabe 1997 (M AFS-H), FGSV-Nr. 759
- Merkblatt für Eignungsprüfungen an Asphalt, Ausgabe 1998, FGSV-Nr. 751
- Merkblatt für das Fräsen von Asphaltbefestigungen, Ausgabe 2000 (M FA), FGSV-Nr. 786/5
- Merkblatt für die Verwertung von Asphaltgranulat, Ausgabe 2000 (M VAG), FGSV-Nr. 754
- Merkblatt für das Rückformen von Asphaltschichten, Ausgabe 2002 (M RF), FGSV-Nr. 786/1
- Merkblatt f
 ür die Verwertung von Asphaltgranulat und pechhaltigen Stra
 ßenausbaustoffen in Tragschichten mit hydraulischen Bindemitteln, Ausgabe 2002, FGSV-Nr. 826
- Merkblatt für Kaltrecycling in situ im Straßenoberbau, Ausgabe 2005 (M KRC), FGSV-Nr. 636
- Merkblatt f
 ür die Verwertung von pechhaltigen Stra
 ßenausbaustoffen und von Asphaltgranulat in bitumengebundenen Tragschichten durch Kaltaufbereitung in Mischanlagen, Ausgabe 2007 (M VB-K), FGSV-Nr. 755
- Merkblatt über die statistische Auswertung von Pr
 üfergebnissen Teil 2: Erkennen und Behandeln von Ausrei
 ßern, Ausgabe 2003, FGSV-Nr. 926/2
- Richtlinien für die Standardisierung des Oberbaues von Verkehrsflächen, Ausgabe 2001 (RStO 01), FGSV-Nr. 499
- Richtlinien f
 ür die Planung von Erhaltungsma
 ßnahmen an Stra
 ßenbefestigungen, Ausgabe 2001 (RPE-Stra 01), FGSV-Nr. 988
- Richtlinien für die Anerkennung von Prüfstellen für Baustoffe und Baustoffgemische im Straßenbau, Ausgabe 2004 (RAP Stra 04), FGSV-Nr. 916

Richtlinien für die umweltverträgliche Verwertung von Ausbaustoffen mit teer-/pechtypischen Bestandteilen

3. Classification of reclaimed asphalt

taking TL AG-StB 09 and TL Asphalt-StB 07, Annex A into account

3.1 Form

Storage yard/Asphalt mixing plant	
Reclaimed asphalt description (U RA d/D)	
Feedstock description	
Size of feedstock	approxt Date
Origin of reclaimed asphalt (building site)	

Reclaimed asphalt

Characte	eristic							-					Testing	Prelim. info
Environm	nental compatibility		Utilisa	Utilisation class A										
Property	//characteristic value			Category/test result/Testing								Testing	Prelim. info	
max. piec	ce size (U)		5	8	11	16	2	2	32	45	56	63		-
Content	of fines (UF)		UH	73	UF_5	5	UI	F ₉ UF		UF_{15}	UF _{NR}			-
Homoger	neity		Large	st value	Sma	llest valu	le	Mean va		lue	Range a		-	-
Bind	ler content (B _S)	[M%]						-						
Soft	ening point (T _{R&B})	[°C)]												-
🗌 piece	Content < 0,063 mm	[M%]												-
or aggre-	Content 0,063/2 mm	[M%]												-
🗌 gate	Content > 2 mm	[M%]												-
Density in raw state ($ ho_{mv}$) [g/cm ³]											-			
Content	of foreign matter (FM)			FM _{1/0}).1		FM _{5/}	0.1			FM_{stated}			-

Aggregates

Property/characteristic value	Category/test result									Testing	Prelim. info
Material identification	_									-	-
Type of aggregate											
Type of additives											
Particle size distribution	1,4D	D		D/2	2 n	าฑ	0,1	25 mm	0,063 mm	-	-
Sieve passing [M%]											-
Max. aggregate diameter [mm]	5,6	8	11,2	2	16	22	,4	31,5	45		
Aggregate shape		-			-					-	-
Aggregate Shape index (SI)	<i>SI</i> ₁₅			SI ₂₀					<i>SI</i> ₅₀		*
Flakiness index (FI)		<i>FI</i> ₁₅		FI ₂₀					FI ₅₀		*
Percentage of crushed aggregates (C)	C _{100/0}	C _{95/1}		C _{90/1}		C _{90/3}		C _{50/30}	$C_{\rm NR}$		*
Resistance to crushing										-	_
Impact crushing (SZ	SZ ₁₈	SZ ₂₂		SZ ₂₆	SZ ₂₆		2	SZ ₃	SZ _{NR}		
LA coefficient (LA)	LA ₂₀	LA ₂₅		LA ₃₀		LA ₄₀		LA_{50}	LA _{NR}		
Polishing coefficient (PSV)	PSV _{state}	ed (42)	(48)	(51)		1	PSV _{st}	ated	$PSV_{\rm NR}$		
Frost resistance	-							-	-		
Water absorption (W_{cm})	<i>W</i> _{cm} 0,5										
Resistance to frost (F)	F ₁ F ₄ F _{stated}										
Resistance to de-icing salt attack [M%]											

