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Technische Universität Braunschweig

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TU Braunschweig

Re-Using High Amounts of Reclaimed Asphalt – Does it work? The German Experience

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2nd Workshop on Asphalt Recycling Technologies, Aachen, 8th September 2025

Motivation

Why do we have to re-use Reclaimed Asphalt (RA) in high amounts?

- RA is not waste, it is a high-quality building material.
  - Europe: EN 13108 Part 8[1]
    - RA on a par with mixtures such as asphalt concrete, stone mastic asphalt, etc.
    - Designation as **product**
  - Germany: TL AG-StB[2]
    - = National implementation of EN 13108 Part 8 in the technical delivery conditions for asphalt granulate
- Circular economy and resource conservation
- Extended service life of natural raw material deposits (aggregates, bitumen).
- High amounts of RA ensures a significant CO-2 reduction.[3,4]
- Using RA saves contractors and agencies money on materials.[5]

An AI-generated image. Tool: Dall-E 3

(1) EN 13108, Bituminous Mixtures – Material specification – Part 8: Reclaimed Asphalt , European Standard, Brussels.

(2) TL AG StB, Technische Lieferbedingungen für Asphaltgranulat, Ausgabe 2009. Forschungsgesellschaft für Straßen und Verkehrswesen, FGSV Verlag, Köln.

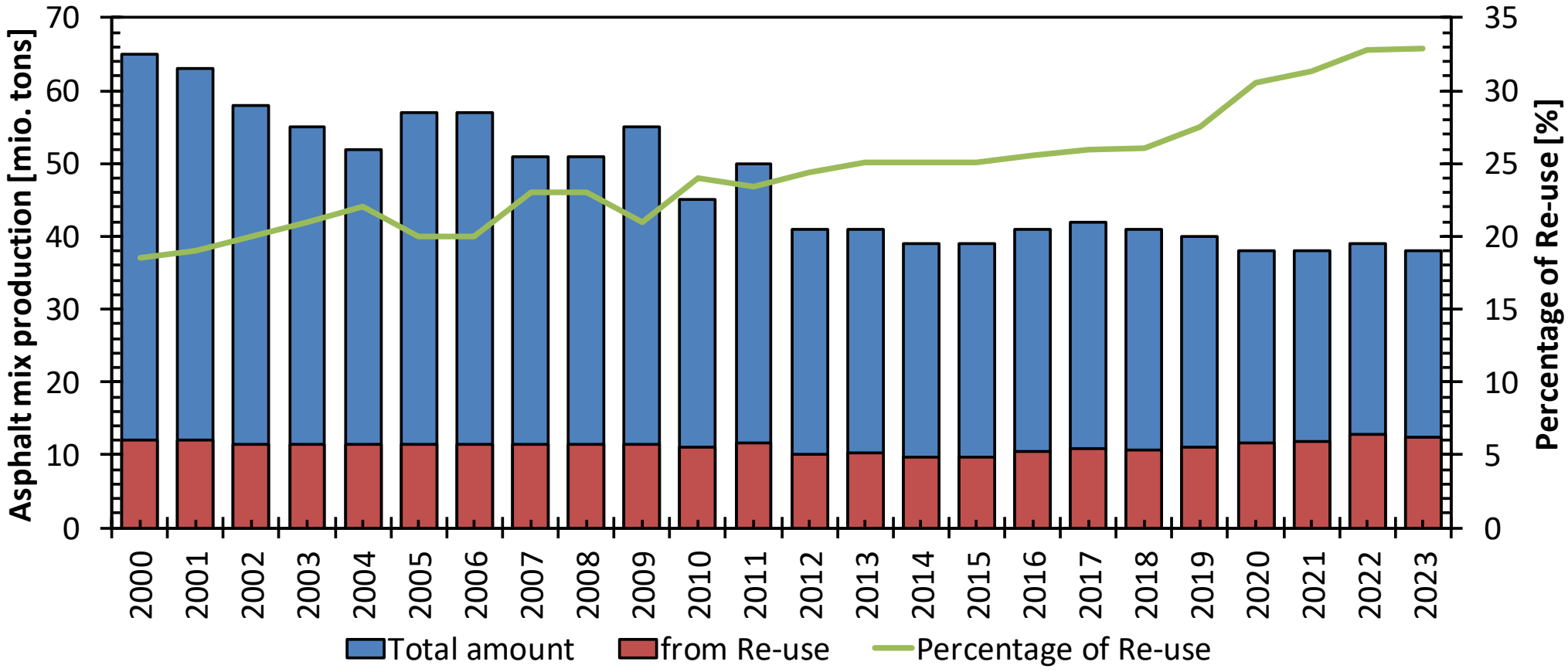
(3) Kessel, T., Pohl, T., Wistuba, M. P., Pasderski, J. & Falter, C. 2022. Road to Sustainability - Offenlegung ökologischer Potentiale im Straßenbau. Straße und Autobahn, Jahrgang 73, Heft 5, 390–394, Kirschbaum Verlag, Bonn.

(4) Kytzia, S. & Pohl, T. 2021. Ökobilanz der Herstellung von Asphaltbelägen. Straße und Autobahn, Jahrgang 72, Heft 8, 641–652, Kirschbaum Verlag, Bonn.

(5) Rathore, M., Zaumanis, M. & Haritonovs, V. 2019. Asphalt Recycling Technologies: A Review on Limitations and Benefits IOP Conference Series: Materials Science and Engineering, Vol. 660, Issue 1, p. 12046, IOP Publishing. DOI: 10.1088/1757-899X/660/1/012046.

Background

Current state of Asphalt Mix Production in Germany



(1) DAV, 2025. Asphalt production in Germany (Status May 2025). Deutscher Asphaltverband e. V. (DAV).

