UNIKASSEL
VERSITÄT

Research and Standardisation on Cold Recycling in Germany

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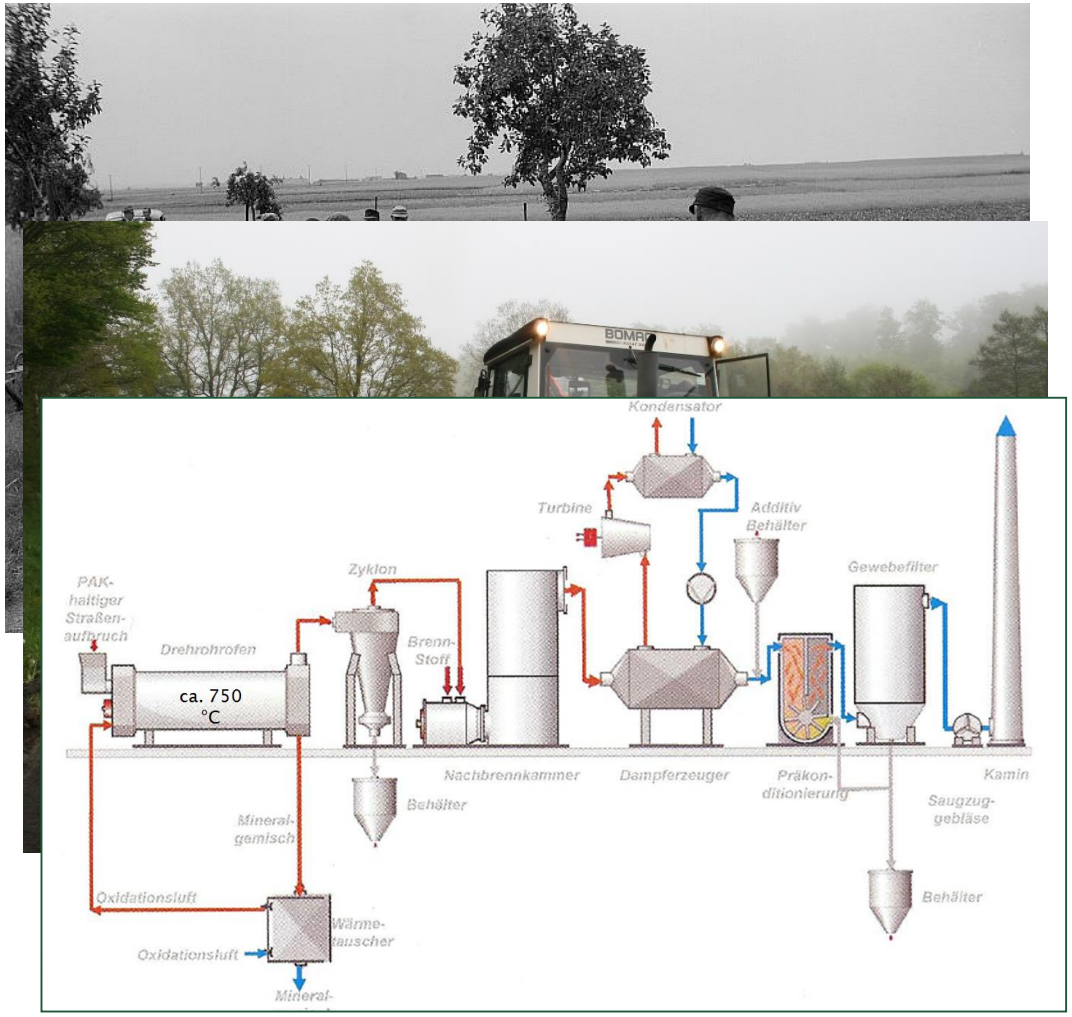
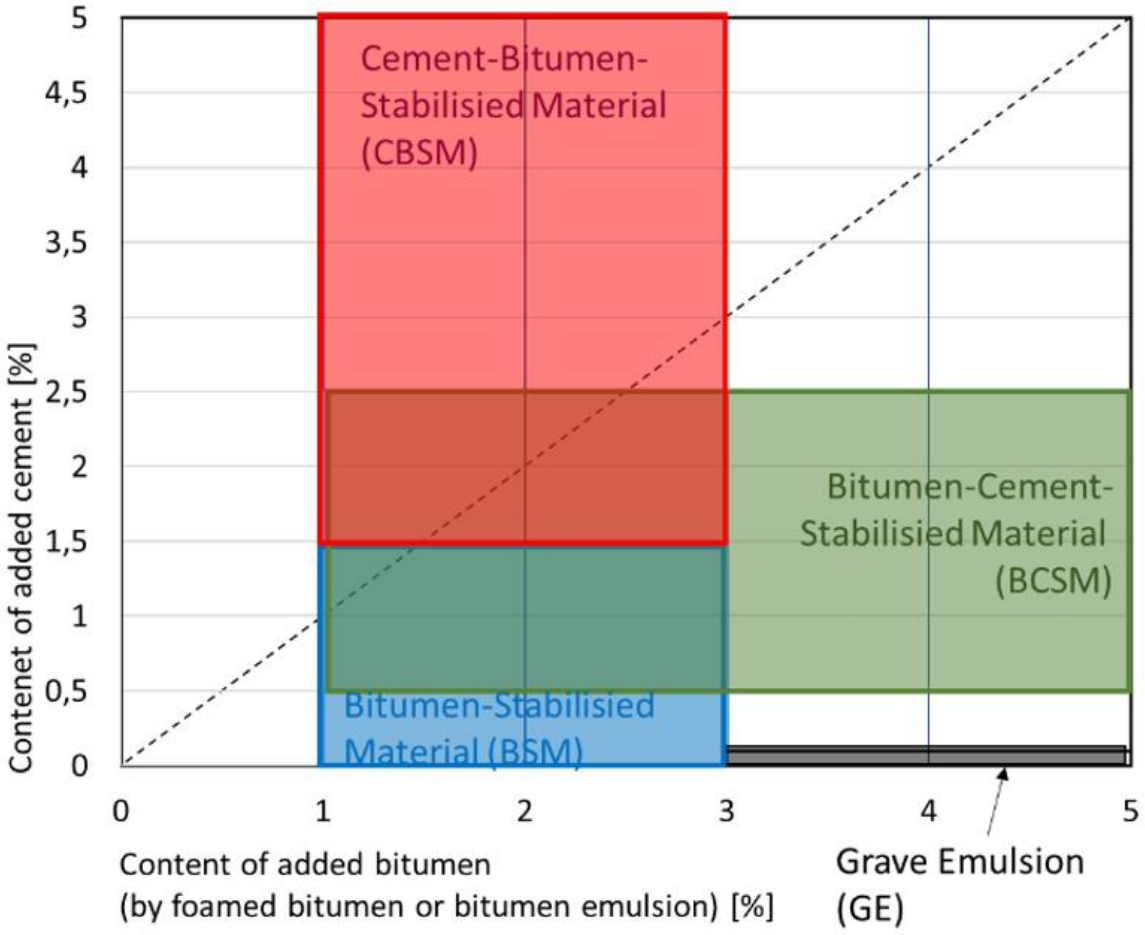
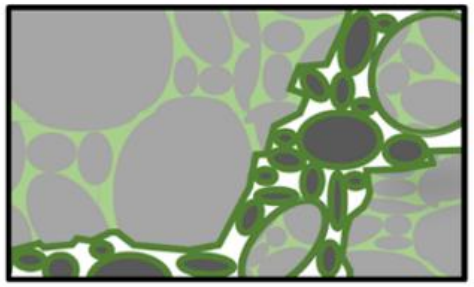
History of Cold Recycling and related specifications in Germany – Application on tar-contaminated reclaimed road materials

