Trajnost kolnika s hladno recikliranim nosivim slojevima i usporedba analiza tijekom životnog vijeka u odnosu na strukture sa samo vrućim asfaltom

Durability of pavements with cold recycled asphalt base layers and LCA-comparison to pure hot mix asphalt structures

Konrad Mollenhauer

8. međunarodna konferencija ASFALTNI KOLNICI 2023. 8th International conference ASPHALT PAVEMENTS 2023
Opatija 11. – 12. 05. 2023.

cold recycled asphalt base layers

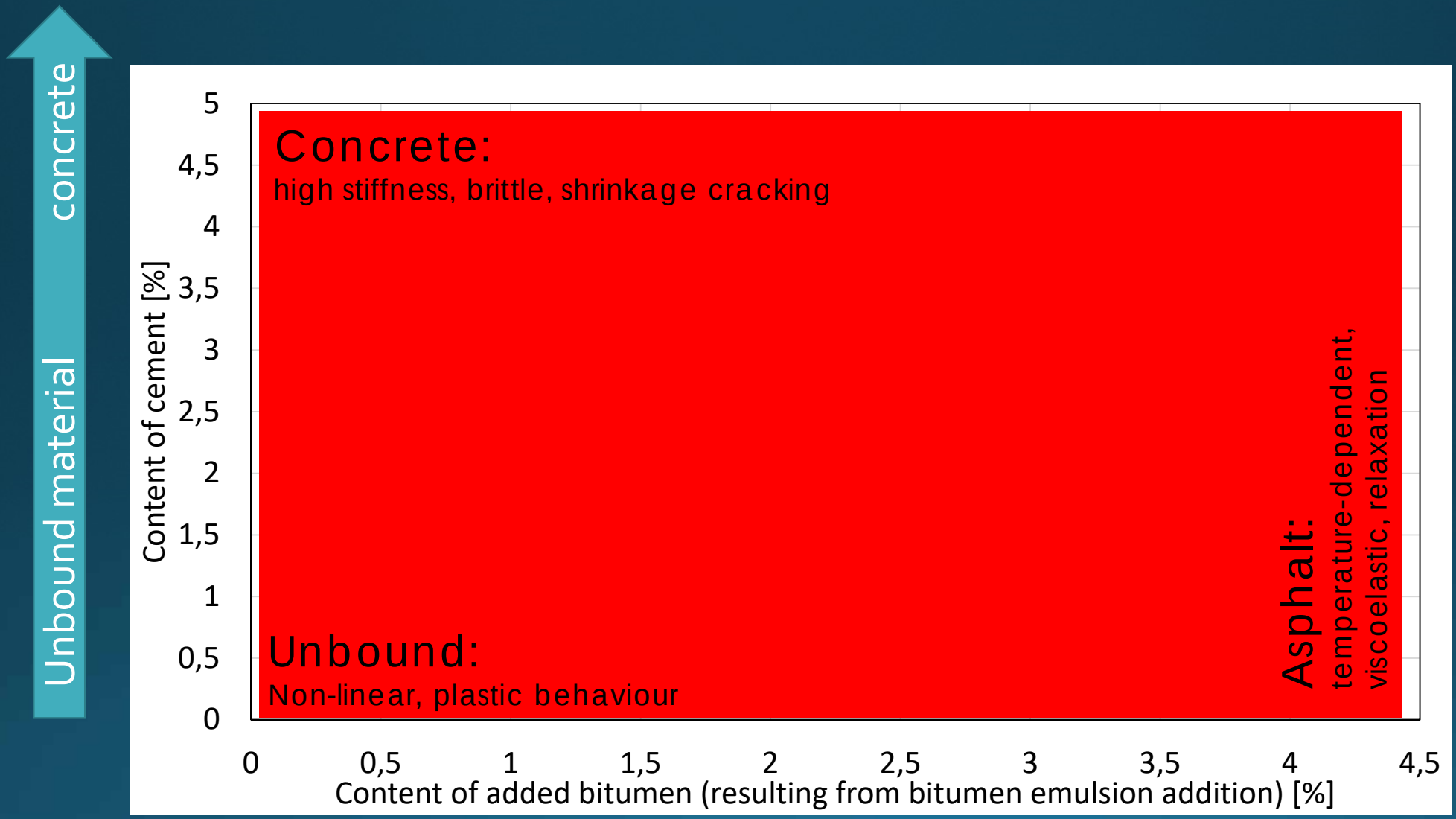
- Definition of materials
- Laboratory performance
- Quality condition of CR-Pavements
- Estimated durability
- Pavement design
- LCA-comparison

- Research Sources:
  - CRABforOERE (CEDR 2017 project) – (2018-2020): (https://www.cedr.eu/peb-new-materials-and-techniques)
  - FE 07.0239 (2019-2021) (funded by German federal ministry of Transportation)

Cold **R**ecycled asphalt **M**ixtures (CRM)

- Composed of:
  - > 75 % Reclaimed asphalt
  - Some natural aggregates
  - Bitumen emulsion
  - Mineral/hydraulic binder (e.g. cement)
  - Water
- Produced and layed at ambient temperature
- Material properties similar
  - to unbound layers during construction
  - to asphalt layers in long-term
  - To lean concrete at high cement contents