Background

Asphalt Re-use/Recycling in Europe

Country	Total amount of site-won asphalt generated in 2022 in tonnes	Amount of reclaimed asphalt available to be used by the asphalt industry in 2022 in tonnes	% of available reclaimed asphalt used in							Total Re-use	Total Recycling	Put to Landfill/Other Aplication/Unknown
			Hot and Warm Mix Asphalt Production	Half Warm Mix Asphalt Production	On-Site Cold Recycling**	Plant Cold Recycling**	Unbound Road Layers	Other Civil Engineering Applications	Put to Landfill /Other Applications/ Unknown			
Austria	1.800.000	no data	no data	no data	no data	no data	no data	no data	no data	50	45	5*
Belgium	2.320.000	1.320.000	90	no data	no data	no data	no data	no data	no data	90	9	1
Croatia	no data	370.000	39	0	0	21	5	no data	no data	65	no data	no data
Czech Repul	2.700.000	2.500.000	20	0	25	5	10	10	10	50	20	30
Denmark	1.320.000*	1.120.000	no data	no data	no data	no data	2	no data	no data	98	2	0
France	no data	7.340.000*	45*	no data	no data	no data	no data	no data	no data	100*	0*	0*
Germany	13.900.000	12.500.000	88	2	0	0	9	0	1	90	9	1
Great Britain	5.400.000	no data	no data	no data	no data	no data	no data	no data	no data	38*	61*	<1*
Hungary	200.000	220.000	90	0	4	0	3	3	0	94	6	0
Ireland	550.000*	550.000*	64	0	no data	no data	no data	no data	no data	64*	20*	16*
Italy	17.000.000	10.400.000	30	no data	no data	no data	no data	no data	no data	no data	no data	no data
Norway	1.116.000	1.116.000	50	0	0	0	45	4	<1	50	49	<1
Romania	34.000*	34.000*	0*	0*	95*	0*	5*	0*	0*	95*	5*	0*
Slovenia	330.000*	129.000	37	0	10	0	18	25	10	47	43	10
Spain	2.500.000	2.100.000	61	0	17	0	4	2	16	78	6	16
Switzerland	1.650.000*	no data	89	<1	<1	<1	<2	<3	6*	89*	5*	6*
Turkiye	1.935.000	1.742.000	1	0	1	0	98	0	0	2	98	0

In Germany most of the RA is re-used in HMA and WMA (88 %)!

Source: EAPA, 2024. Asphalt in Figures 2023. European Asphalt Pavement Association (EAPA), Brussels.

Regulatory Framework in Germany

German Closed Substance Cycle Act
(dt. Kreislaufwirtschaftsgesetz)(1)

↓

Standards in Germany:

z.B. TL AG, M WA, TL- und ZTV Asphalt-StB, ARS

↓

Individual Standards of German states

Source: Adobe Stock Photos

(1) Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Bewirtschaftung von Abfällen (Kreislaufwirtschaftsgesetz KrWG) vom 24.02.2012.

Regulatory Framework in Germany

Technical delivery specifications for asphalt mixtures

Technical delivery conditions for RA

Additional Technical Contract Conditions

+ Merkblatt für die Wiederverwendung von Asphalt, Ausgabe 2009/Fassung 2013 (M WA)

Information sheet for the Re-use of asphalt

Regulatory Framework in Germany new/updated Standards in 2025/26 (?)

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Technical delivery specifications for asphalt mixtures

Technical delivery conditions for RA

Additional Technical Contract Conditions

+ Merkblatt für die Wiederverwendung von Asphalt, Ausgabe 2025 (M WA)

Information sheet for the Re-use of asphalt

Regulatory Framework in Germany

Requirements for the Re-use of Reclaimed Asphalt (RA) in Hot Mix Asphalt (HMA)

No fundamental restriction on the quantity of RA added to the new HMA mixture!

- According to TL Asphalt no addition of RA to porous asphalt (PA) mixtures
- According to ZTV Asphalt no addition of RA to Stone Mastic Asphalt (SMA) mixtures

Asphalt Mixture without RA

=

Technical equivalence
(same requirements according to regulations!)

Asphalt Mixture with RA

Calculation of the maximum addition quantity

Maximum possible amount of RA granulate depends on…

…its composition and quality
(acc. to TL Asphalt-StB 07, Appendix D)

- Binder viscosity, Gradation, etc.
- Uniformity: e.g. Binder content, Homogenity of the RA granulate
- Degree of binder ageing
- Recovery & Processing of the RA granulate
- Storage conditions

…the technique of the asphalt mixing plant
(acc. to M WA)

- Direct addition of RA granulate into the asphalt mixing plant (heating by hot aggregates, batchwise addition)
- Elevator addition (heating by hot aggregates, continuous addition)
- Throwing band or center addition (heating with aggregates)
- Parallel drum (separate heating)

High Amounts of Reclaimed Asphalt – What does it mean?

- No strict definition
- ‚High RA' = approaching or exceeding standard values
- Often defined relative to standard values in federal state in Germany

Asphalt mixture type	Amount of RA granulate in Germany		High Amount of RA
	Standard values (1)	Mean values (1)	Definition by ISBS (!)
AC D (surface)	≈ 0 - 30 M.-%	23,2 M.-%	> 40 M.-%
AC B (binder)	≈ 0 - 50 M.-%	31,2 M.-%	> 50 M.-%
AC T (base)	≈ 20 - 60 M.-%	38,7 M.-%	> 60 M.-%
SMA	0 M.-%	/	> 0 M.-%

(1) 2025, Statistical Analysis of data from asphalt mixtures from „Niedersächsische Landesbehörde für Straßenbau und Verkehr" from 2018 to 2021; AC D: 2.831 mixtures, AC B: 2.257 mixtures, AC T: 2.746 mixtures.

