Construction of a high quality asphalt wearing course with more than 90% reclaimed asphalt pavement (RA); a case study.

Dipl. Ing. Matthias Nölting, Sasol Wax GmbH, Germany
Lab. Ing. Gerhard Riebesehl, Storimpex Asphaltec GmbH, Germany
Dipl. Ing. Christian Denck, Behörde für Stadtentwicklung und Umwelt, Amt für Verkehr und Straßenwesen, Germany

Abstract

It is widely accepted that reuse of RA in the construction of hot mix asphalt is environmentally friendly and also economically beneficial. Addition rates vary from country to country and depending on mix design but very rarely exceed 50wt% in the final mix.
This paper describes a case study about a mix design incorporating more than 90% RA. This mix meets German standards for a wearing course subjected to high traffic loads. An area of 3850 m^2 aged asphalt concrete wearing course is milled off. Binder content and mineral composition of the RA coming from a selected road surface is analyzed. The grading curve of the minerals inside the RA is inspected. Adjustments with virgin aggregate are calculated to generate a final grading curve that meets specification and to accommodate for slightly higher binder content due to rejuvenator addition. Based on the properties of the extracted bitumen proper rejuvenator dosage is calculated as well.
The RA is heated in a newly designed heating drum and then transferred into a 3t batch mixer. In the mixing process the calculated mineral adjustment is added and homogeneously mixed in together with a hydrocarbon reactivator compound. This compound rejuvenates the aged binder and also adjusts modulus to a desired target level. Finally the mix was successfully paved on exactly the site the RA came from.

Introduction

In pre-industrial times mankind was used to recycle all kinds of materials, simply because of scarce resources. As societies developed more waste occurred and in the second half of the 20th century many industrialised nations were forced by overflowing landfills to recognize that resources were and are discarded at an unsustainably high level. The energy crisis in the 1970's motivated first programmes to collect and reuse energy intense products such as Aluminium and other metals. Increasing pollution of the environment created new awareness which quickly added paper, glass and many other products to the list. Today there is a high but still growing awareness that resources need to be conserved. Governments incentivise collection and recycling systems. Waste material management, sorting, trading and reuse have become a viable and often very profitable business. In addition to recycling many countries motivate campaigns to actually avoid creation of waste.
Aged asphalt, torn up from roads, was treated analogue to these developments. By today discarding asphalt in landfills has fortunately diminished to a rare exception. In fact, asphalt has probably become one of the few construction materials that in some countries, e.g. Germany, are almost fully recycled.
At first glance the situation would appear to be satisfactory and well under control. There are numerous countries where apparently close to 100% of asphalt that is removed from streets and other surfaces is re-used. However, in almost all cases this asphalt is recycled at very low levels of economic value. Unbound asphalt granulate is used to reinforce road shoulders, mixed into minerals for road bases and gets used to construct simple rural gravel roadways. If used in hot mix asphalt, technical regulations most often restrict use of RA to base courses and other low value applications.

There are exceptions, but at present use of recycled asphalt is mostly focusing on the mineral content of the material. The primary motivation is to manage and utilize the volume of RA that occurs and to lower input cost.
In many countries current technical practice and prohibiting technical regulations prevent the recovery of the full value that is inherent in recycled asphalt.
Looking at typical asphalt designs the biggest cost factor in a mix is bitumen. The second most expensive material inside RA is coarse aggregate, especially in wearing courses where high quality aggregates are used. Present practices can be improved to better use these materials.
This paper describes a technology that makes full use of the resources inherent in RA.