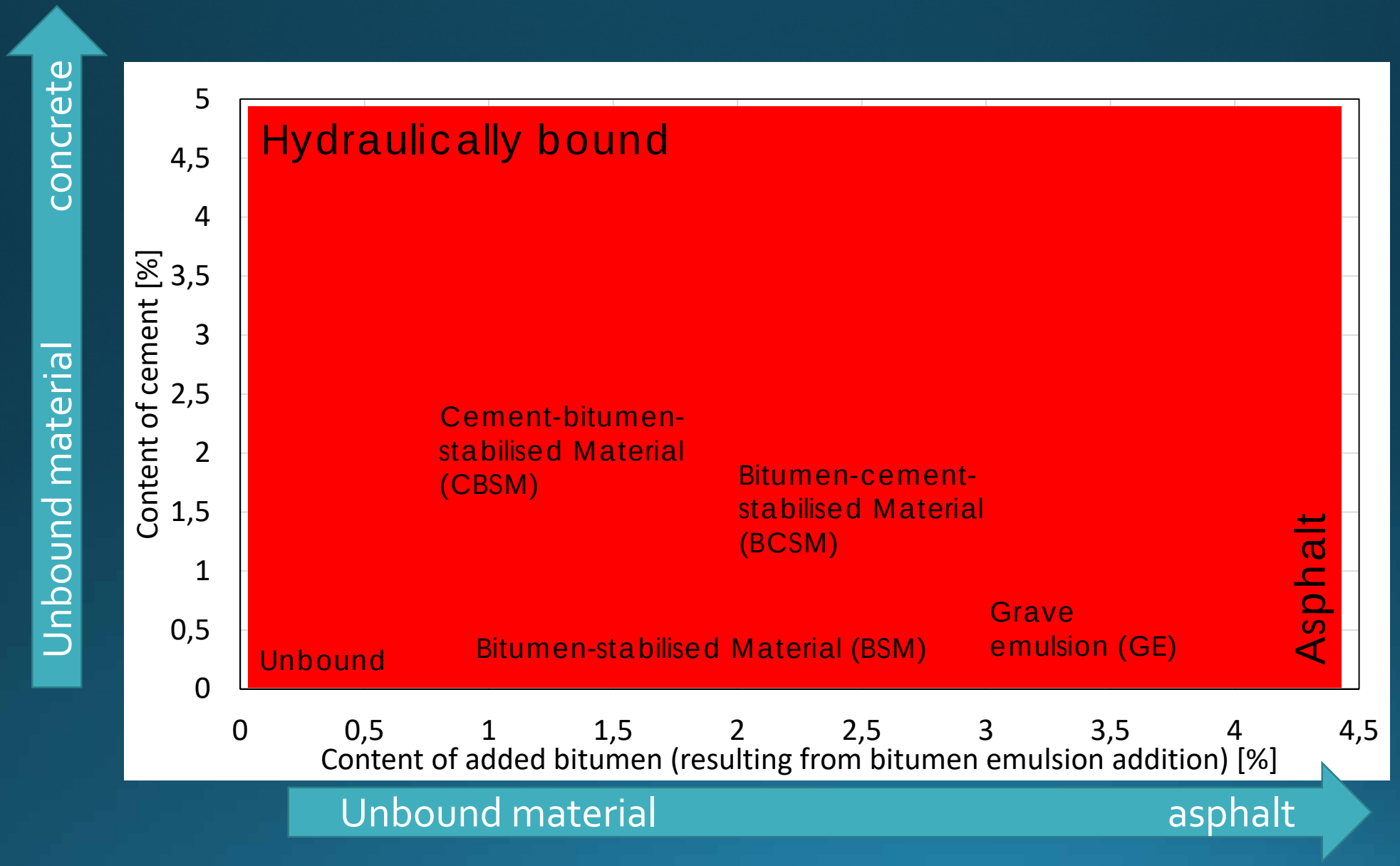
Range of CRM materials



Unbound material — concrete

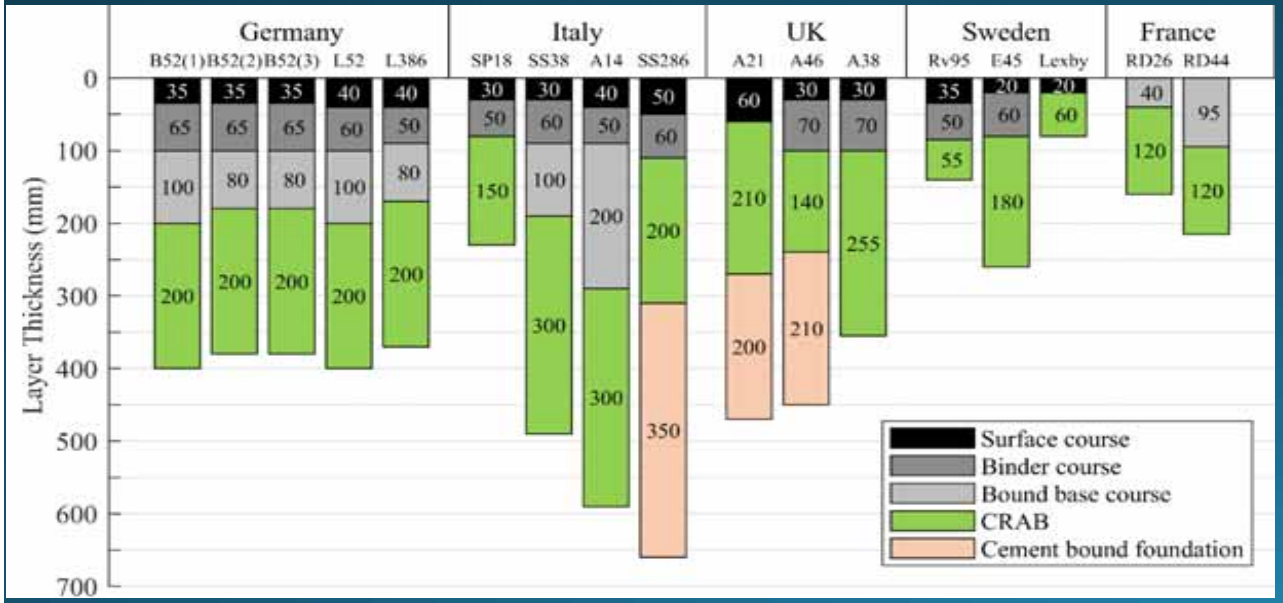
Unbound material — asphalt

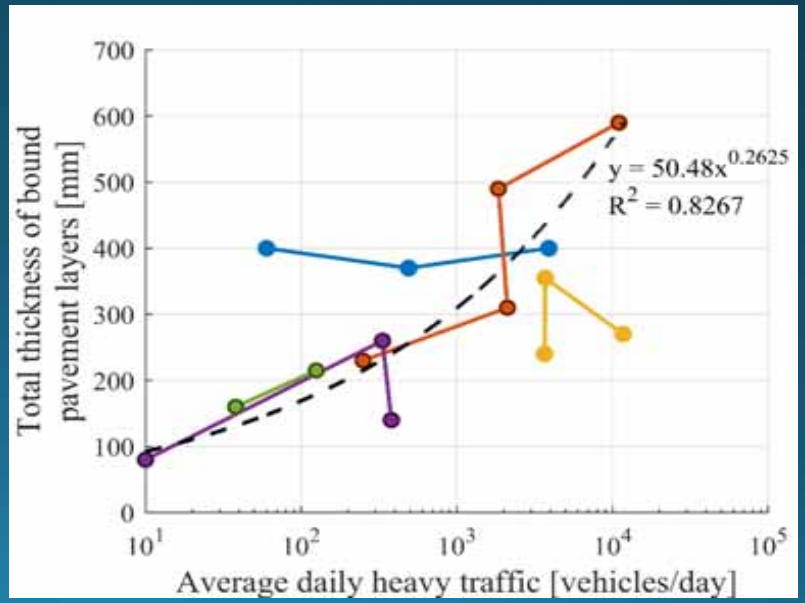
Range of CRM materials



Assessment of existing pavements with CRM bases

- 15 sections in Europe (FR, GE, IT, SE, UK) were assessed
- Evaluation of applied mix design, pavement design, traffic and climatic loading and surface condition
- Common pavement design results





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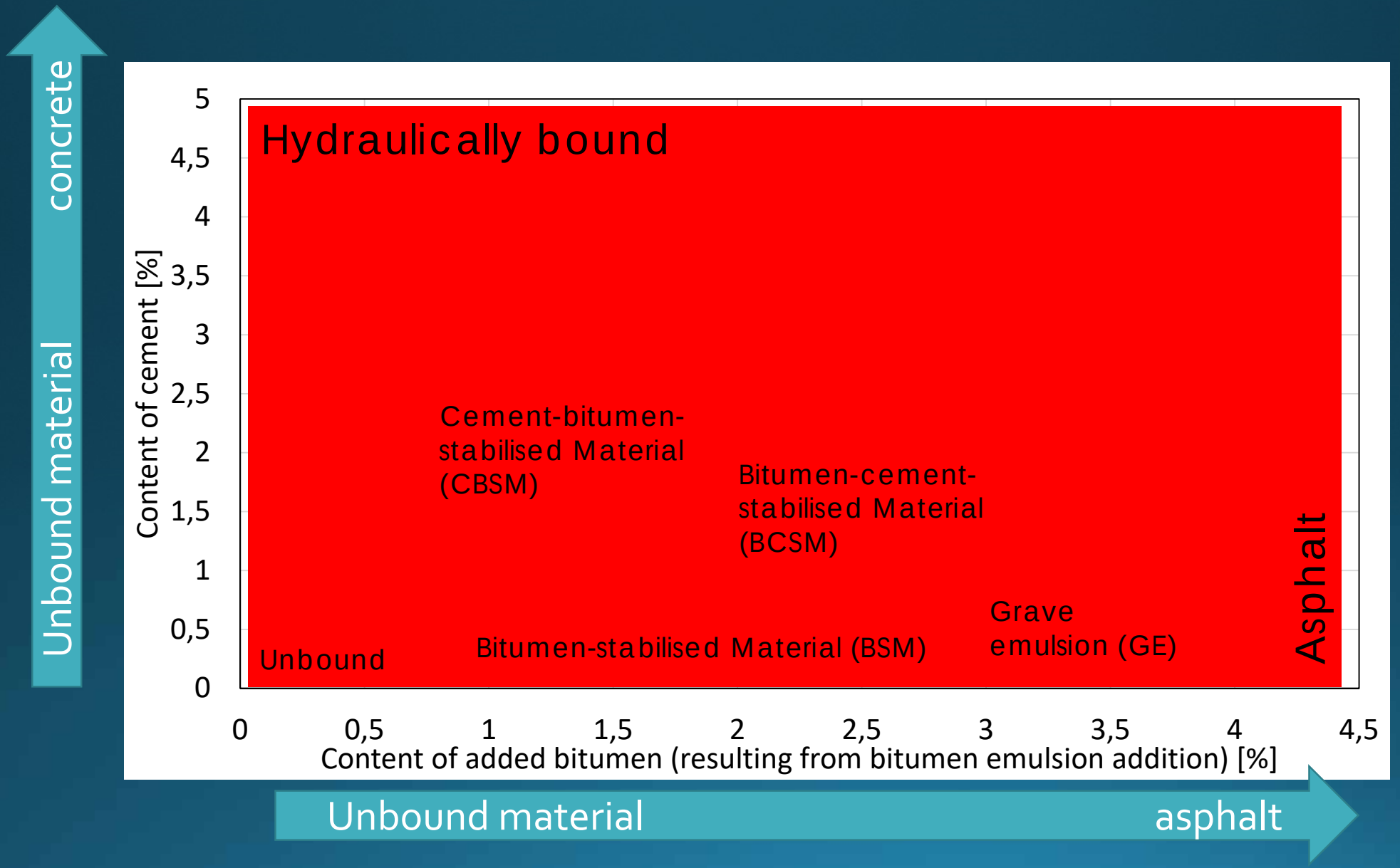
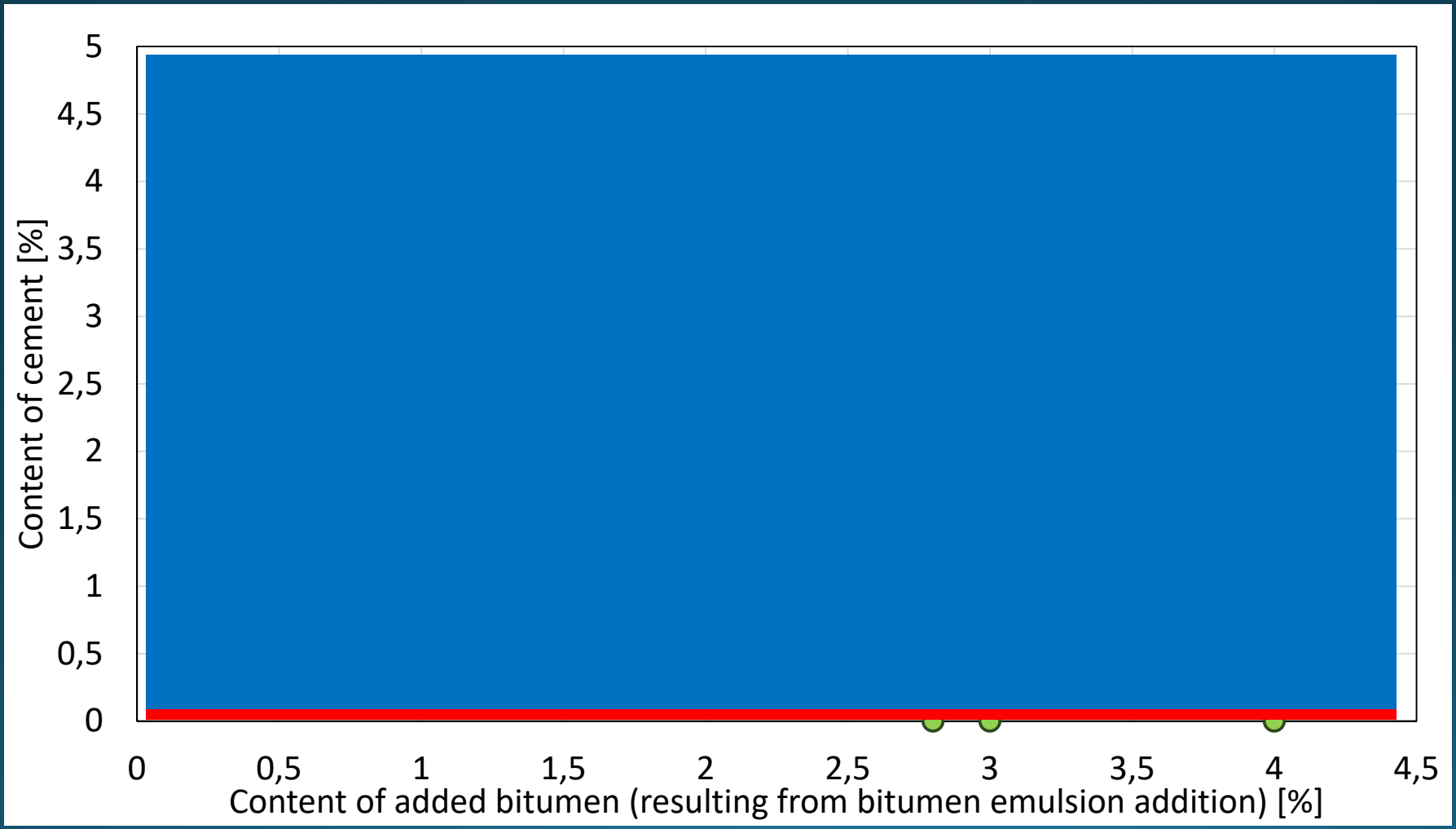