Regeneration of RA binder

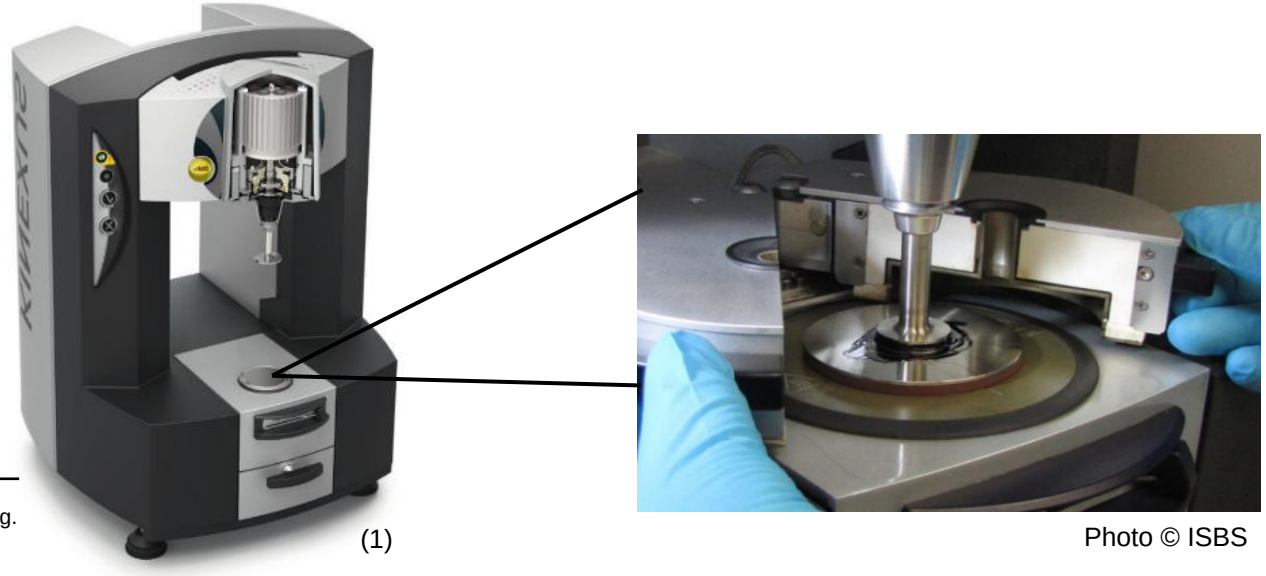
a.) Using fresh, soft bitumen

- The more viscous the aged binder is or the higher the addition rate of RA granulate, the more fresh binder or more soft binder needs to be added
- Technical limitation: The total binder content of the asphalt mixture is limited, otherwise the asphalt mixture will become too soft!

b.) Addition of a Regenerator in very small amounts

- Instead of the fresh binder or in addition, a Regenerator is added

State-of-the-art: Determination of Regenerator type & amount based on rheological tests in the Dynamic Shear Rheometer (DSR)



(1)

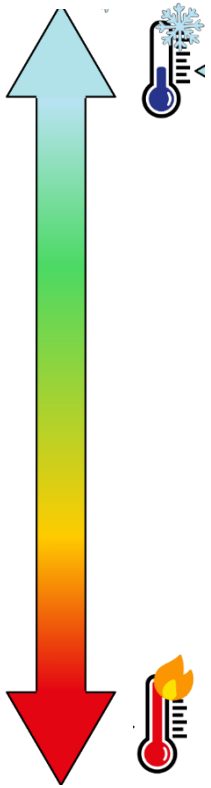
Photo © ISBS

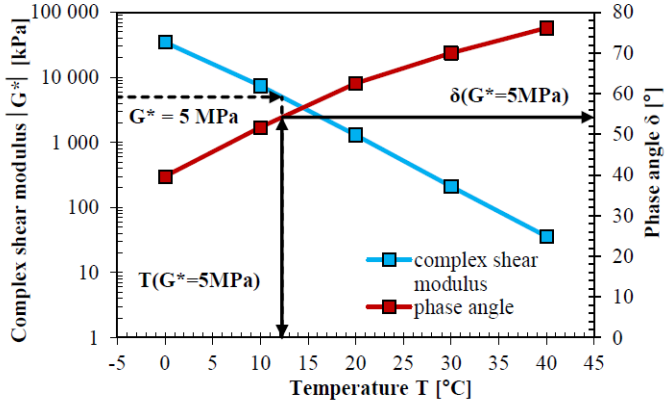
(1) NETZSCH, 2025. Kinexus DSR Series, Redefining Rheometer Capabilities for Asphalt Binder and Bitumen Testing. NETZSCH-Gerätebau GmbH, Analyzing & Testing, Selb, Germany.

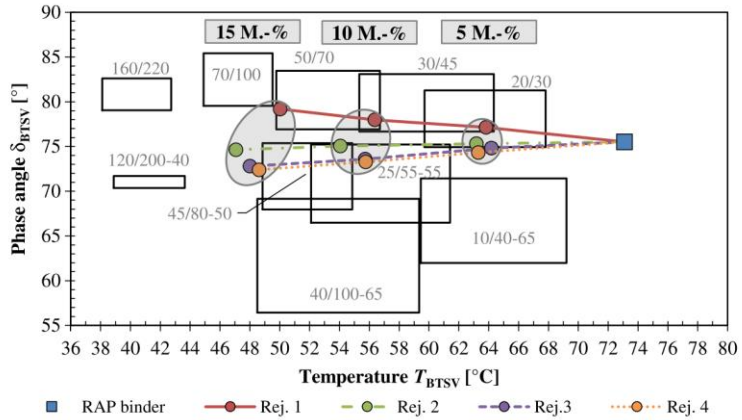
Technical challenges when using high amounts of RA

Binder design for the resulting asphalt mixture – necessary Regenerator dosage

- **Temperature sweep test (T-sweep test)** (1,2)
  - Dynamic Shear Rheometer (DSR)
  - 8 mm parallel plate geometry (2 mm gap)
  - Test temperatures from -10 °C to 40 °C
  - Test frequency 1,59 Hz
  - Parameter T @ G* = 5 MPa
- **Binder Fast Characterization Test (BTSV)** (3,4)
  - Dynamic Shear rheometer (DSR)
  - 25 mm parallel plate geometry (1 mm gap)
  - Test temperatures from 20 °C to 90 °C
  - Temperature ramp 1,2 °C / min
  - Test frequency 1,59 Hz
  - Parameter T (G* = 15 kPa)







(1) EN 14770, 2023. Bitumen and bituminous binders - Determination of complex shear modulus and phase angle using a Dynamic Shear Rheometer (DSR). European Committee for Standardization (CEN), Brussels.

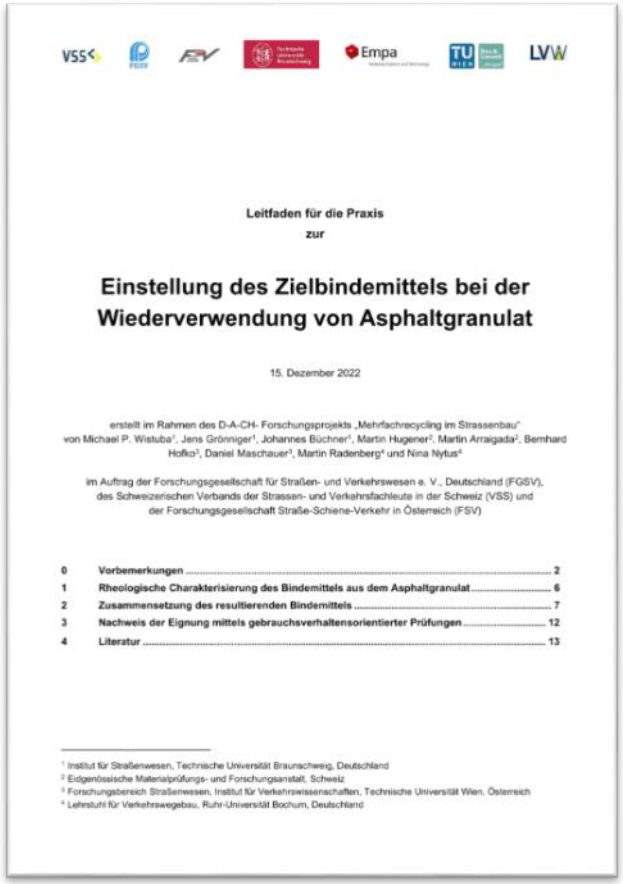
(2) Büchner, J., Wistuba, M. P., Miesem, S., Neliepp, M., Dietzsch, M. & Sandor, M. 2023. Rheological Characterisation of Regenerator Blending Lines. Road Materials and Pavement Design, Vol. 24, Sup. 1: EATA 2023, Taylor & Francis. DOI: 10.1080/14680629.2023.2180994.