Technical challenges for hot mix containing high levels of RA

Milling and stockpiling of RA
The purpose of this paper is to describe and explain the production of hot mix asphalt exclusively from RA without compromising performance of such asphalt versus hot mix asphalt produced from virgin material.
Following the old wisdom "garbage in equals garbage out" it must be emphasized that RA is to be treated as a valuable source of raw material right from the point where the decision is made that a asphalt surface has to be removed. Road constructions that are designed and built in layers should be milled layer by layer. These layers contain mineral aggregates of different grades and often also different bitumen. Especially in wearing courses selected mineral aggregates of high value are used. If milled together with deeper layers the RA will be "contaminated" with aggregates of lesser value that e.g. would not pass the criteria for PSV and thus cannot be used in a wearing course again. That means the RA will automatically lose value because it will now end up in binder or base courses.
Equal care should be applied for processing and stockpiling of RA. An excellent description of best practice can be found in the Technical Recommendations for Highways, TRH 21:2009 published by SABITA[1]. Properly processed, stockpiled and analysed RA is a non negotiable prerequisite for the use of very high RA levels or even asphalt production exclusively from RA. In Germany it is required to draw one sample per 500t of material for analysis. Smaller stockpiles still have to be analysed via a minimum of 5 samples drawn on different positions of the stockpile. The analysis must cover: Binder content, Softening point, minerals 0 to 0,063 mm, 0,063 to 2 mm as well as > 2 mm.

Mixing plant technology
When high percentages of RA are introduced into a mix it is absolutely necessary to ensure that the binder contained in RA is fully melted. In mixes where virgin materials are added this binder must perfectly commingle with the newly added binder. A good indication is that binders are deemed to be easily pumpable in liquid form at a temperature approx. 70-80°C above their softening point. At this temperature they are also liquid enough for homogenisation of RA binder with virgin binder or rejuvenators in the mixing process. To influence the properties of the resulting binder in a high RA mix the virgin binder is chosen to compensate for aging and hardening that almost always is found in the binder contained in RA. This is not only necessary for the in situ mixing of paving grade binder with binder in RA. In e.g. Germany RA is also allowed for mixes that by classification require polymer modified bitumen. In order to accommodate the binder inside RA the virgin bitumen is modified at higher levels than normal, in other words the binder is deliberately "overmodified".

[1] Technical Recommendations for Highways, TRH 21:2009, SABITA 2009, Ch.7

Proper commingling is a function of temperature and mixing time, but it must be emphasised that without introduction of sufficient heat energy into RA mixing time cannot compensate for that effect.

Any existing asphalt mixing plant can be run with RA. But without special plant modifications the RA content that can be used without impairing asphalt quality or creating emissions beyond legal limits is very low and usually ends at 30% maximum.
In batch plants the possibility of transferring heat from superheated virgin aggregates finds its limits at approx. 30%. A phenomenon that needs strict observation is spontaneous expansion of water contained in RA. Conventional drum mixing plants have the problem that the heating flame and very hot gases can come into direct contact with the binder contained in RA. This contact damages the binder and some of it is even incinerated.
Special equipment like twin dryer drums or double barrel drum mixing plants are especially designed to accommodate high levels of RA and can push the possible addition of RA to hot mix beyond the 50% level[2].

A good method to control how well both heat transfer and mixing time are determined correctly is to do trial mixes without addition of virgin binder and filler. This method is very simple to run in a batch plant. The RA dosage chosen for a mix is introduced into the mixer together with the coarse aggregates according to mix design. The pugmill is set to a mixing time deemed appropriate. One batch should be discarded immediately; it could be influenced by residual material in the plant. The second batch is then discharged into the shovel of the front end loader of the plant. The material is then dropped on an even surface and spread out. Then two controls are mixed in the same way, one batch with 10 sec. more mixing time and one with 10 sec. less. A simple visual inspection will show how much of the RA binder has melted and was transferred onto the virgin aggregate.

Fig. 1: 25% RA, mixed with superheated light coloured virgin aggregate
The visible difference in colour of the batches can be used to assess a mixing time to achieve good commingling of RA binder with virgin binder.