CRM materials in analysed pavements



Surface condition assessment

1,0 very good — 2,0 — 3,0 — 4,0 — 4,5 bad

Country	Section	Con-struction	Condition assessment	Daily heavy traffic	Mean quality value		95 % quality value (worst section)	
					rutting	cracking	rutting	cracking
GER			015	3900	1,9	1,0	2,2	1,2
GER			017	60	1,3	1,0	2,0	1,0
GER	L		017	365	1,5	1,4	1,8	3,5
SWE	Rv95	2014	2019	380	2,1	1,4	2,3	2,8
SWE			019	333	1,7	1,5	1,8	2,8
FR	R		019	125		1,2		2,1
FR	R		-	38				
ITA	SS38	2007	2019	1850		1,0		1,0
ITA	SS268	2016	2017	2115		1,0		1,0
ITA	S		019	250		2,7		4,5
ITA			019	11000		1,2		1,7
UK	A46	2006	2018	3664	1,6	1,4	1,6	1,8
UK	A21	2002	2018	11700	1,6	1,0	2,0	1,0

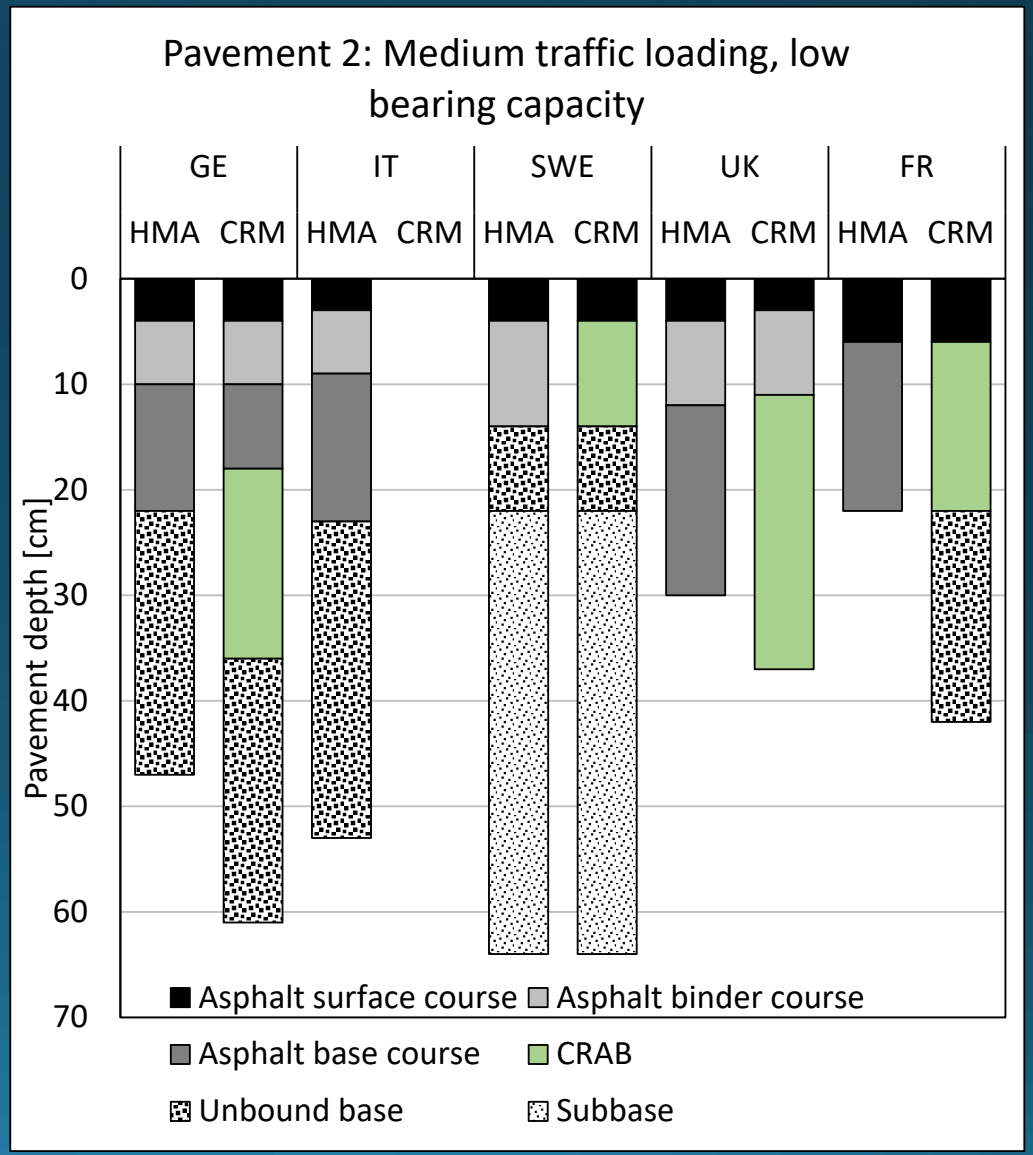
Pavements with high traffic loading show good condition

Pavement showed shrinkage cracking (in early life)