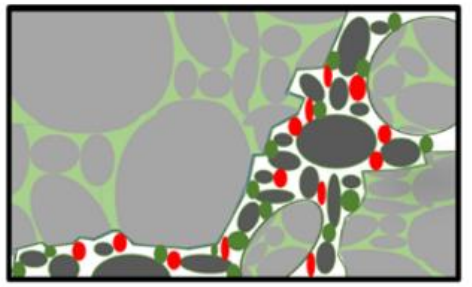
- Specification documents:
  - From 1970: Hot Recycling was successfully applied since late 1970s with increasing recycling rates for reclaimed asphalt (RA) and higher RA-Additon in new HMA.
  - ~ until 1975: Coal tar was used as binder, then banned because of high carcinogenicity (still ~ 1000 mil t. of road materials in network)
  - 1993: Specification for recycling of tar-contaminated reclaimed road materials (tar-RRM) with bitumen emulsion
  - 2001: Cold recycling was introduced 2001 as procedure for recycling of tar-RRM
    (Definition of tar-contaminated RA: ≥ 25 ppm (mg/kg) PAH_{16} in reclaimed road material)
  - 2005: Introduction of specification document M KRC (Guideline for Cold Recycling) both for RA and tarRRM -> relatively wide application
  - 2015: Bundesrechnungshof (federal financial audit agency) banned recycling of tar-RR because of enlarging the contaminated mass and transfer of tar-RR to federal roads
  - Since 2016: Specification activity within FGSV (German Road and Transportation Research Association)
  - 2019: Introduction of EN 13108-31: Asphalt Concrete with Bituminous Emulsion