(3) EN 17643, 2022. Bitumen and bituminous binders – Determination of equi-shear modulus temperature and phase angle using a Dynamic Shear Rheometer (DSR) – BTSV test. CEN, Brussels.

(4) Schrader, J., Wistuba, M. P., Cannone Falchetto, A., Riccardi, C. & Alisov, A. 2019. A new Binder-Fast-Characterization-Test using DSR and its Application for Rejuvenating Reclaimed Asphalt Binder. Journal of Testing and Evaluation, American Society for Testing and Materials (ASTM). DOI: 10.1520/JTE20180893.

Technical challenges when using high amounts of RA

Binder design for the resulting asphalt mixture – necessary Regenerator dosage



Leitfaden für die Praxis
zur

Einstellung des Zielbindemittels bei der Wiederverwendung von Asphaltgranulat

15. Dezember 2022

erstellt im Rahmen des D-A-CH- Forschungsprojekts „Mehrfachrecycling im Strassenbau"
von Michael P. Wistuba[1], Jens Grönniger[1], Johannes Büchner[1], Martin Hugener[2], Martin Arraigada[2], Bernhard Hofko[3], Daniel Maschauer[3], Martin Radenberg[4] und Nina Nytus[4]

im Auftrag der Forschungsgesellschaft für Straßen- und Verkehrswesen e. V., Deutschland (FGSV), des Schweizerischen Verbands der Strassen- und Verkehrsfachleute in der Schweiz (VSS) und der Forschungsgesellschaft Straße-Schiene-Verkehr in Österreich (FSV)

[1] Institut für Straßenwesen, Technische Universität Braunschweig, Deutschland
[2] Eidgenössische Materialprüfungs- und Forschungsanstalt, Schweiz
[3] Forschungsbereich Straßenwesen, Institut für Verkehrswissenschaften, Technische Universität Wien, Österreich
[4] Lehrstuhl für Verkehrswegebau, Ruhr-Universität Bochum, Deutschland

Design of the resulting binder

Use case 1: Binder design with specification of the addition rate of RA

Use case 2: Binder design with specified fresh binder

Guide (2) (German)

Report (1) (German)

(1) Wistuba, M. P., Grönniger, J., Hugener, M., Arraigada, M., Hofko, B., Maschauer, D., Radenberg, M. & Staschkiewicz, M. 2022. Mehrfachrecycling im Straßenbau (MARS), Schlussbericht zum D-A-CH Forschungsprojekt im Auftrag von FGSV, VSS und FSV.

(2) Wistuba, M. P., Grönniger, J. & Büchner, J. 2022. Leitfaden für die Praxis zur Einstellung des Zielbindemittels beider Wiederverwendung von Asphaltgranulat, erstellt im Rahmen des D-A-CH- Forschungsprojekts „Mehrfachrecycling im Strassenbau", im Auftrag von FGSV, VSS und FSV.

Research project „Beurteilung des Potentials von Maximalrecycling“[1]
(Potential of re-using maximum amounts of RA)

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Project Outline

- Time: From 2023 to 2025
- Client: BASt on behalf of Federal Ministry of Transport
- Partners: ISBS (lead), Schäfer Consult, Ostfalia Suderburg

Research Objectives and Contents

- Analyzing German pilot projects of road construction with high amounts of RA
- Evaluating the experiences, the technical feasibility and the performance properties of asphalt mixtures with high amounts of RA
- Identifying the limits of RA amounts including requirements for RA granulates, mixing plant technologies, mixing technologies, binder regeneration
- Definition of technical requirements for the maximum re-use of RA and for resulting performance
- Supporting future standardization for re-using high amounts of RA in Germany
- Life Cycle Assessment (LCA) of road construction with high amounts of RA and assessing potential environmental benefits

(1) Wistuba, M. P., Büchler, S., Kollmus, F., Schäfer, V., Di Turi, T. & Walther, A. 2025. Beurteilung des Potentials von Maximalrecycling (MAWI), Laufendes Forschungsprojekt 07.0322/2023/ERB i.A. der Bundesanstalt für Straßenwesen (BASt), Laufzeit 2023-2025. Technische Universität Braunschweig; Schäfer Consult, Ostfalia Suderburg.

Research project „Beurteilung des Potentials von Maximalrecycling“
(Potential of re-using maximum amounts of RA)