Designed for provisionally use

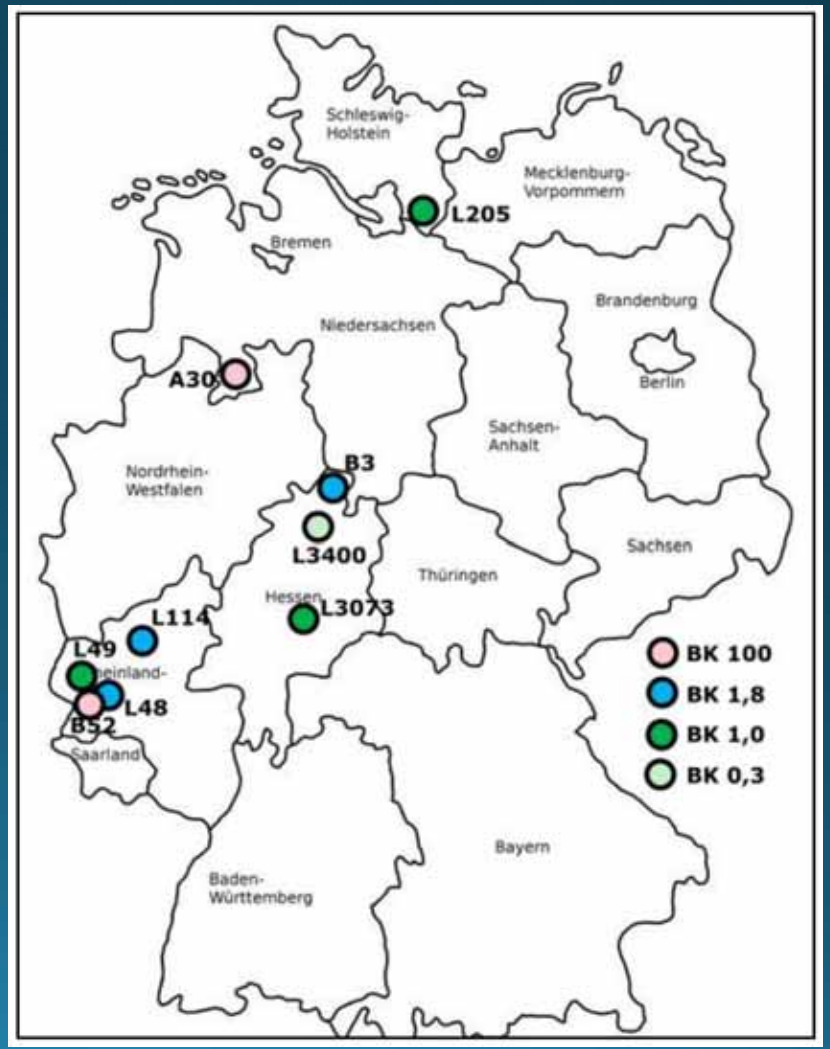
Assessment of national pavement design procedures for CRM and HMA

- Translation of national pavement design procedures in english
- Application for low and medium trafficked „model“ pavements
- When CRM is applied, thickness surplus for base layer thickness is observed
- Surplus ranges between **1,0 (SE, FR) via ~1,3 (IT, UK) to ~1,8 (GE)**

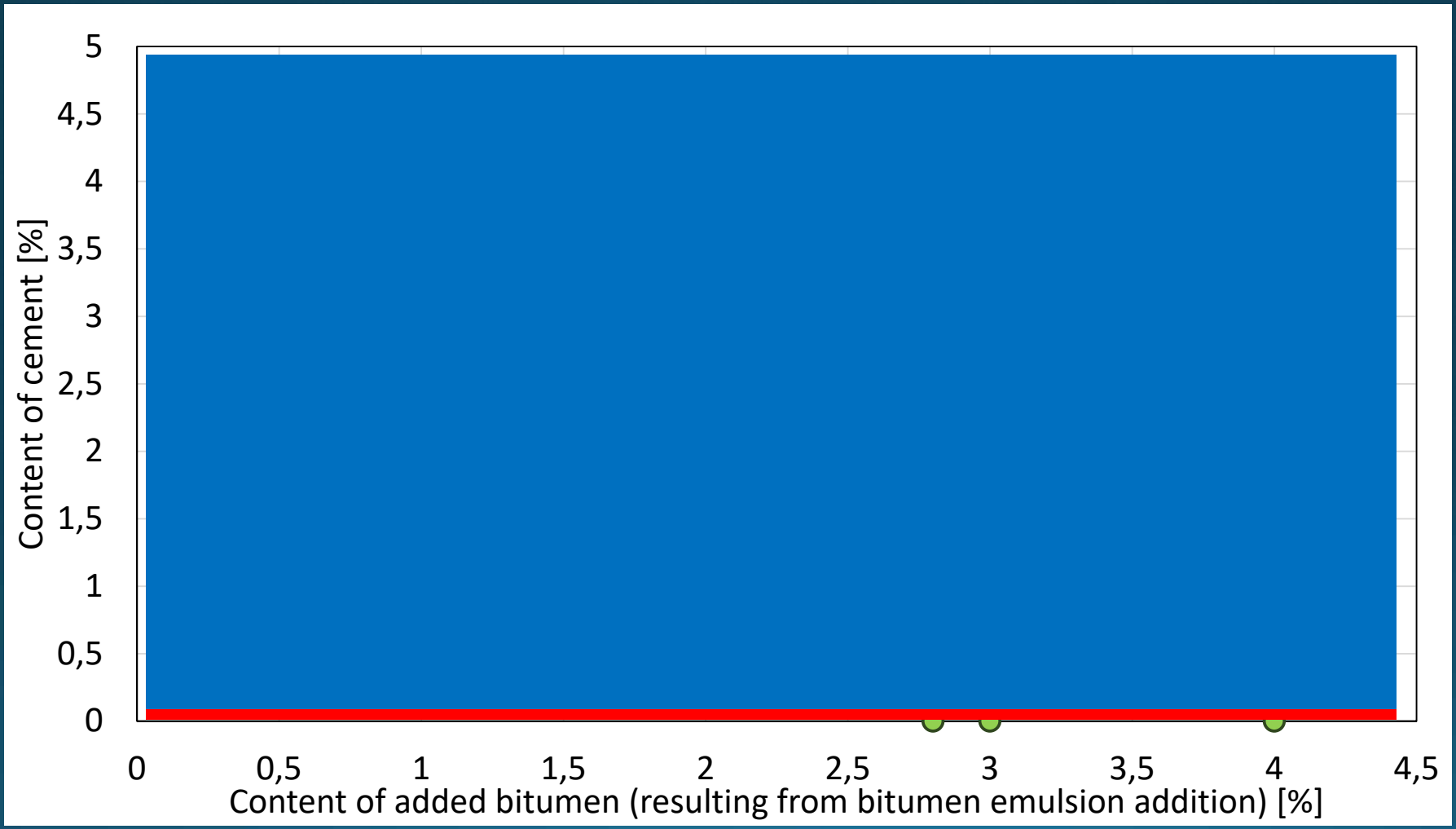


Assessment of mechanical properties of CRM bases

- 10 sections including CRM base layer
  - Low - high traffic
  - Age between 5 and 17 years
  - Different bitumen-cement ratio
- Coring samples and laboratory-prepared specimens
- Stiffness modulus tests
- Fatigue tests
- Application of mechanistic-empirical pavement design