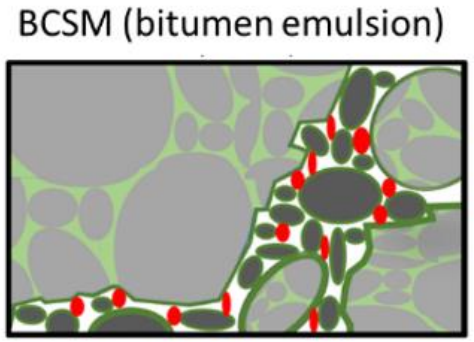


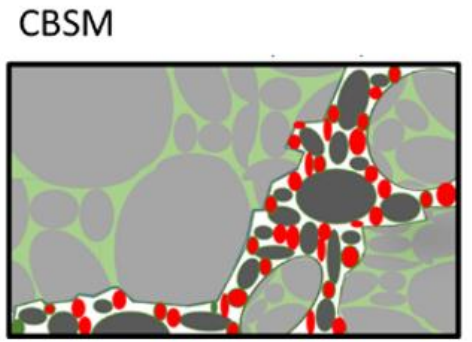
Variety of „Cold Recycled Materials“











Research in Germany on CRM

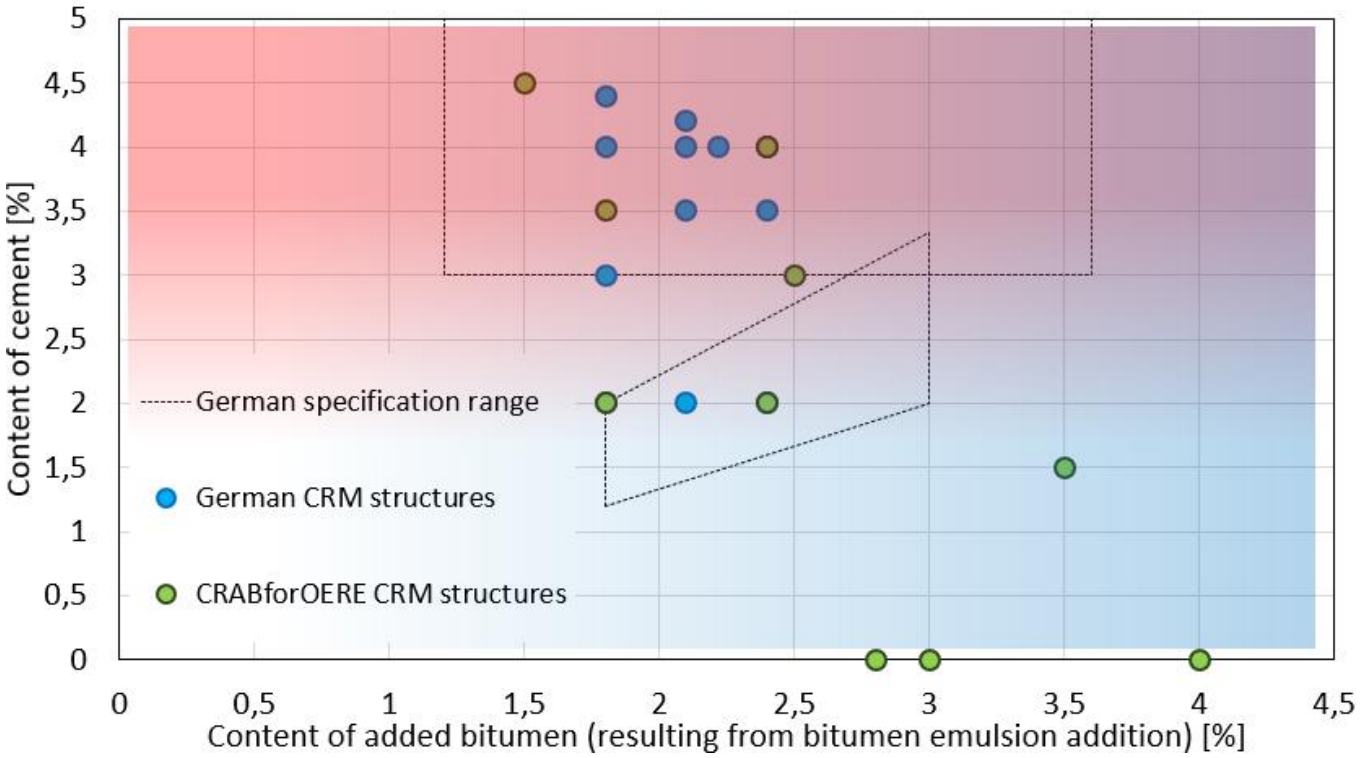
a. 2011: EU FP 7-Project: Direct-Mat:
   Introduction of cold recycling technologies as feasible recycling option

b. 2013-2015: CEDR-project “CoRePaSol”:
   Comparison of several cold recycling strategies

c. 2018-2021: CEDR-project “Crab4Oere”:
   Validation of cold recycling procedures,
   Proposal of harmonized mix and pavement design procedures