[2] Technical Recommendations for Highways, TRH 21:2009, SABITA 2009, Ch.9

Moving from high levels of RA to full recycling in the federal state Hamburg in Germany

Regulatory environment for hot mix containing high levels of RA

Until 1996 the use of recycled asphalt was only regulated via the technical rules issued by the Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV). FGSV is a joint body of government, industry and academia that develops and institutes technical recommendations, manuals and specifications for road infrastructure. Two documents contain important sections concerning the use of RA:

- Merkblatt für die Erhaltung von Asphaltstraßen, Teil Bauliche Maßnahmen, Wiederverwendung von Asphalt, 1985
- Merkblatt für die Lieferung von Ausbauasphalt, 1990 - M VAG 1993

The first guideline covers the upkeep and maintenance of asphalt roads and contains a special section of construction involving RA. It was issued 1985. The second document focuses on the RA itself.

In 1996 Germany issued a new federal law named Kreislaufwirtschafts- und Abfallgesetz (KrW-/AbfG). This law was launched to move the national economy towards avoidance of waste and re-use of natural resources and raw materials. For road building the KrW-/AbfG and its subsequent decrees require that wherever possible alternative or recycled materials have to be preferred over any materials that deplete natural resources. All materials have to be reintroduced into the cycle of materials according to their specific properties. This very clearly means that asphalt produced with or from RA that performs equal to an asphalt exclusively made from new materials <u>must</u> get preference.

Until 2001 the regulatory documents only covered quality requirements on homogeneity of RA and the binder contained in RA (mainly its hardness). It was simply understated that the mineral aggregates used in asphalt were already quality controlled at first use.

RA was mainly produced by deep milling or by taking up the full asphalt package in large broken pieces. Such RA is considered to be inhomogeneous and can therefore only be used in base layers.

A technical specification for RA (TL AG-StB 01) and a manual for handling and use of RA (M VAG 2000) contain the framework that enables the use of selectively milled RA in either binder or wearing courses. In 2006 the specifications were updated to be synchronized with the technical specifications for mineral aggregates.

Originally it was expected that these regulatory documents would boost the use of RA in higher value asphalt compositions. However, with a few exceptions RA is still produced by non-selective methods. The use of RA has increased but this only means that the law regulating avoidance of waste and recycling (KrW-/AbfG) is widely ignored and not implemented. In reality valuable materials like highly defined coarse aggregates, crushed sands and special white aggregates from wearing courses end up in base courses. The economic value inherent in RA contained in binder and wearing courses is not used to optimise economics of hot mix asphalt.

From the beginning of 2009 specifications were harmonized with the European Norms (DIN EN 13108). Use of RA is now lifted into the highest level of national specifications.

Today 3 documents containing specifications govern the use of RA. This sounds complicated but for practical reasons the regulatory documents are split in sections. One document (TL Asphalt-StB 07) concerns itself with technical specifications for asphalt in general, the second document (ZTV Asphalt-StB 07) regulates specifications with regards to contractual issues and finally a third specification (TL AG-StB 09) is dealing with RA quality itself. These specifications are supplemented by a manual for the re-use of asphalt named MWA 2009.

TL Asphalt-StB 07 is allowing use of RA for all asphalt designs with the exception of porous asphalt (PA). It regulates composition of mixes and quality requirements depending on the different mix design categories. All quality requirements are universal; they encompass mixes that contain R. An important issue is regulated in section 3.1.1 of TL Asphalt- StB 07. The softening point of an asphalt mix containing RA has to meet the requirements of the binder specified in the call for bids. To accommodate hardened binder contained in RA it is only allowed to use virgin bitumen that is one grade softer than the specified bitumen. The softest grade allowed is a 70/100 PEN paving grade binder. ZTV Asphalt-StB 07 contains another important rule for binder in mix formulated with RA. The softening point R&B of a recovered binder from site control after paving is not allowed to exceed the softening point stated in the suitability test for the mix design

The regulations also specify mineral aggregate quality and the determination/classification of grading curves in the RA. Whenever properties are in doubt or cannot be properly obtained from previous documentation, the required tests have to be carried out to prove suitability of the RA for the intended use. On top of these requirements it has always to be documented that stockpiles are properly homogenized.