CRM materials in analysed pavements



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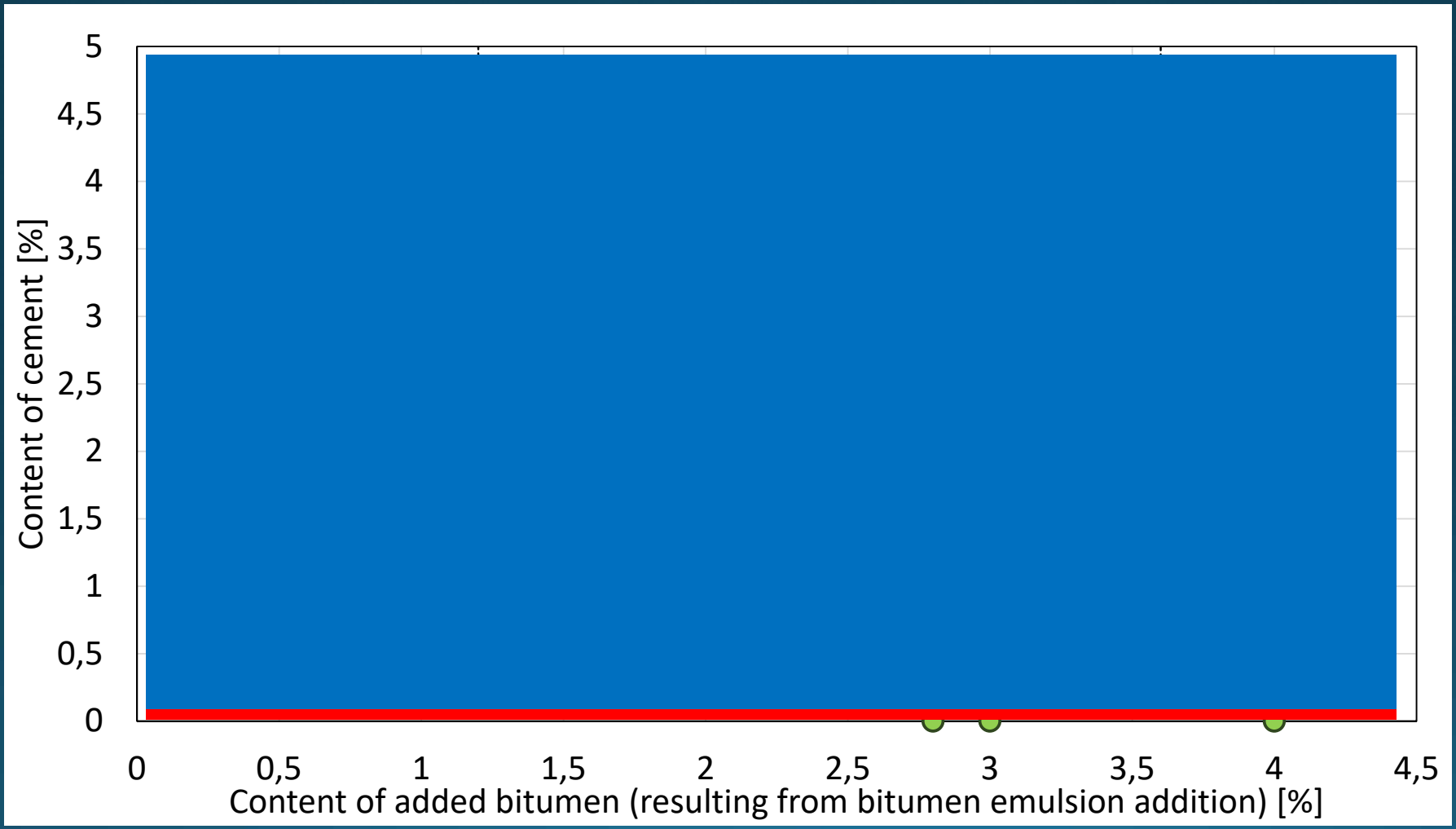
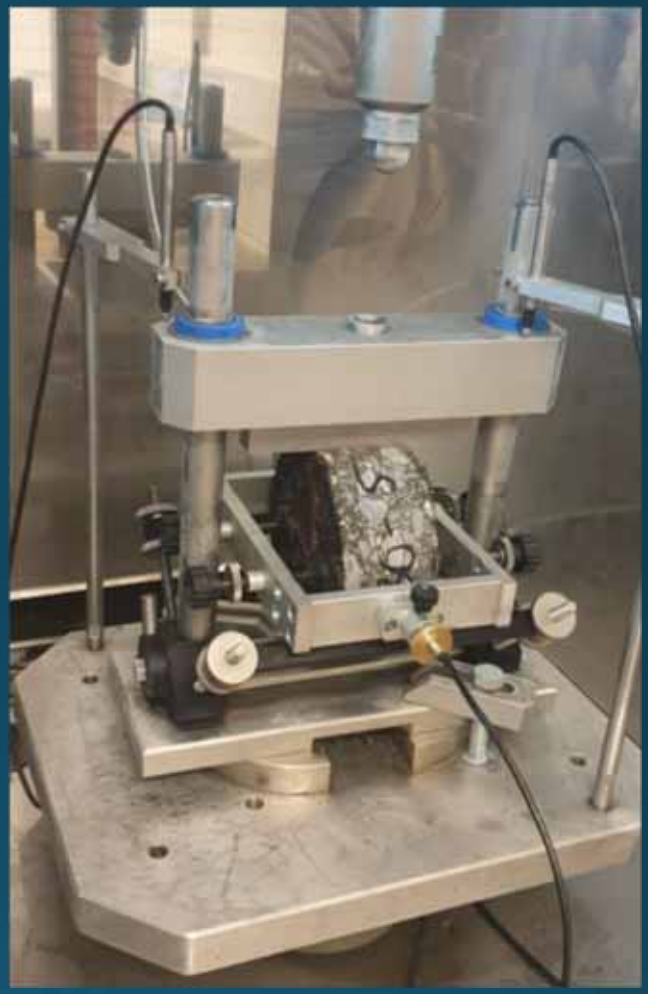
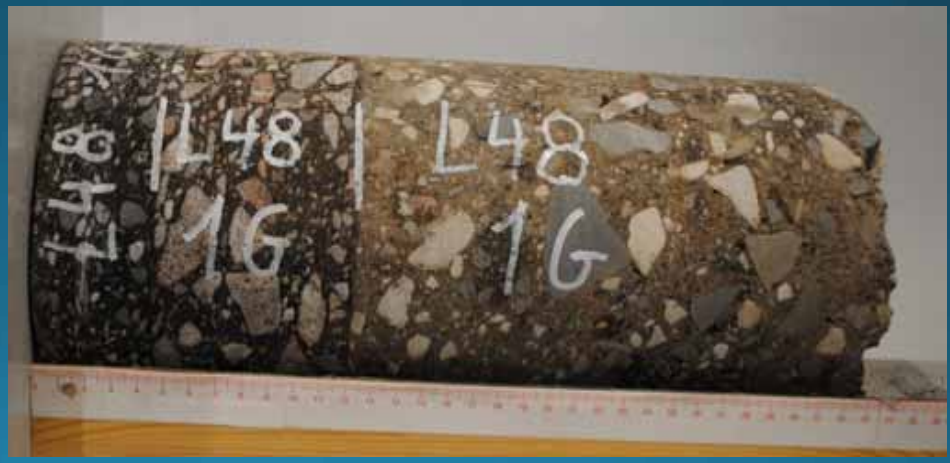


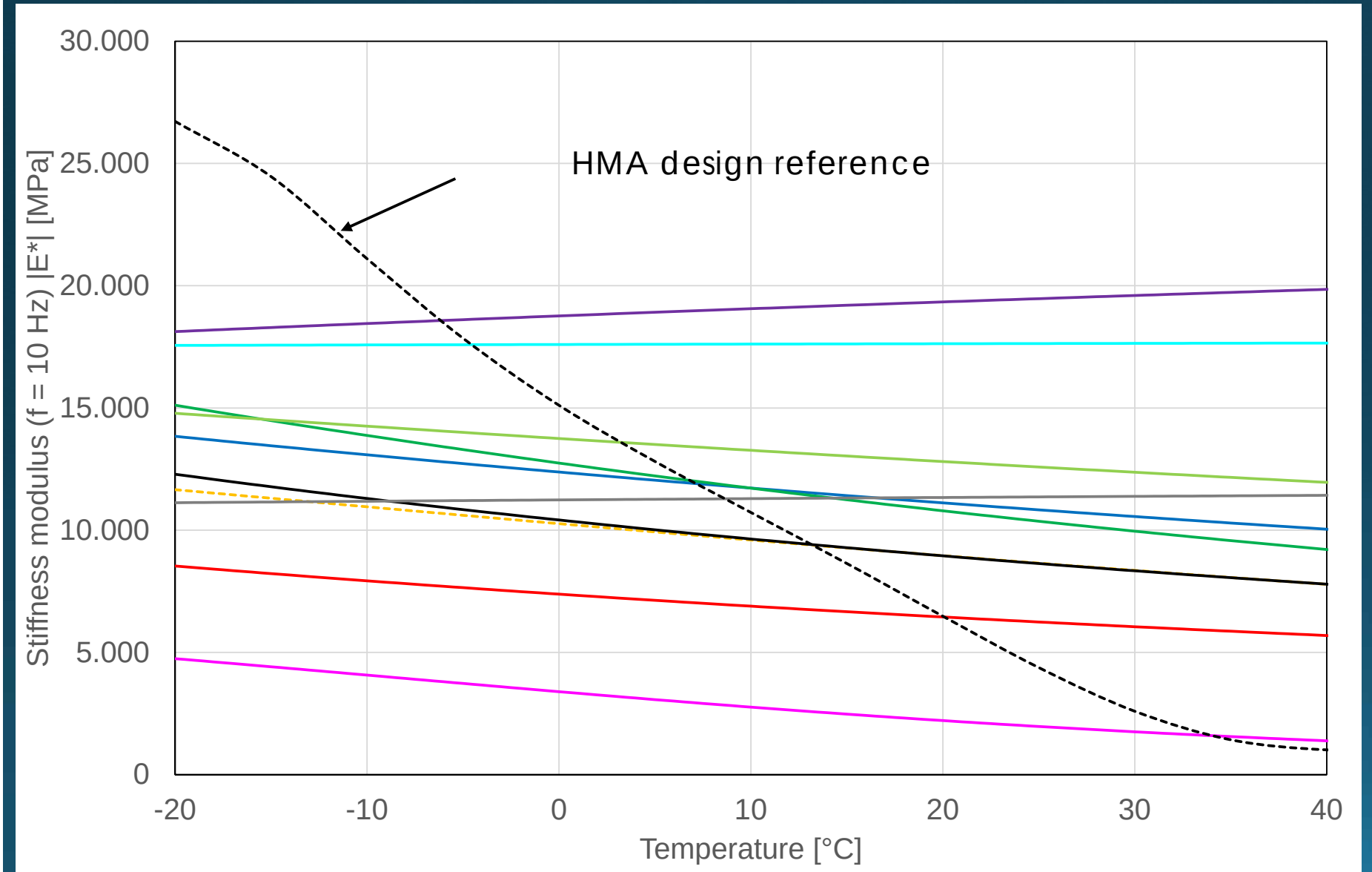
Evaluation of core samples

- Cyclix Indirect Tensile Stress tests (CIDT):
- Stiffness tests (EN 12697-26)
- Fatigue tests (EN 12697-24)