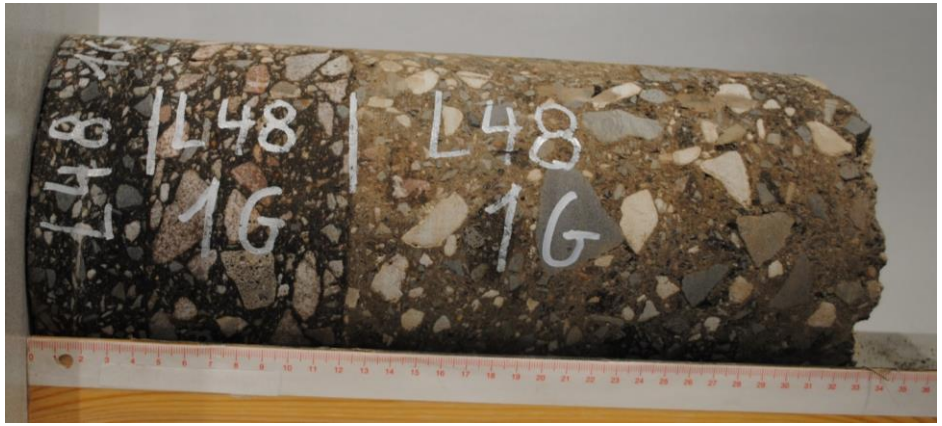
d. 2014-2023: PhD-dissertations
   (Miljkovic, Kalantari, Al-Mohammedawi)

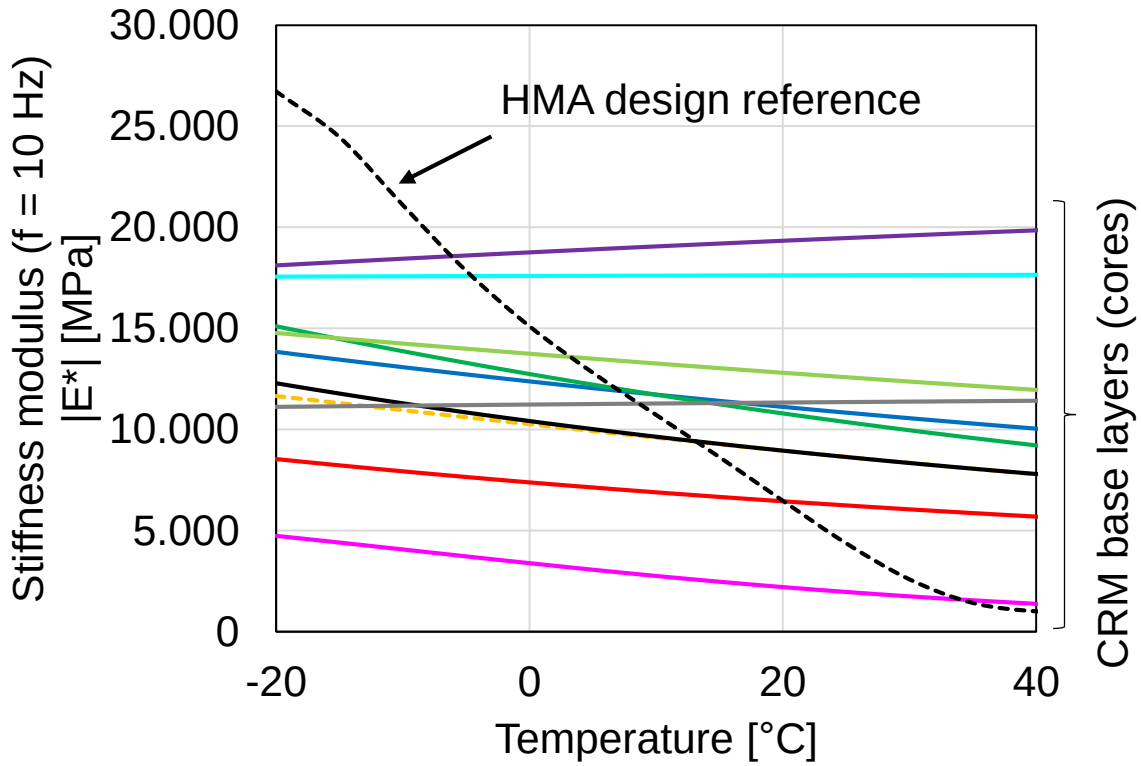
e. 2020-2022: German project: “Verification of mix and pavement design of Cold Recycled Pavements”:
   Proof of durability of ”old” CRM pavements



Most-important findings of research projects

- CRM pavements result in similar durability as conventional HMA pavements, when properly deigned
  - Empirical pavement designs result in surplus thickness of CRM base layer of +20 to +50 % compared to HMA base layer
  - German way of mix design (CBSM with cement content > 3 %) shows danger of shrinkage cracking
- International experiances on lab mix design procedure differ considerably
  - Compaction methods and energy
  - Curing procedures
  - Strength and stiffness test procedures and temperature
- In Germany, specification procedures and limits results in high cement contents – therefore reduced viscoelasticity