Whilst the general asphalt specifications (TL Asphalt-StB) do allow use of RA in all mixes except PA the contractual regulations (ZTV Asphalt-StB) exclude use of RA in Stone Mastic Asphalt (SMA). Reason for this peculiar phenomenon is that the European regulations do allow RA into SMA. Therefore a general specification must comply. Because some concerns regarding use of RA in SMA still exist it is excluded in the contractual regulations in Germany. However, a subsection of ZTV Asphalt-StB allows the clients to specifically tender for SMA with RA content. This means that the decision about use of RA in SMA is left to the client and not to the consultant or contractor.

The manual MWA, 2009 contains helpful practical information.

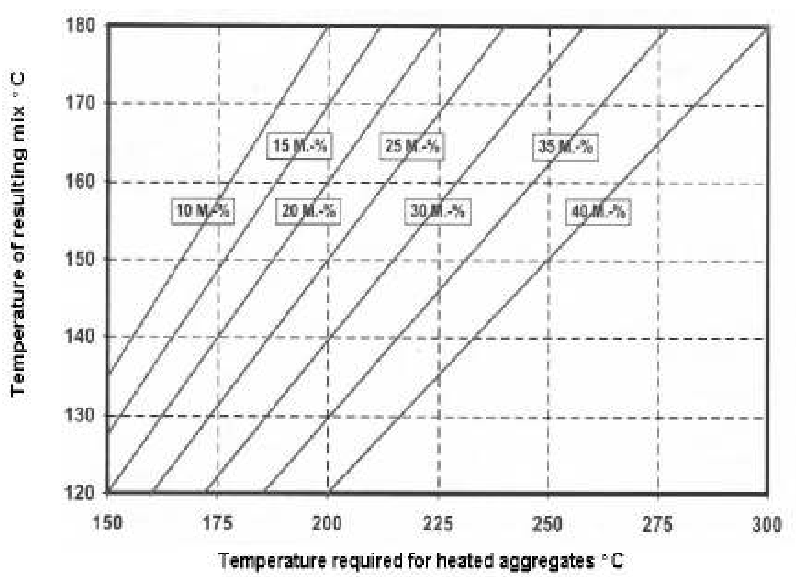

Fig.2: Required temperature for heated aggregates in °C for addition of dry RA at levels up to 10 and 40%M
Source: FGSV, Merkblatt für die Wiederverwendung von Asphalt, Köln 2009

This only deals with addition of dry RA. Fig.3 shows how to correct for moisture content

	Water content in RA %M					
	1	2	3	4	5	6
RA in %M	Temperature correction in °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				
35	14	28				
40	16	32				

Fig.3: Amount of temperature increase needed to correct for water content in RA
The grey area marks the area that is considered critical
Source: FGSV, Merkblatt für die Wiederverwendung von Asphalt, Köln 2009

Amongst a host of valuable information it also states the maximum RA capabilities of different types of mixing plants. As there are virtually no drum mixing plants in Germany this list only refers to batch mixing plants:

- Heat Transfer via superheated aggregates, pugmill addition: 30M.-%,
- Heat Transfer via superheated aggregates, continuous addition of RA to hot elevator: 40M.-%,
- RA heating together with aggregates (addition to drying drum via centre ring or special throwing belt): 40 M.-%,
- RA heating in separate apparatus (Parallel drum): 100 M.-%.