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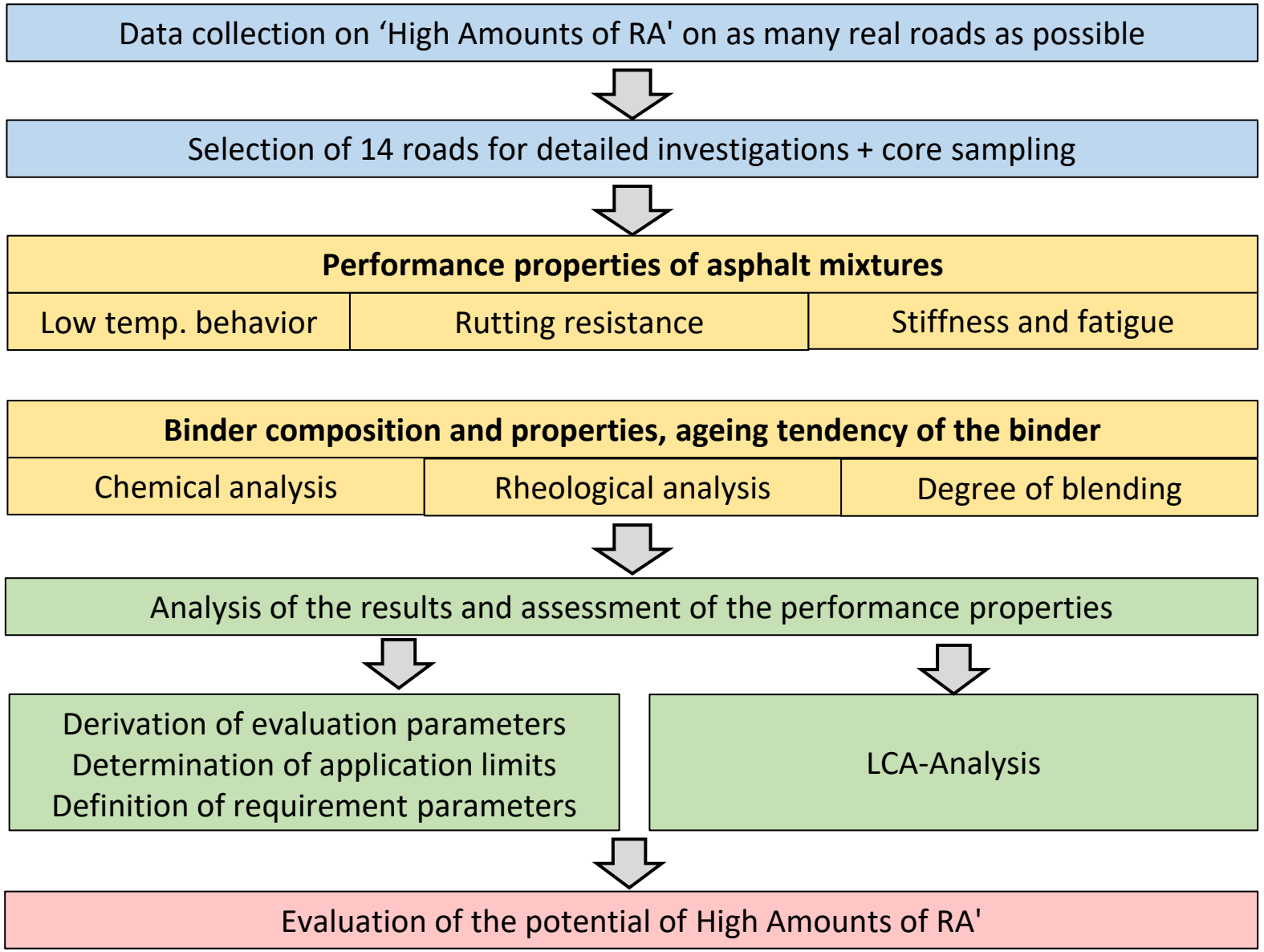
Methodology



Research project „Beurteilung des Potentials von Maximalrecycling“
(Potential of re-using maximum amounts of RA)

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Institut für Straßenwesen
TU Braunschweig

Asphalt pavement layers investigated

Asphalt mixture type	Quantity	Amount of RA [%]
AC D	10	35 to 90
AC B	6	50 to 85
AC T	10	60 to 90
SMA	3	20 to 50
SMA B	2	60
Total	31	

Di Turi [2024]

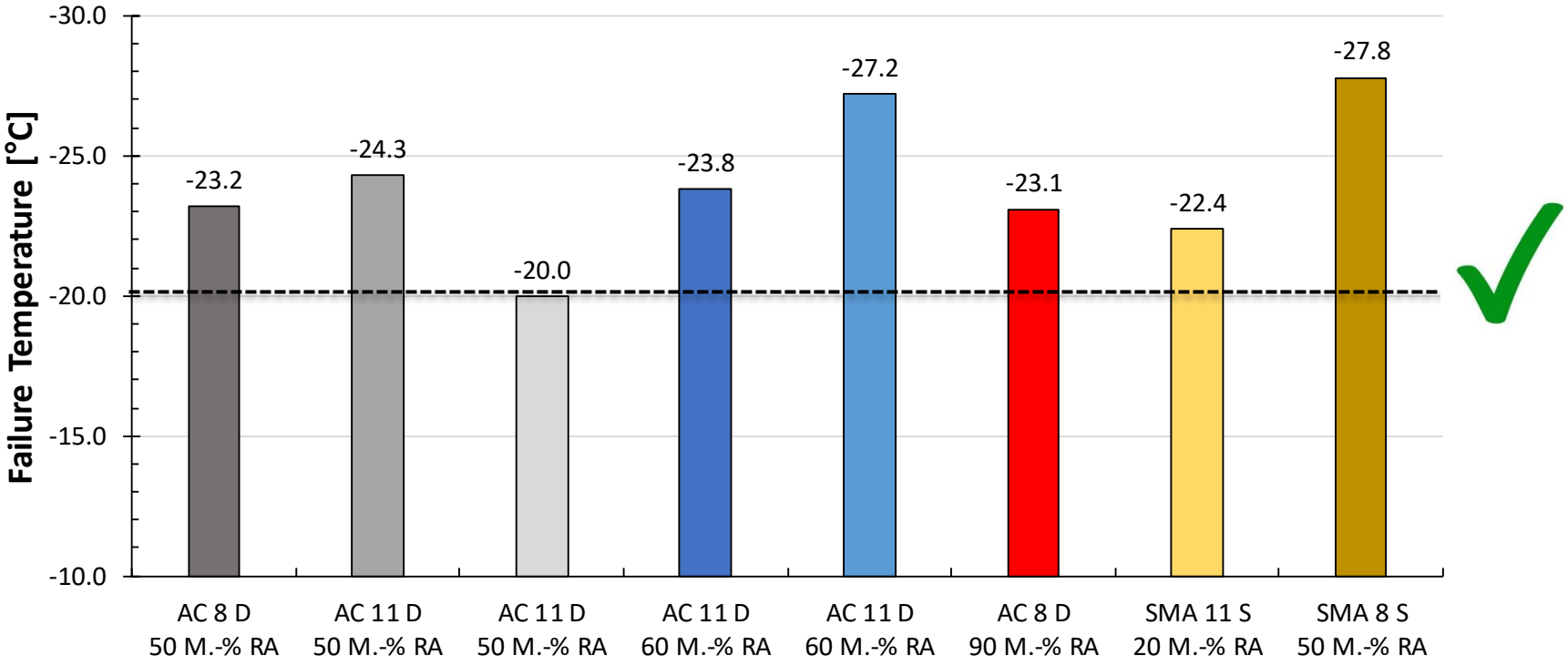
Di Turi [2024]

Photo © ISBS

https://umap.openstreetmap.fr/de/map/lage-versuchsstrecken-max-rc-bw_1021985#6/48.012/9.229