Specification in federal German road administration

Roads are structured in

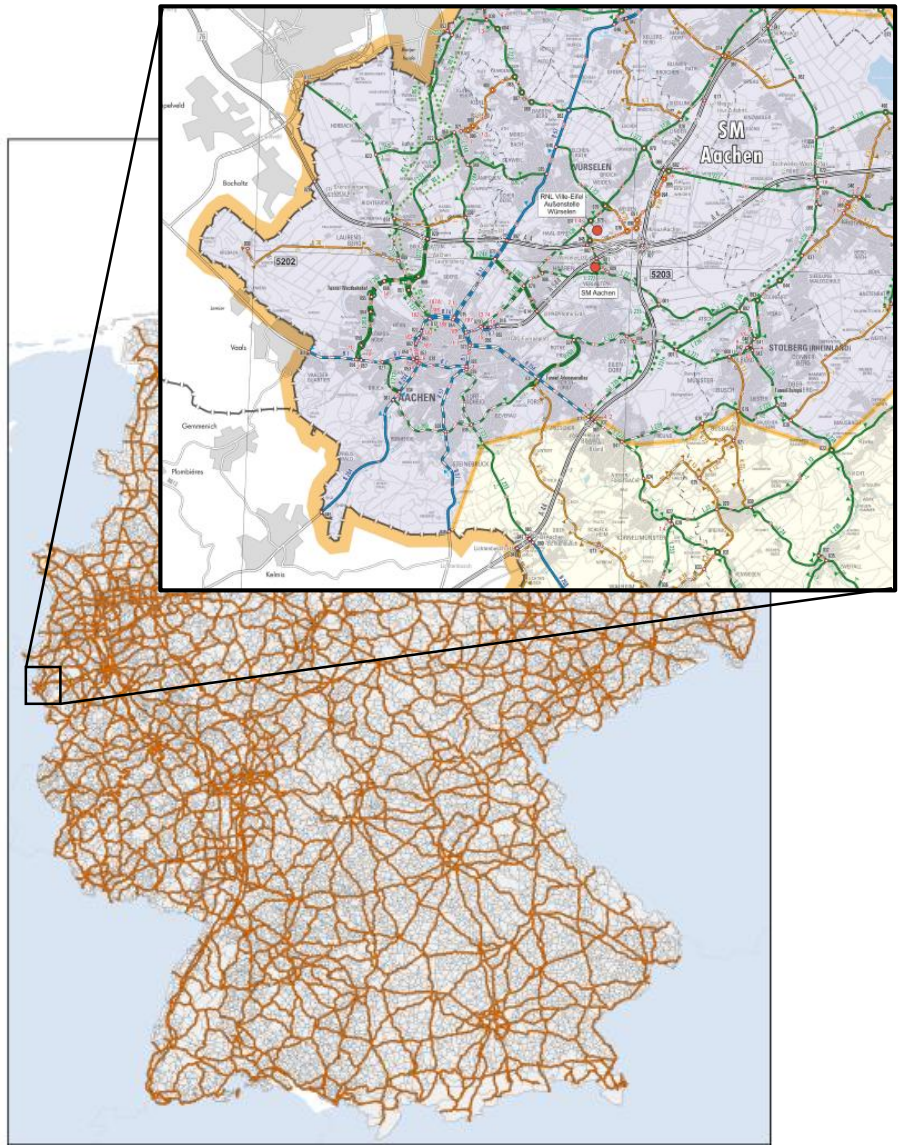
- federal roads (federal ministry of transportation BMDV) (BAB, B)
- State roads (state ministry of transportation) (L)
- County / City roads (K) (county/city administrations)

FGSV specification documents are

- introduced by BMDV for federal roads
- recommended by BMDV for use for other roads

State/County/City administrations can use individual specification documents

Without specification, no application



Specifications on CRM

- Existing FGSV documents:
  - M KRC (Guideline for Cold-in-place Recycling), 2005
  - M VB-K (Guideline for Cold-in-Plant Recycling), 2007 (1993)
  - RStO (Empirical Pavement Design), 2024 (reference to M KRC)
- „New“ European standard: EN 13108-31 (AC BE), 2019
- Additional (regional) specifications
  - CRM for recycling of tar-RRM in use in some German regions

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- Current specification works in three technical committees
  - AK 4.5.9:
    Since 2016: Pavement design of asphalt pavements on low-volume roads
  - AK 6.2.6:
    Since 2018: Revision of M KRC
  - AL 7.3.4:
    Since 2019: Asphalt base layers with bituminous emulsion (AC BE)
- Goal: Common specification of CRM material properties

FGSV

- Mix design rules:
  - M KRC:
    - Res. bitumen: 1,2 % - 3,6 %
    - Cement: 3 % - 6 %
    - ITS(5°C, 28 days): 750 to 1.200 kPa
  - M VB-K:
    - Res. bitumen: 1,8 % - 3 %
    - Cement: 1 % - 2 %
    - ITS(5°C, 28 days): 700 to 1.000 kPa
- Pavement design rules:
  - M KRC: Layer thickness – especially feasible for full-depth reclamation
  - M VB-K: +20 % thickness compared to hydraulically bound base layer
  - Since 2024, RStO refers to M KRC structures