Binder

Property/characteristic value	Test result	Testing	Prelim. info
Bindemittelart		_	
Softening point Ring-and-ball $(T_{R\&B})$ [°C]			-
Needle penetration (pen) [1/10 mm]			-

* Changes possible due to milling and breaking

3. Classification of reclaimed asphalt taking TL AG-StB **09** and TL Asphalt-StB 07, Annex A into account

3.2 Example of classification of reclaimed asphalt for addition to asphalt binder mixture

Storage yard/Asphalt mixing plant	Musterbau GmbH & Co. KG, Musterstadt							
Reclaimed asphalt description (U RA d/D)	22 RA 0/16							
Feedstock description	Asphaltfräsgut AC 16 B S							
Size of feedstock	approx. 1.500 t Date 1. Sept. 2009							
Origin of reclaimed asphalt (building site)	Baulos 0815, Bundesstraße B 88 bei Musterstadt							

Reclaimed asphalt

Charact	eristic		-										Testing	Prelim. info
Environm	nental compatibility		Utilisa	ation cla	ss A		1							
Property	//characteristic value			Category/test result/Testing									Testing	Prelim. info
max. pied	ce size (U)		5	8	11	16	22	1	32	45	56	63	5	-
Content	of fines (UF)		UI	73	UF ₅	UF ₅ UI		F ₉ UF ₁₅		UF_{15}	UF			_
Homoge	neity		Large	st value	Sma	Smallest value		Mean value		ue	Range a		-	-
Bind	der content (B _S)	[M%]		5,8		4,7		5,3			1,1		1	-
Soft	ening point $(T_{R\&B})$	[°C)]	6	8,6		64,5	60		66,4		4,6			-
piece	Content < 0,063 mm	[M%]	1.	2,1		6,7		9,8			5,4			-
or aggre-	Content 0,063/2 mm	[M%]	2	7,7		19,8		23,6			7,9			_
🗌 gate	Content > 2 mm	[M%]	7.	71,8		62,4		66,5			9,4			-
Density in	n raw state ($ ho_{mv}$)	[g/cm ³]	2,574								5	-		
Content	of foreign matter (FM)			FM _{1/0}	0.1	FM _{5/0.1} FM _{stated}						5	_	

Aggregates

Property/characteristic value	Category/test result									Prelim. info
Material identification	-									-
Type of aggregate	Granu	vacke, I	rnungen	5	1					
Type of additives				kei	ne			-	5	1
Particle size distribution	1,4D	D	D/2	2	2 mm	0,12	25 mm	0,063 mm	_	-
Sieve passing [M%]	100	93,1	68,3	3 3	3,5	13	3,6	9,8	S	_
Max. aggregate diameter [mm]	5,6	8	11,2	16	22	,4	31,5	45	5	
Aggregate shape					-			•	-	_
Aggregate Shape index (SI)		<i>SI</i> ₁₅		SI ₂₀				<i>SI</i> ₅₀		*
Flakiness index (FI)		<i>FI</i> ₁₅		FI ₂₀				FI ₅₀		*
Percentage of crushed aggregates (C)	C _{100/6}	C _{95/1}	C	C _{90/1})/3	C _{50/30}	$C_{\rm NR}$		*
Resistance to crushing				_	-					
Impact crushing (SZ	SZ ₁₈	SZ ₂₂	SZ	SZ ₂₆ S		2	SZ ₃	SZ _{NR}		1
LA coefficient (LA)	LA ₂₀	LA ₂₅	L	1 ₃₀	LA	10	LA ₅₀	LA _{NR}		
Polishing coefficient (PSV)	PSV _{state}	ed (42)	(48) (5	51)		PSV _{sta}	ted	PSV _{NR}		
Frost resistance	-							-	-	
Water absorption (<i>W</i> _{cm})				5						
Resistance to frost (F)	F ₁ F ₄ F _{stated}							^F stated		
Resistance to de-icing salt attack [M%]			ł							

Binder

Property/characteristic value	Test result	Testing	Prelim. info
Bindemittelart	Straßenbaubitumen	-	
Softening point Ring-and-ball $(T_{R\&B})$ [°C]	66,4	4	_
Needle penetration (pen) [1/10 mm]			-

* Changes possible due to milling and breaking

Annex

Additional information about the German Asphalt Paving Association (DAV) and further DAV-guidelines

More information about the German Asphalt Pavement Association DAV and the German Asphalt Research Institute DAI as well as an overview of their publications (brochures, guidelines and research reports) you will find on the internet:

www.asphalt.de



Further publications in English and in other languages www.asphalt.de \rightarrow Literatur \rightarrow International



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