(First) Results on the performance properties – Resistance to cold cracking

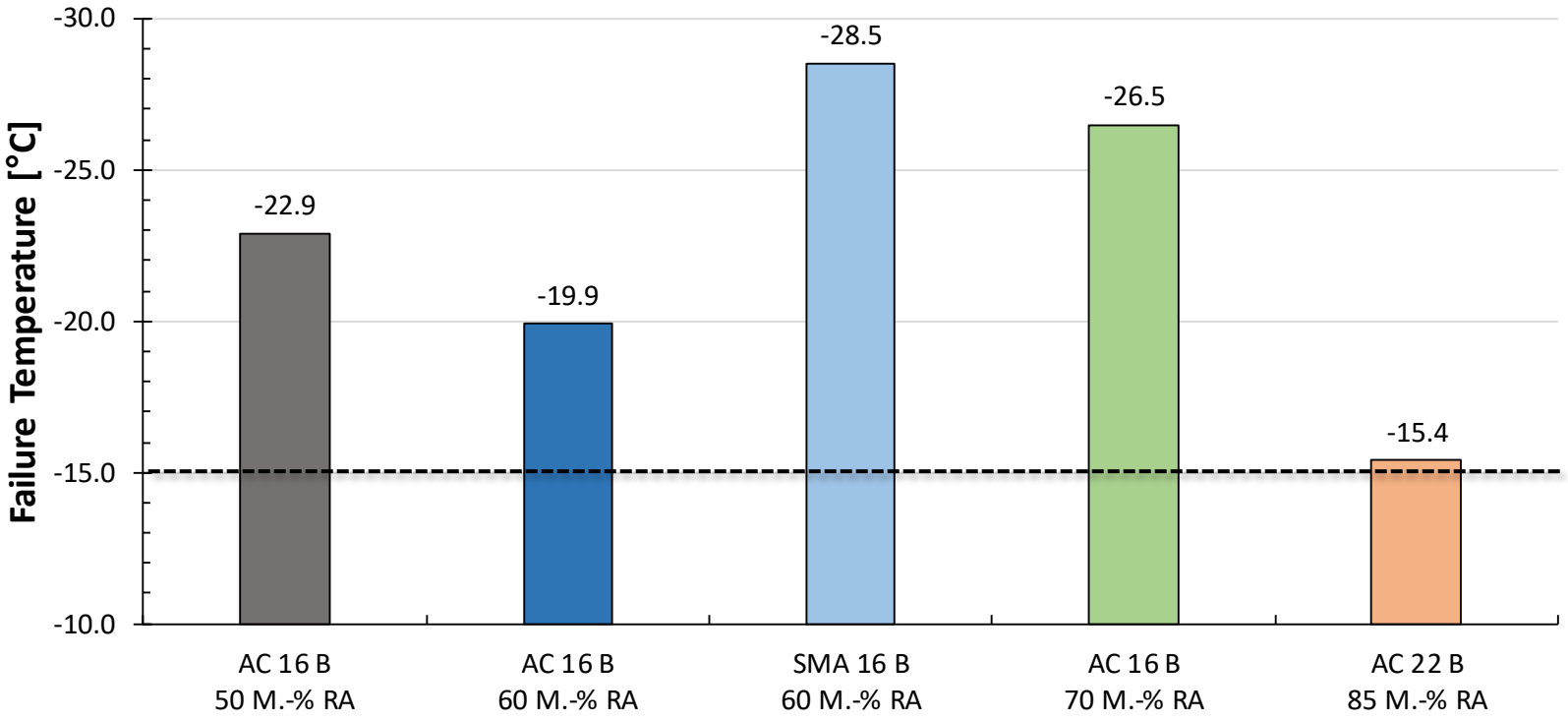
Thermal Stress Restrained Specimen Test (TSRST)



- **Failure temperatures are at a low (advantageous) level (below a temperature of -20°C)**
- **Use of > 50 M.-% RA in AC D and use of RA in SMA without loss of resistance to cold cracking**

(First) Results on the performance properties – Resistance to cold cracking

Thermal Stress Restrained Specimen Test (TSRST)



- **Failure temperatures are at a low (advantageous) level (below a temperature of -15°C)**
- **Use of > 50 M.-% RA in binder layers without loss of resistance to cold cracking**

(First) Results on the performance properties – Rutting resistance

Uniaxial Cyclic compression test

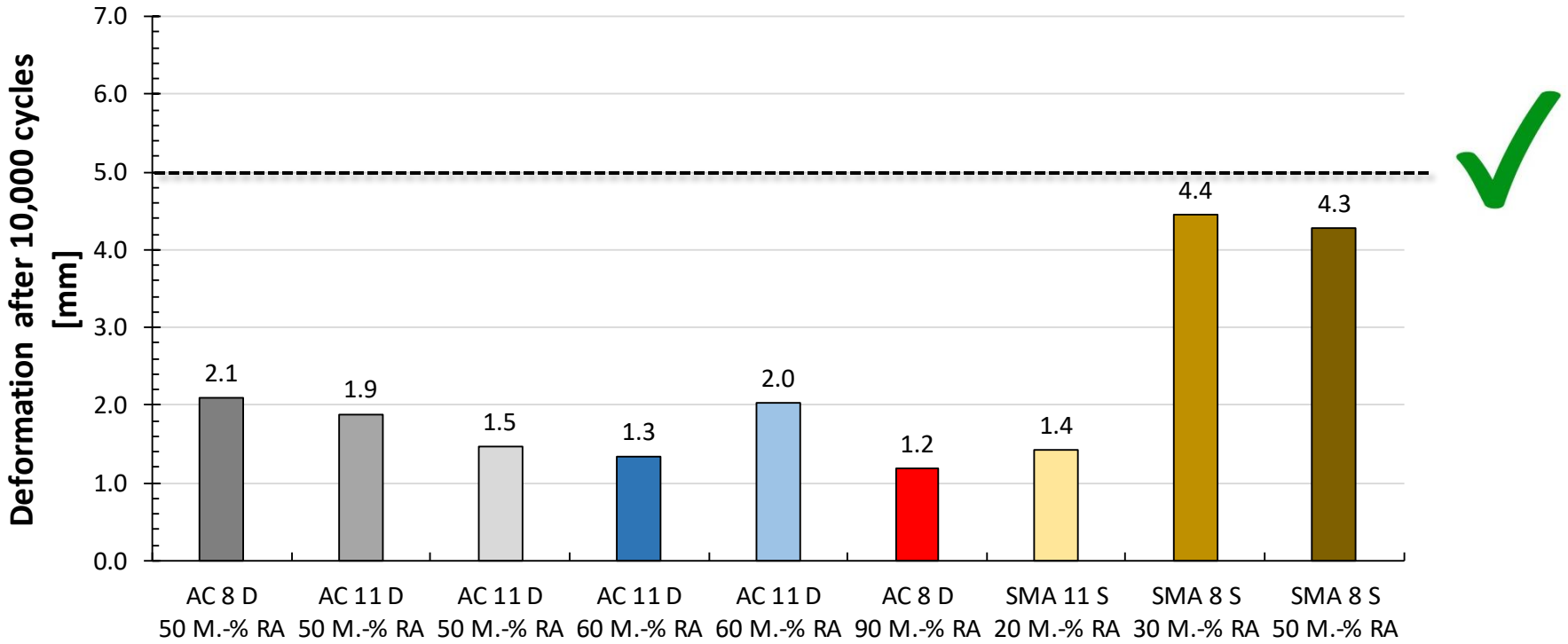
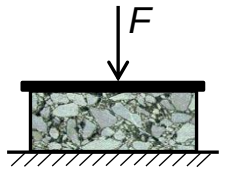