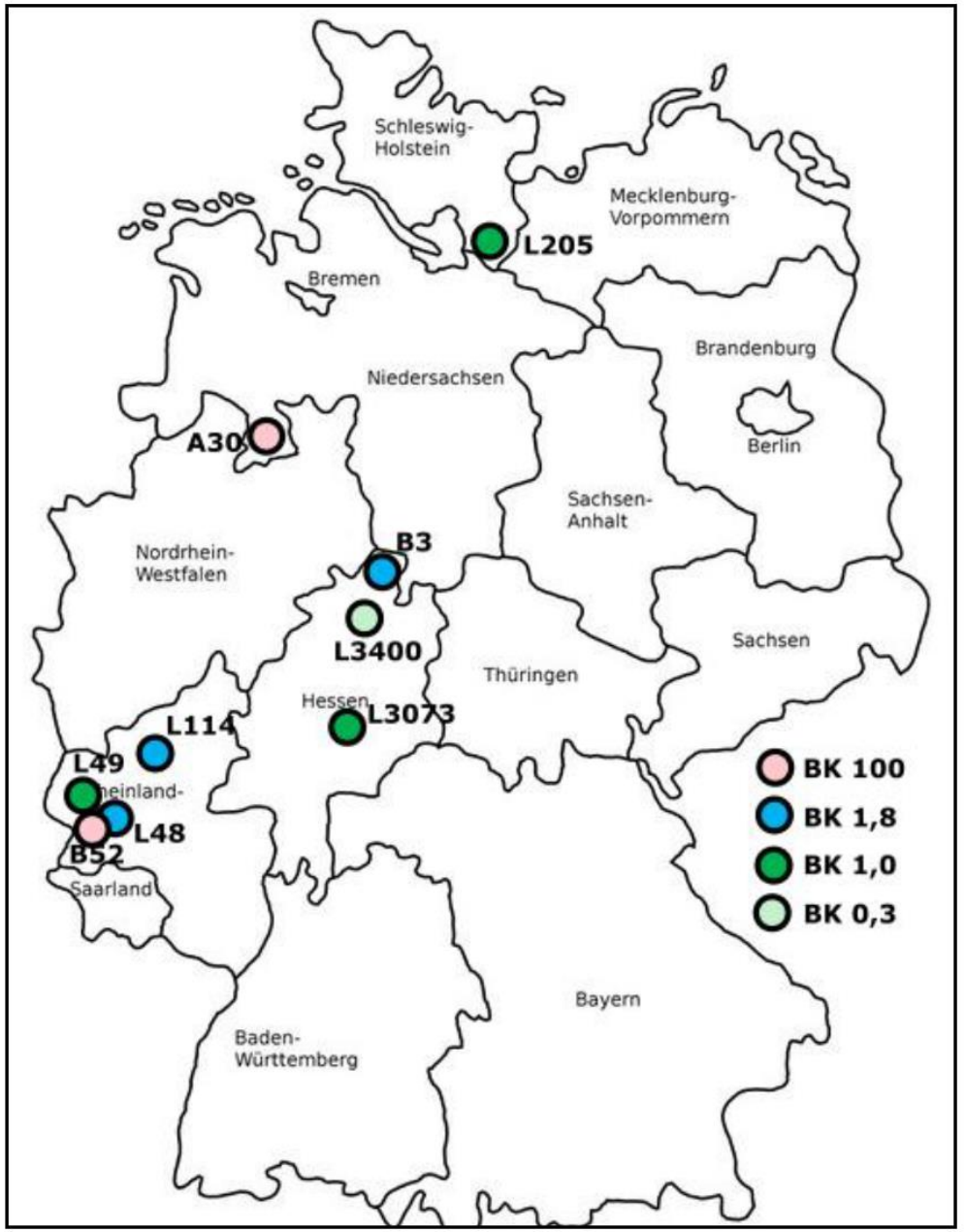
Development of new specifications

- Definition of three material classes:
  1. AC BE: In-plant for high homogeneity, controlled mix composition, low tolerances for pavement works
     Fuly comparable to HMA base or binder layers
  2. High-quality CRM: In-plant or In-Place prepared BCSM of good homogeneity, high RA-content.
  3. CRM: In-place produced BCSM with higher tolerances in composition to meet heterogeneity in full-depth reclamation
- Adjusted empririal pavement designs for these material types, e. g.
  - „Class 1“: Same thickness as HMA
  - „Class 2“: HMA thickness x 1,2
  - „Class 3“: HMA thickness x 1,5
- Current research for support of specification development

FE 04.0239 (2020-2022; Ruhr-Uni Bochum, Uni Kassel)
„Verification of mix and pavement design for CRM base layers“

- Identification of 10 asphalt pavements with CRM base layer
- Assessment of surface condition, structure, traffic and climatic loads
- Assessment of void content, stiffness and fatigue of core specimens
- Calculation of remaining service life

Section	ADT Kfz/d] (% HV)	Thickness [cm]		Condi
		CRM	HMA	Evene
1	50.000 (21 %)	25	29	1,8
2	50.000 (21 %)	25	31	1,9
3	26.000 (15 %)	20	18	1,8
4	4.176 (6,4%)	18	18	1,9
5	2.676 (24 %)	18	11,5	
6	2.307 (7 %)	18	12	2,3
7	2.096 (10 %)	12	4	
8	1.659 (5 %)	16	4	1,2
9	1.220 (2,9 %)	20	14	1,8
10	605 (2,5 %)	18	18	1,8