Even if the RA is dry (preferably by storage under roof) it is most often not possible to add as much RA as the technical equipment of the plants would allow. The reason for this shortfall is that the bitumen contained in RA is often severely aged. This ageing manifests itself in binder hardening, the needle penetration drops and the softening point increases.
Bitumen ages by:

- Oxidation
  Reaction of bitumen with oxygen
- Volatilisation
  Evaporation of lighter binder constituents
- Polymerisation
  Combination of like molecules to form larger molecules, resulting in progressive binder hardening
- Separation
  Removel of bitumen constituents in selective absorption by some porous mineral aggregates

The value in Germany for evaluating bitumen characteristics against contract specification is the softening point that is described by the Ring and Ball (R&B) method. Therefore all specifications that deal with RA also focus on this value. The present specifications only allow adjustment of the softening point by in situ blending with the total addition level of RA and by using softer virgin bitumen for blending in the mixer. But use of softer binder is capped at one grade above specified binder.

This leads to a recycling quote far below technical capability and also far below the intent of the German law for waist avoidance and recycling (KrW-/AbfG).

To reach better compliance with the recycling law and also to further improve the sustainability of asphalt pavements it is necessary to further evolve specifications and to explore new technologies as well.

From Saseler Weg to Pollhornweg, case studies about full recycling of an asphalt wearing course

Excellent results coming from laboratory research on regeneration of RA with highly defined fluxoil for use in base courses as well as in SMA applications have prompted the Hamburg authority „Behörde für Stadtentwicklung und Umwelt“ (BSU) to use such products in a full scale trial. The goal of this trial was to validate the laboratory findings in a full depth asphalt construction with three layers
The trial site „Saseler Weg“ was used to trial hot mix asphalt containing high levels of RA where the softening point of the resulting binder of the mix was adjusted via the addition of highly defined fluxoil. This viscous product is produced from the high boiling fraction of recycled engine oils. All light components are removed by destillative process; the product is de-metallized and has a flashpoint > 220°C.
For this trial the softening point of 52-56°C was targeted. It was to be achieved by using 50/70 PEN virgin binder, RA and fluxoil. The softening point found in the different RA selected for the trial ranged from 62,4°C to 82,6°C. With fluxoil it was possible to use 40-50%M of RA. For the control it was necessary to use a softer bitumen grade and the addition level of RA had to be reduced in order to meet the targeted softening point range.

	Section I with fluxoil **AC 22 T Hmb**	**Section II without fluxoil** **AC 22 T Hmb**	**Section I with fluxoil** **AC 16 B N**	**Section II without fluxoil** **AC 16 B N**	**Section I with fluxoil** **AC 8 D N**	**Section II without fluxoil** **AC 8 D N**
RA content	50 %	25 %	40%	30%	40%	40%
Binder content from RA	2,0 %	1,1 %	2,20%	1,50%	2,2 M.-%	2,2 M.-%
Virgin binder	0,6 M.-% (B50/70)	2,8 M.-% (B70/100)	1,1 M.-% (B50/70)	2,7 M.-% (B70/100)	3,8 M.-% (B50/70)	4,2 M.-% (B70/100)
Fluxoil	1,4 M.-%	-	0,9 M.-%	-	0,4 M.-%	-
Resulting binder content	4,0 M.-%	3,9 M.-%	4,2 M.-%	4,2 M.-%	6,4 M.-%	6,4 M.-%
R&B of RA binder	82,6 °C	67,6 °C	73,2 °C	63,7 °C	62,4 °C	62,4 °C
R&B virgin binder	52,0 °C	46,0 °C	52,0 °C	45,0 °C	52,0 °C	46,5 °C
R&B targeted for resulting binder	52,0 °C	52,2 °C	52,0 °C	51,8 °C	52,0 °C	52,0 °C
R&B found in mix	55,0 °C	57,2 °C	56,2 °C	56,8 °C	53,0 °C	55,0 °C

Fig.4: Comparative data on asphalt mixes used in the Saseler Weg trial
Souce: Behörde für Stadtentwicklung und Umwelt, Hamburg 2010

The comparative performance testing proved that the high RA mix with fluxoil was performing equal or better than the control. The Thermal Stress Restrained Speciment Test (TSRT) delivered clear results that the asphalt mixed with high RA content and fluxoil has a significantly better cold temperature performance that the control.