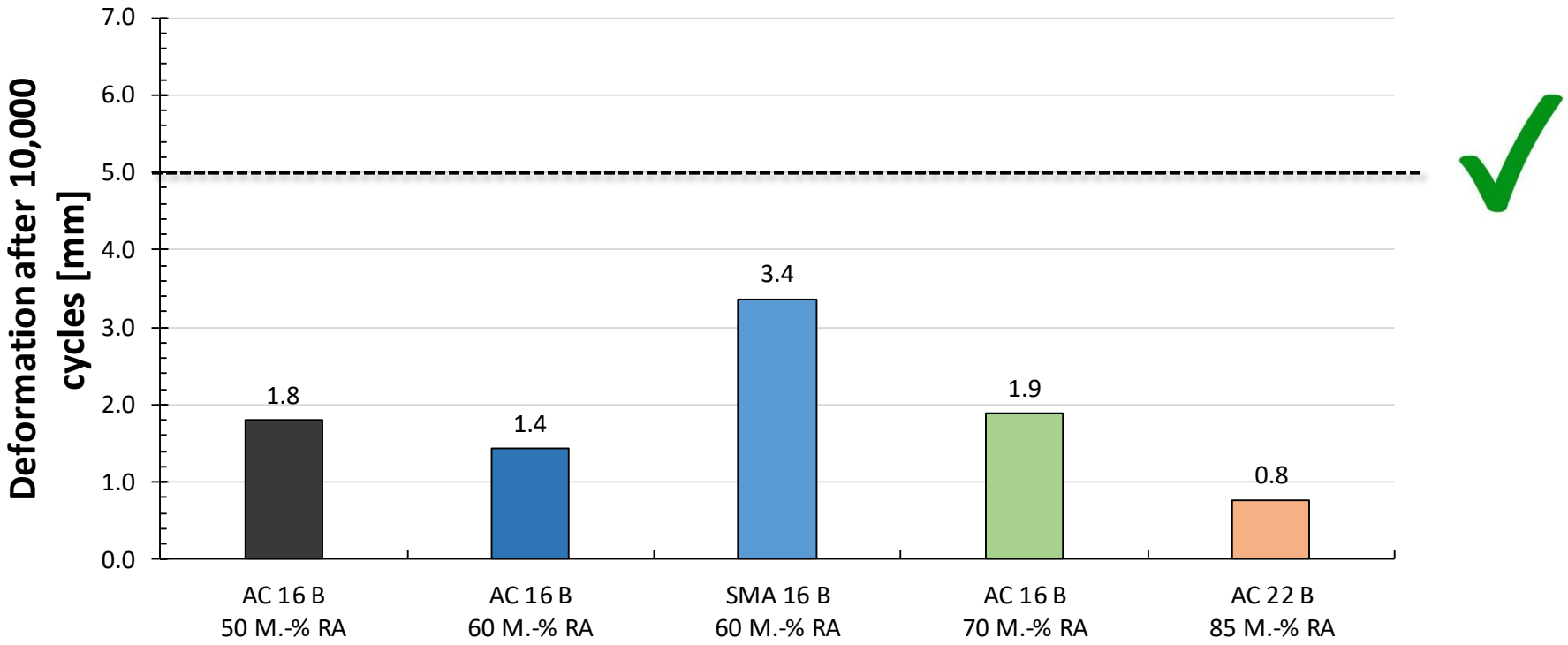

Photo © ISBS

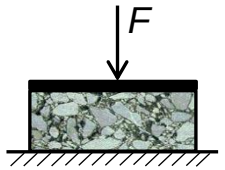


- **Good Rutting Resistance (no requirements)**
- **Use of > 50 M.-% RA in AC D and use of RA in SMA without loss of resistance to rutting**

(First) Results on the performance properties – Rutting resistance

Uniaxial Cyclic compression test





- **Good Rutting Resistance (no requirements)**
- **Use of > 50 M.-% RAP in binder layers without loss of resistance to rutting**

(First) Results on the performance properties – Fatigue

Cyclic Indirect Tensile test on cylindrical shaped specimens (CIT-CY)