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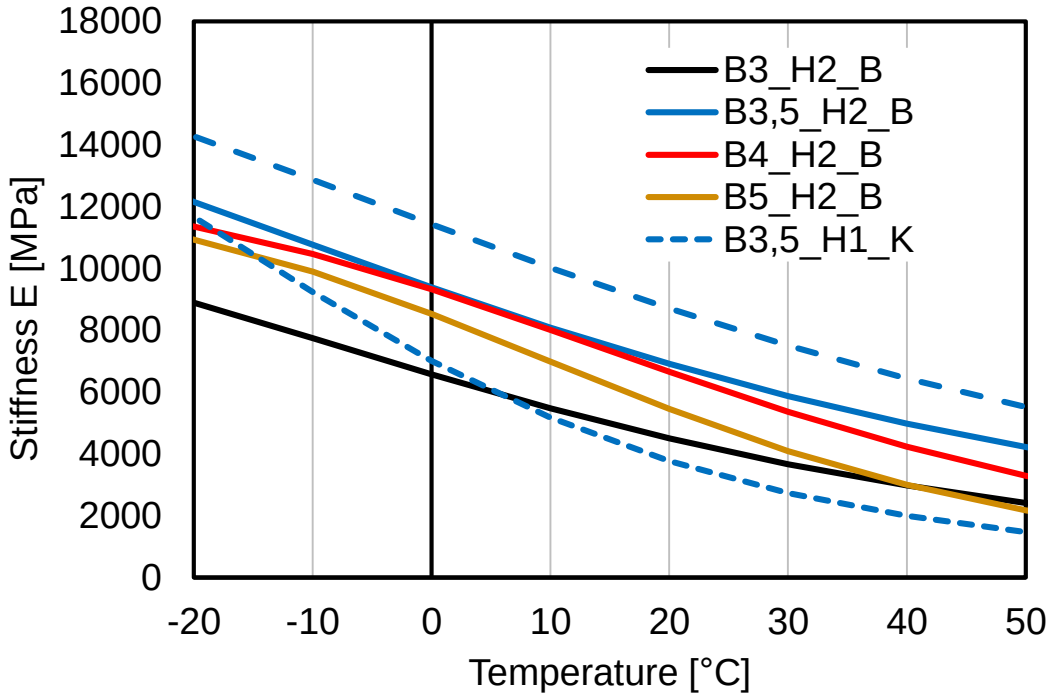
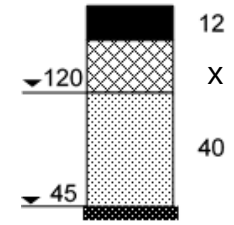
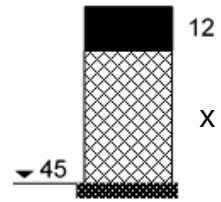
- 9 of 10 existing pavements with CRM base layer show good condition in service lifetime
- CRM layers with low cement content show asphalt-like behavior, however less temperature-dependency than HMA
- When HMA-MEPDG is applied on CRM pavements, design thickness factor of between 1,14 and 1,6 is derived



Results of MEPD calculations:

ADT (heavy veh.)	900	90	30	5
Layer thickness [cm] of **asphalt** (or CRM) base layer with sub-base	18 **23** **+28 %**	14 **19** **+38 %**	12 **17** **+44 %**	10 **16** **+60 %**
Layer thickness [cm] of **asphalt** (or CRM) without sub-base	30 **34** **+14 %**	26 **30** **+17 %**	26 **30** **+17 %**	22 **26** **+19 %**