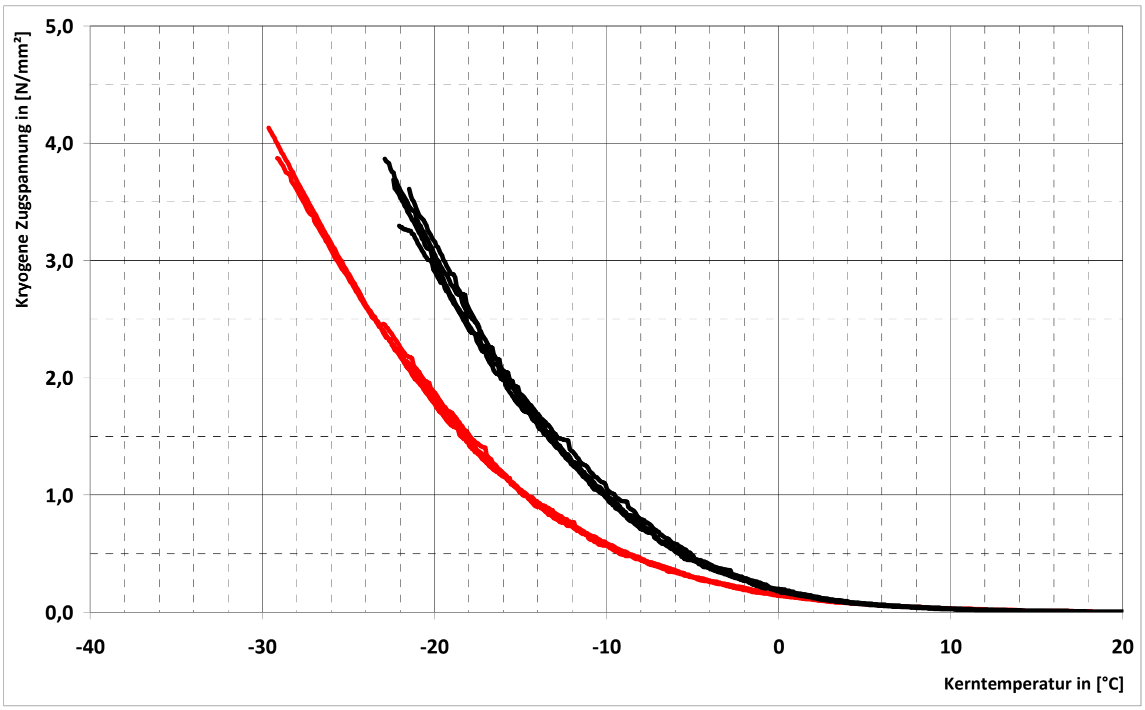

Fig.5: TSRT test data for binder layer mixes used in the Saseler Weg trial
Souce: Behörde für Stadtentwicklung und Umwelt, Hamburg 2010

The red curve in Fig.5 displays that the binder layer mixed with RA and fluxoil has a significantly better performance than the control (black curve). The fluxed mix can be cooled 4°K lower than the control and requires a slightly higher cryogenic tension for breaking.
The TSRT tests for the wearing course are almost identical to the binder layer. The base course also shows an improvement for the fluxed material but it is less pronounced.

The very positive practical results obtained on the Saseler Weg trial site as well as the convincing findings from the analytics performed on the mix used during the trial have proven that rejuvenation of significantly aged binders in RA is not only possible in an laboratory environment. The upscale to plant level was realised without any problems and has shown that aged binder can be fully regenerated, enabling the use of much higher RA levels than present specifications would allow.
A logical question arising from above work is if it is possible to not only use 50%M RA but to produce new high quality hot mix asphalt exclusively from RA and a rejuvenator system.