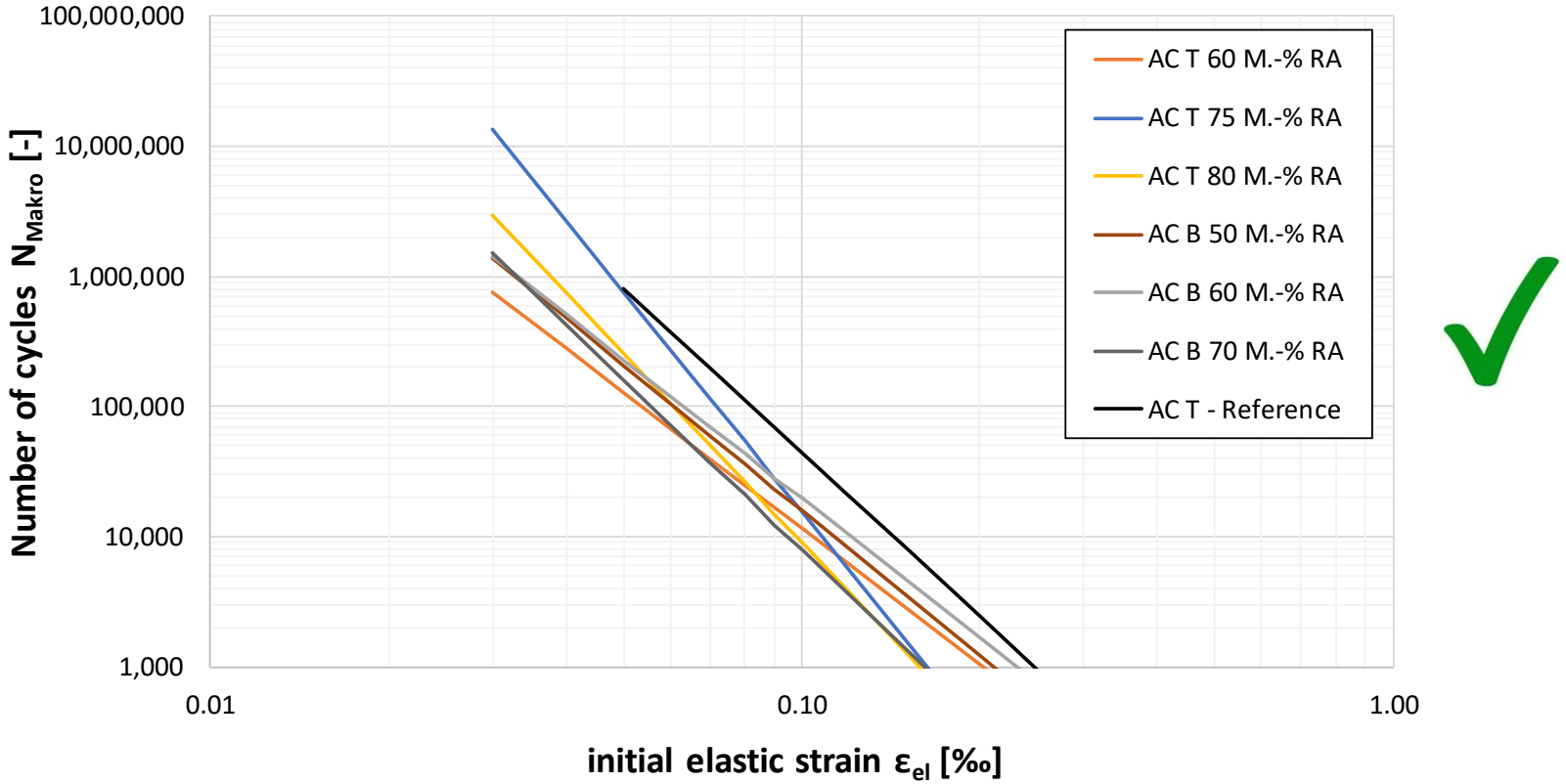


Photo © ISBS

- **Fatigue functions of RA-variants with similar N_{Makro} values at 0,1 ‰, yet different ε_6 values**
- **Below RDO-reference asphalt, but still in a good area**

Conclusions and Final Remarks

Recommendations

- Milling of layers from homogeneous road sections (only from one construction site) and, ideally, only layer-by-layer milling
- Single-variety stockpile management
- Fractionated, dry storage
- Control of the binder and filler content of the fractions
- Asphalt mixing plant with parallel drum or better in counterflow action with a hot gas generator
- Extended mixing time
- Mix design based on performance properties
- Adjustment of Mix Design and performance properties through trial mixtures
- Dosing of the regenerator or fresh binder on the basis of rheological tests


Photo © ISBS


Photo © Wistuba

(1) Leutner, R., Renken, P. & Lobach, T. 2005. Wirksamkeit der Zugabe von Asphaltgranulat auf die mechanischen Eigenschaften von Asphaltdeckschichten. TU Braunschweig, Institut für Straßenwesen.

(2) Grönniger, J., Renken, P. & Wistuba, M. P. 2009. Verwendung von Fräsasphalt aus Offenporigen Asphaltdeckschichten auf möglichst hohem Wertschöpfungsniveau, Abschlussbericht zum Forschungsprojekt FE 07.0212/2006/CGB im Auftrag des Bundesministeriums für Verkehr, Bau- und Stadtentwicklung. TU Braunschweig, Institut für Straßenwesen.

(3) Hollatz, A. & Zweschper, Y. 2012. Erhaltungskonzepte für Asphaltstraßen in Baden-Württemberg - Pilotstrecken mit Maximalrecycling. Asphalt, Issue 8, 10–14.

(4) Wistuba, M. P., Grönniger, J. & Isailović, I. 2015. Optimierung des Recyclinganteils in Asphalttrag- und -binderschichten (ORAB), Schlussbericht, i.A. des österreichischen Bundeministeriums für Verkehr, Innovation und Technologie (BMVIT) und der Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft (ASFINAG). Technische Universität Braunschweig, Institut für Straßenwesen.

(5) Denck, C. 2017. Aktueller Stand zum Asphaltrecycling am Beispiel Hamburg. Kolloquium Kommunales Verkehrswesen 2017, FGSV Verlag, Köln.

(6) Klumbach, S. & Schmidt, V. 2021. Entwicklungen im Straßenbau – Wie Maximalrecycling und Qualitäts-Straßenbau Baden-Württemberg 4.0 (QSBW 4.0) den Straßenbau effizienter und ökologischer gestalten können, Technische Akademie Esslingen, 7.-8. September 2021, Esslingen.

(7) Zaumanis, M., Poulikakos, L. D., Boesiger, L., Kunz, B., Mazzoni, H., Bruhin, P., Lötscher, D. & Schellenberg, U. 2023. Highly Recycled Asphalt Pavement (HighRAP), Forschungsprojekt ASTRA 2019/001 (ASTRA). EMPA, Schweiz.

Conclusions and Final Remarks

- The reuse of asphalt is an international "flagship" of the German construction industry.
- The reuse of asphalt is illustrated in the technical standards and has been the standard in Germany for years.
- Multiple reuse of asphalt (in small quantities) is demonstrably possible (see MARS research project [1]).
- The reuse of asphalt appears to be possible without any problems, even with high addition rates, without having to accept losses in performance (see the project presented [2]).
- Binder design for the resulting asphalt mixture can be carried out with a high degree of reliability using measurements in the DSR. In individual cases, it may be advisable to check the performance of the resulting asphalt.
- With high amount of RA, sufficient regeneration is possible if a Regenerator (currently usually in combination with fresh bitumen) or a very soft bitumen is used.
- It is assumed that sufficient regeneration is also possible with bio-Regenerators (purely from renewable raw materials) and without fresh bitumen [3].
- The product range of Regenerators is large, not all Regenerators fulfill the requirements for sustainability to the same extent, methods for evaluation are being developed [4,5].

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(2) Wistuba, M. P., Büchler, S., Kollmus, F., Schäfer, V., Di Turi, T. & Walther, A. 2025. Beurteilung des Potentials von Maximalrecycling (MAWI), Laufendes Forschungsprojekt 07.0322/2023/ERB i.A. der Bundesanstalt für Straßenwesen (BASt), Laufzeit 2023-2025. Technische Universität Braunschweig; Schäfer Consult, Ostfalia Suderburg.

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