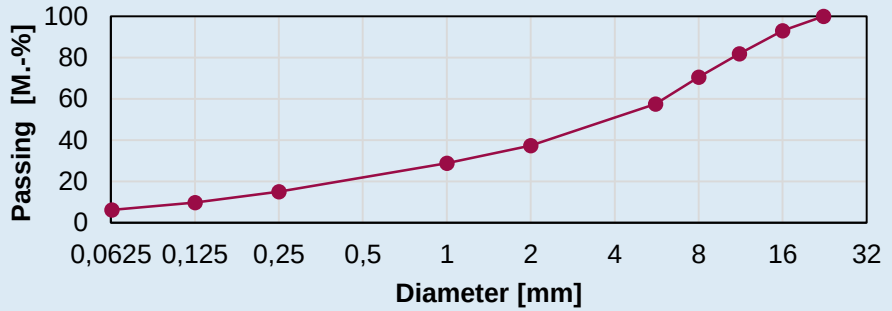


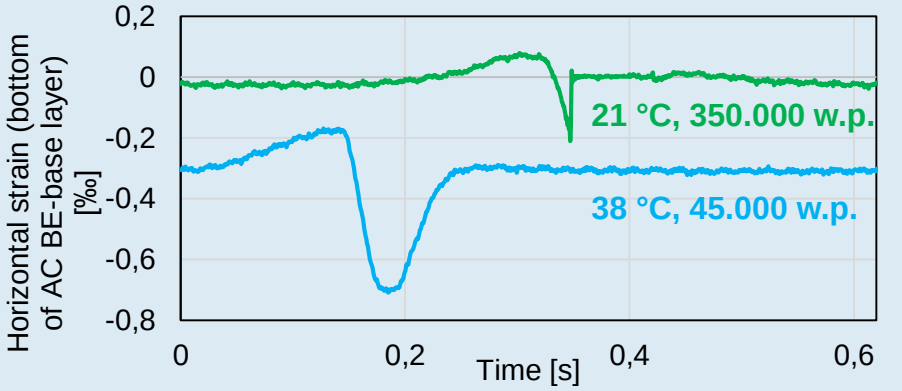
Ongoing research projects: FE 07.0304: Applicability of EN 13108-31 specifications for AC BE (2023-2024)

- Application of EN 13108-31 mix design procedures for development of a feasible AC BE-base layer material
- Proof of concept by paving a model pavement and accelerated loading
- Verification of MEPD
- Pavement structure:
  - 4 cm SMA surface course
  - 14 cm AC BE-base layer
- Results:
  - High rutting
    - high summer temperature
    - Moist AC BE
  - Mix preparation demands for dry RA
  - At intermediate temperatures structure fulfils loading requirement (1.000.000 5-t-wheel passes)
  - Verification of MEPD (bottom-up-cracking)
  - Design law for rutting required

Mix design:

- 75 % RA, 15 % filler, 10 % natural aggregates
- Bitumen emulsion: 4,5 %, HRB (cement): 1 %

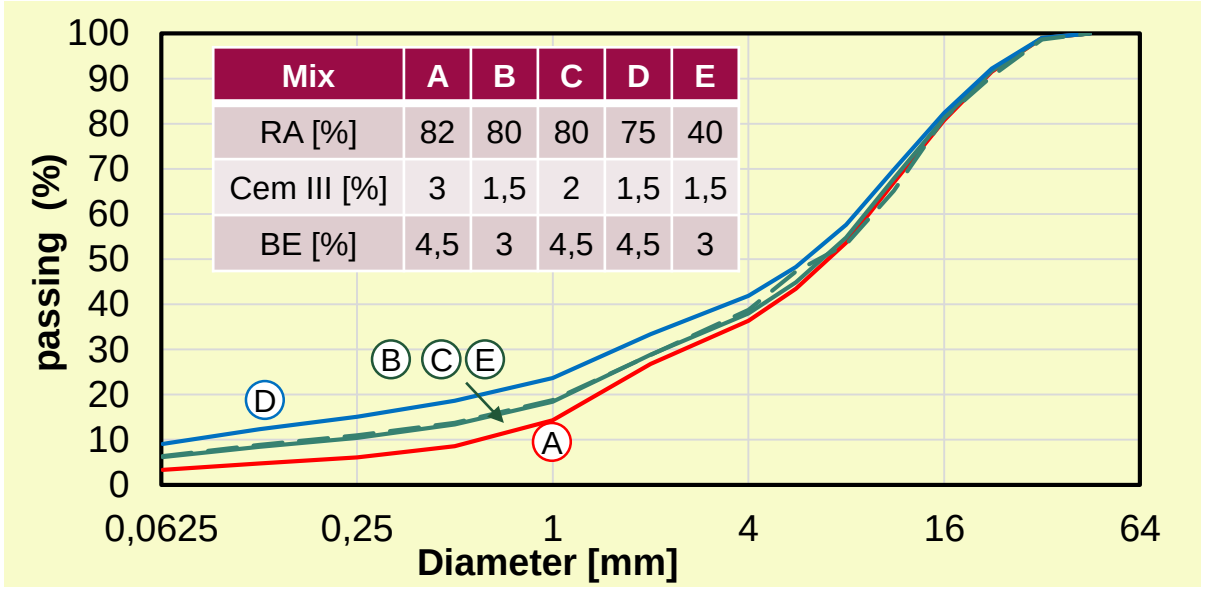




Ongoing research projects: FE 07.0329: Feasible laboratory mix design procedures for CRM (2023-2025)

- Design of 5 different CRM
- Construction of CRM pavements with 5 BSMs
  - Assessment of field compaction
  - Assessment of bearing capacity
  - Assessment of mechanical properties of core samples after 28 days, 56 days, ~200 days
- Evaluation of laboratory procedures for mix design
  - Various laboratory mixer
  - 4 compaction procedures (gyratory, vibratory, static, wheel roller)
  - Variation of curing conditions (temperature, moisture, duration)
  - Variation of strength tests (ITS 5 °C, ITS 15 °C, SCBT)
  - Stiffness, fatigue by CIDT
- Objective:
  Identification of laboratory procedures which allow differenciation between 5 mixtures in the same way as observed in real structures

Mix	A	B	C	D	E
RA [%]	82	80	80	75	40
Cem III [%]	3	1,5	2	1,5	1,5
BE [%]	4,5	3	4,5	4,5	3



Thank you very much for your interest!