In 2010 it was tried for the first time on a public road in Germany to produce an asphalt wearing course almost exclusively from RA. It was decided to select a road with a significantly aged wearing course. To make the trial very obvious the wearing course was to be removed, taken to a mixing plant and to be repaved at the very same site it was milled from. The Pollhornweg site was chosen, it is located in a commercial area in the port of Hamburg. The road is very straight and because it is subjected to a large number of high axle loads it was found to be ideal for this trial. The asphalt surface had reached the end of its life, displaying cracks, opening of the middle seam, loss of aggregates and many repairs. Most of the surface was a 11mm asphalt concrete mix. Goal of the trial was to prove that by using a rejuvenator system containing a rejuvenator component and a Warm Asphalt additive together with this RA the wearing course could be fully recycled and meet the performance specifications for a road of this category.

Different to the Saseler Weg trial the rejuvenator was blended with a Fischer Tropsch Wax. Previous trials on private properties had proven this combination to be very effective. The second additive is not only improving the asphalt quality up and above what can be reached with fluxoil, it also is necessary to ensure that the mix temperature can be kept low enough to not produce technical or environmental problems with the exhaust from the mixing plant. Heating RA to a suitable temperature for use in a mix made up exclusively from RA can produce a score of problems, even in specialized equipment such as parallel drums. When the binder contained in RA is exposed to excessive heat there will almost always be a problem with a too high rate of carbon based emissions and the already aged binder is damaged further. Another problem is that at high temperatures bituminous vapours and aerosols are generated that can cause irreversible clogging of the baghouse filters. Such clogged filters can only be discarded and replaced. Running the mix at warm mix temperatures solves both problems in most plants. The combination of wax and fluxoil also produces an extremely workable mix, even at reduced temperatures.

The recycled wearing course was paved on Sept. 25th. 2010. In the week prior to paving operation the suitability test for the mix design was performed. To meet an approved contemporary mix design for an 11mm asphalt concrete according to valid Hamburg specifications the RA taken from site was mixed with the rejuvenator wax combination called Storbit. To meet the mix design grading curve small amounts of RA from another site had to be added because the grading curve for 11mm AC had changed over time. As the Storbit will increase the binder content in the mix it was inevitable to add small amounts of virgin aggregates in order not to exceed the binder content specified for the chosen mix design.
Manufacture of the mix was performed without any problems. The two different RA components and the new aggregate were dosed via feeder bins according to mix design onto a belt leading into the parallel drum.

Kornzusammensetzung des Gesteinskörnungsgemisches

mm	Rückstand	Durchgang	M.-%
> 45,00			
45,00			
31,50			
22,40			
16,00		100,0	grobe GK 62,2
11,20	1,5	98,5	
8,00	14,5	84,0	
5,60	17,5	66,5	
2,00	28,7	37,8	
1,00	8,9	28,9	feine GK 28,8
0,25	13,1	15,8	
0,125	4,4	11,4	
0,063	2,4	9,0	
< 0,063	9,0		Füller

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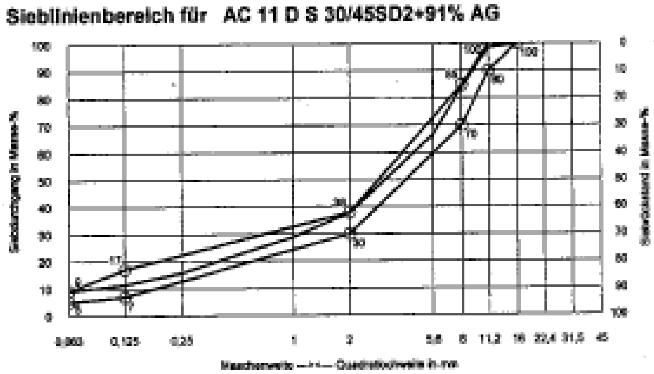