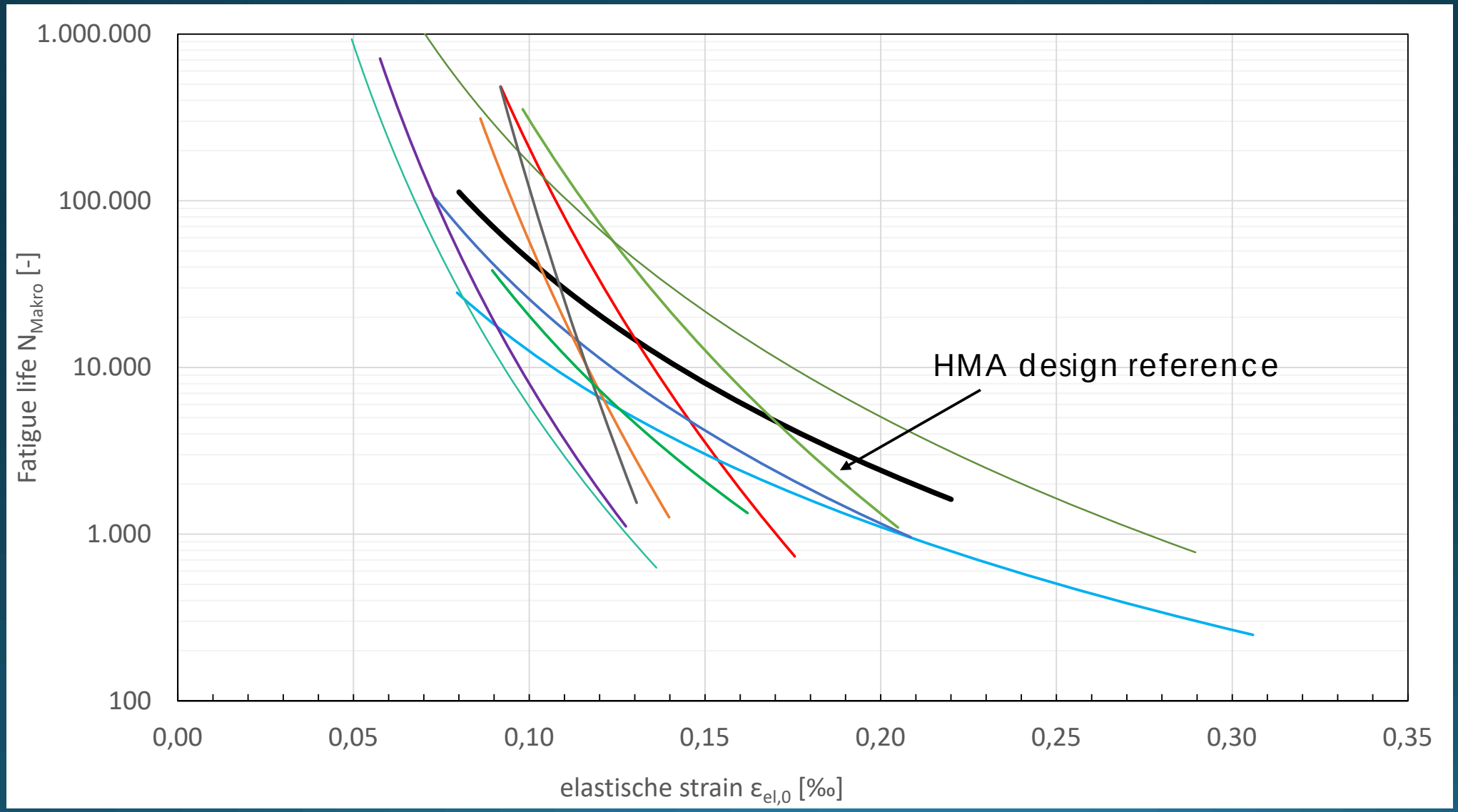




Stiffness modulus (cored samples)

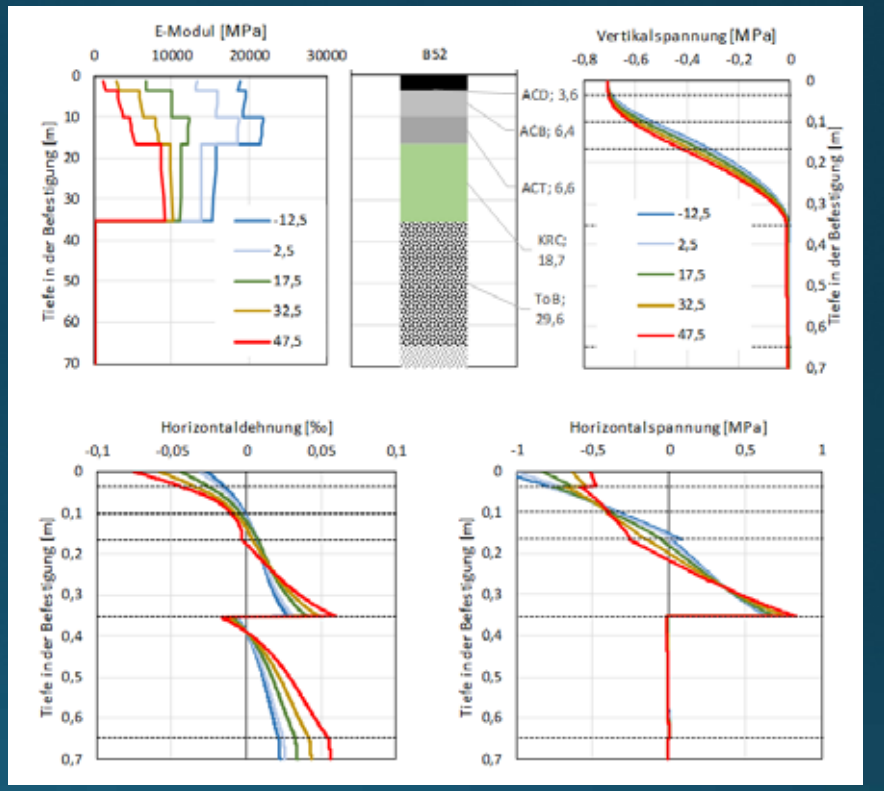


Fatigue performance (cored samples)

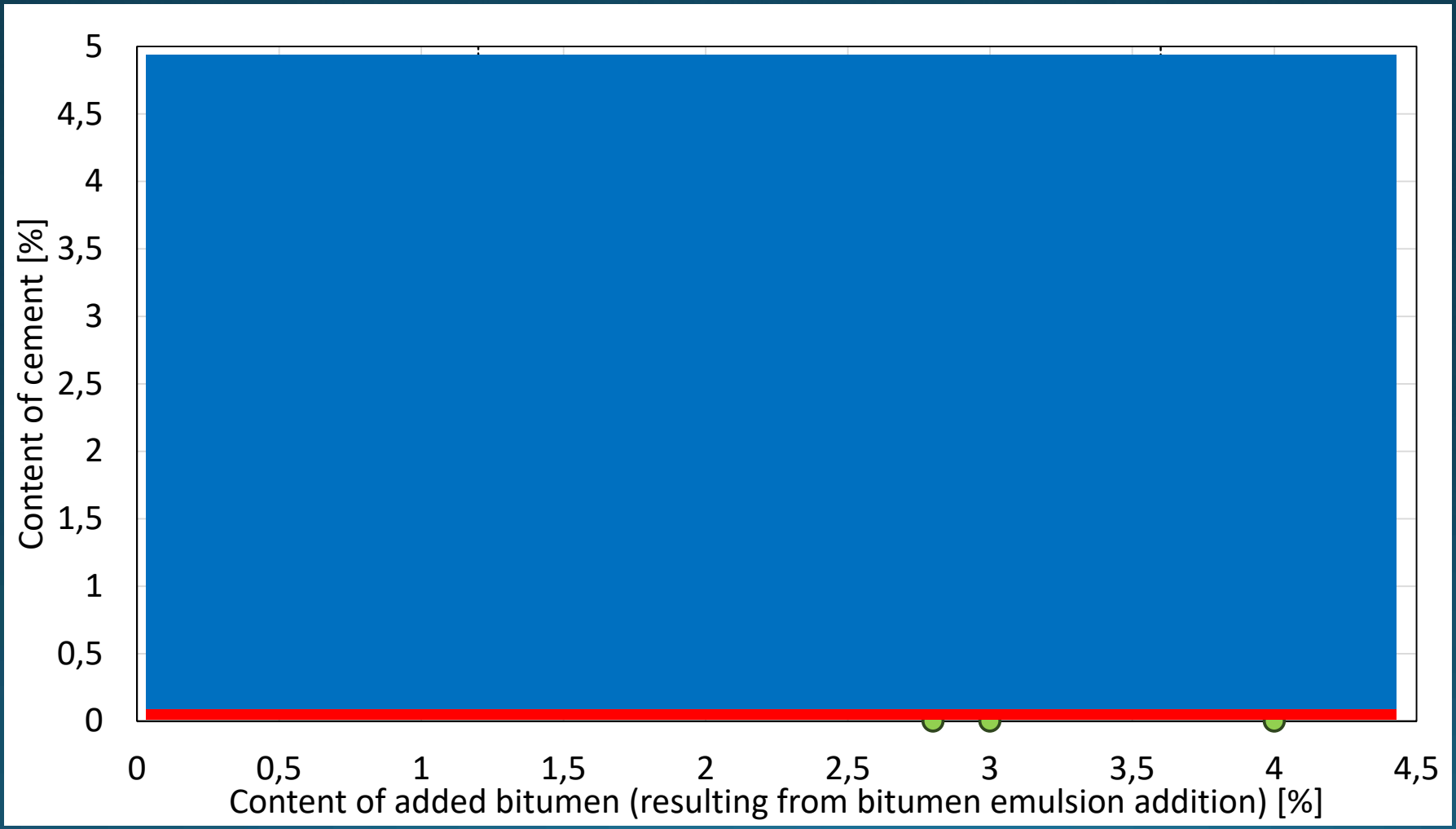


Results of back-calculated MEPD

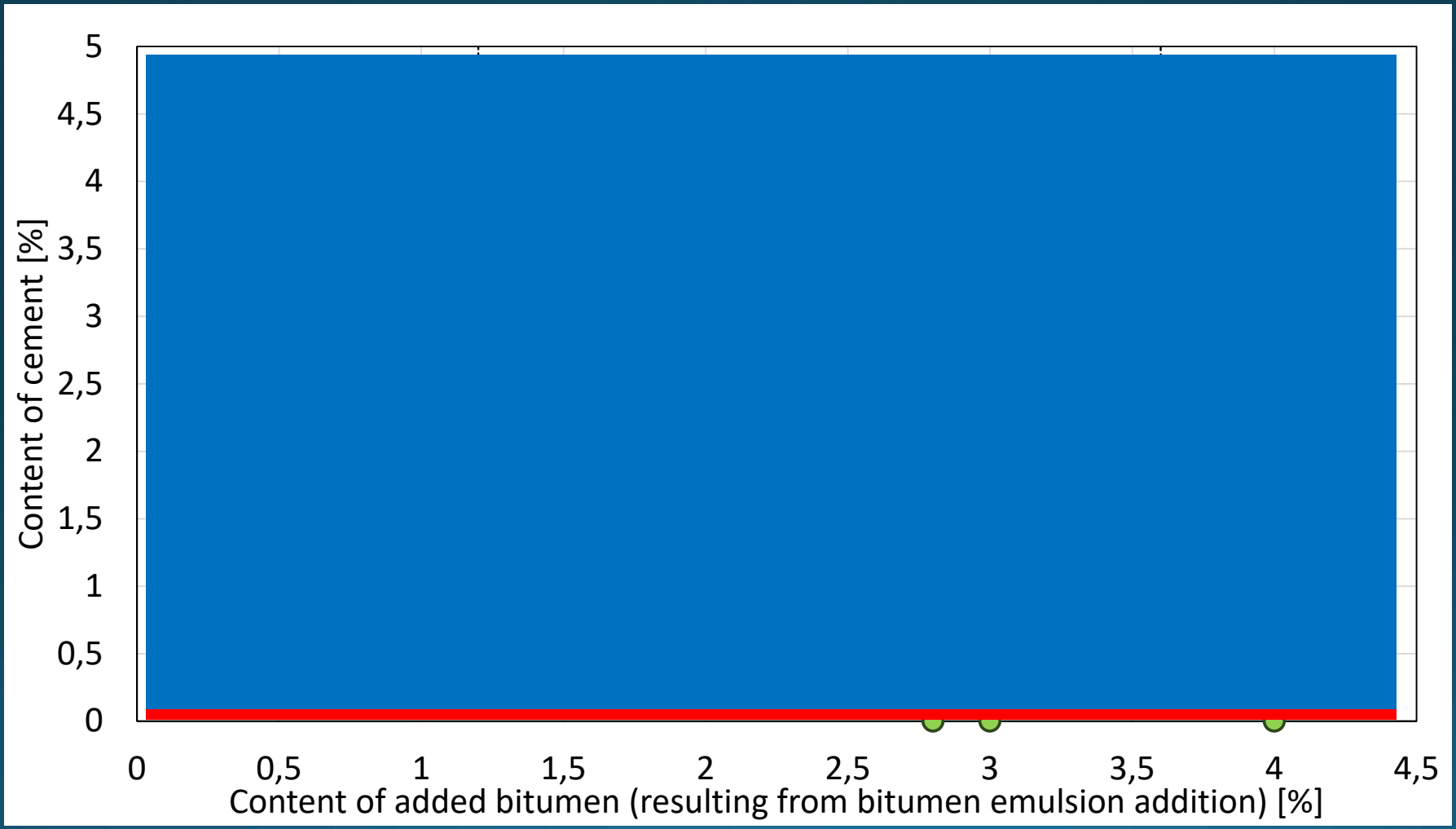
Section	ADT Kfz/d] (% HV)	Thickness [cm]		Condition value (1…5)		FWD	MEPD result [%]
		CRM	HMA	Eveness	cracks	Tz	
1	50.000 (21 %)	25	29	1,8	2,3	4,5	**4,2**
2	50.000 (21 %)	25	31	1,9	2,9	3,1	**<<1**
3	26.000 (15 %)	20	18	1,8	1,0	4,9	**<<1**
4	4.176 (6,4%)	18	18	1,9	1,0	6,1	**1,9**
5	2.676 (24 %)	18	11,5			3,9	**<<1**
6	2.307 (7 %)	18	12	2,3	1,0	3,3	**<<1**
7	2.096 (10 %)	12	4				**541**
8	1.659 (5 %)	16	4	1,2	1,9	2,3	**<<1**
9	1.220 (2,9 %)	20	14	1,8	1,4	4,1	**<<1**
10	605 (2,5 %)	18	18	1,8	1,0	5,5	**<<1**