Fig.6: Grading curve for Polhornweg trial
Souce: Rezeptur für Asphaltmischgut, Deutag, Hamburg 2010

Mischguteigenschaften		Mischgut-zusammensetzung	Sollwert	
			min	max
Rohdichte	Mg/m³	2,499		
Raumdichte	Mg/m³	2,427		
Hohlraumgehalt (ber.)	Vol.-%	2,9	2,5	4,5
Hohlraum mit Bindemittel ausgefüllt, HFB	%	81,3		
Proportionale Spurbildungstiefe (60 °C Luftbad / Gummirad)	%	8,8		
Spurbildungstiefe (50 °C Wasserbad / Stahlrad)	mm	3,9		
Verdichtungstemperatur	°C	125,0		

Fig.7: Mix properties Polhornweg trial
Souce: Rezeptur für Asphaltmischgut, Deutag, Hamburg 2010

In the parallel drum the material was carefully heated to 160 °C and transferred into the pugmill where the Storbit was added during the mixing process. The mix was sampled at the mixing plant with 160°C, after a short transfer the material reached the site with 150°C measured in the paver. As ambient temperatures increased the mix temperature was dropped by approx. 10°C. The mix composition showed no deviation against the suitability test and complied with the requirements specified in ZTV/St-Hmb.09. The properties of the paved layer also met these requirements. All cores were tested for adhesion between layers. The shear force trial results met and exceeded the required standards.

Interesting to note is that the AC / mixed from the old wearing course performed exceedingly well in the wheel tracking test (see Fig.7). This test normally is not required for such mix designs. Experience shows that a mix design with virgin 50/70 paving grade binder would fail the test at approx. 12500 cycles. This mix however has a wheel track after 20.000 cycles of 3.9mm. This value is almost competitive to a SMA 0/8 with PEN 45 PmB. The specified value for Hamburg according to ZTV/St-Hmb.09 such 8mm SMA is 3.5 mm.

Summary
The results of pre paving examinations, testing against specification as well as performance testing, on and around the Pollhornweg trial show that with this new technology a development is kicked off that clearly has the potential to produce asphalt from almost 100% RA meeting the current performance criteria for asphalt mixes even of high load categories. The aged binder inside the RA can be rejuvenated with relatively small amounts of additives; the flux component selected for these trials is even a recycled product. It needs to be emphasised that this product has a good track record and is specifically composed and produced for use in asphalt. It meets high safety health and environmental standards and is free of aromatics. Surely there are other products in the market but they need to be carefully inspected if they are suitable for use. Generally the term „fluxoil“ unfortunately has often bad connotations. All too often old engine oil or even more dubious substances get used „straight from the collection drum“.

Storbit replenishes the bitumen components that disappeared from the bitumen in RA by way of the ageing mechanisms described in this paper. Bitumen can be completely rejuvenated. Combined with all other necessary processes like selective milling, proper stockpile management, constant analysis and monitoring of RA components and properties this technology opens the way to use RA on the highest possible level of value generation.

STORIMPEX, the producer of the additive combination has not only more than 20 years experience with use of highly defined fluxoils in asphalt. Their expertise was combined with Sasol's technology for asphalt additives. Rejuvenation technology is not only about adding a „miracle substance" to RA. Designing mixes with high RA content also involves a high level of understanding and controlling of input materials. Going to RA levels far above 50% also requires suitable plant hardware. Only few existing plants are already equipped in a way that they can handle fully recycled asphalt without the need for plant modification or significant investment.
Very obviously the savings produced from re-use of aggregates and bitumen are significant and can more than amortise investment into new technology.

The authors thank the Hafen Port Authority (HPA) of Hamburg for enabling the Polhornweg trial. Thanks also go to the BSU as local authority for sharing results obtained by the trial work.
BSU signals to proceed with this technology in 2011. After positive evaluation the specifications of the federal state of Hamburg will be opened to enable regular use of the technology.