CRM materials in analysed pavements



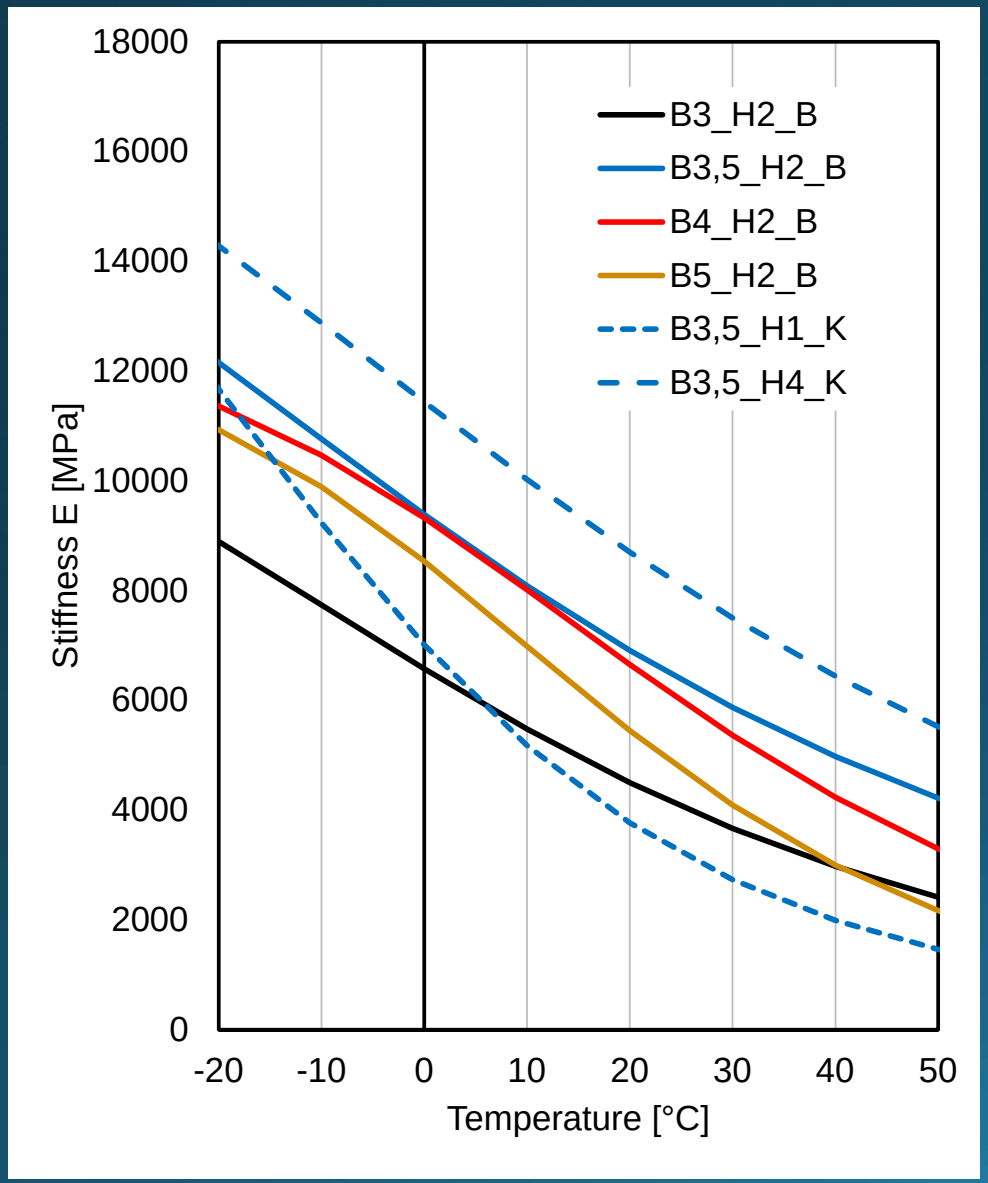
CRM materials, prepared in Laboratory

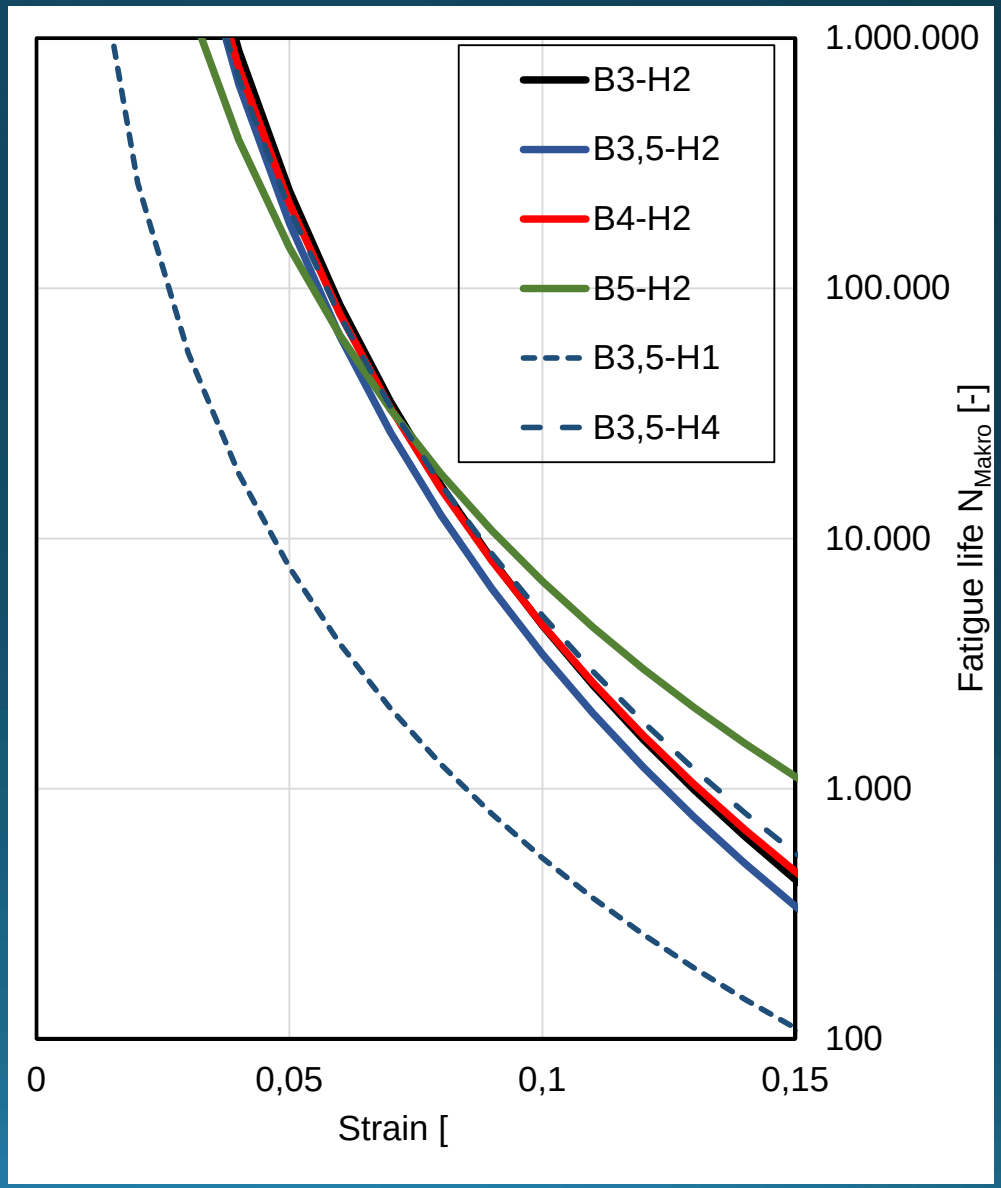


Laboratory-assessment of CRM performance

- Preparation of CRM mixtures with common bitumen emulsion and mix granulate with varied binder contents:
  - RA-content: 70 %
  - Bitumen emulsion: **3,5 %** *(resulting added bitumen): 2,1* **%**
  - Hydraulic road binder: **2,0 %** and 4,0 %
- Compaction of slab specimens and coring of cylindrical specimens
- Curing (20 °C, 50 % r.h., 28 and 180 days)
- Stiffness and fatigue testing
- Application of MEPD

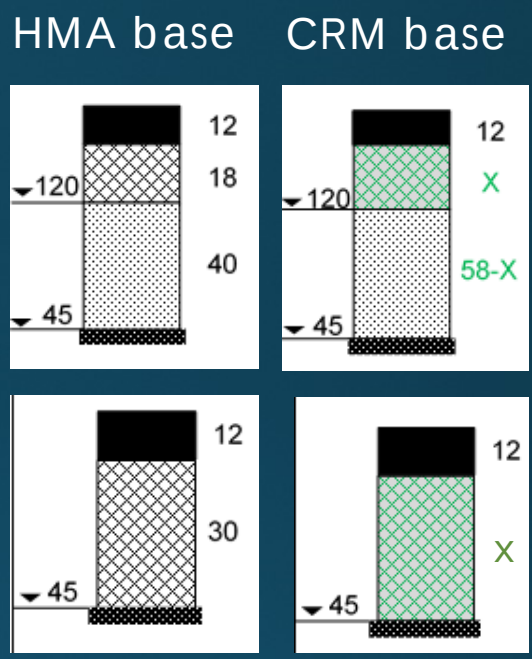
Stiffness and Fatigue characteristics of CRM samples





Proposed Pavement design for CRM

- Results of CRABforOERE-Project:
  - Pavements with CRM bases have similar durability properties as „pure" HMA bases
  - Empirical pavement designs result in **design thickness factor of 1,5** in maximum
- Results of FE 04.0239:
  - CRM layers with low cement content show asphalt-like behaviour, however less temperature-dependency than HMA
  - Whem HMA-MEPDG is applied on CRM pavements, **design thickness factor of between 1,14 and 1,6** is derived



Base layer thickness x [cm] for HMA and **CRM**

ADT (heavy veh.)	900	90	30	5
with sub-base	18 23 +28 %	14 19 +38 %	12 17 +44 %	10 16 +60 %
without sub-base	30 34 +14 %	26 30 +17 %	26 30 +17 %	22 26 +19 %

Life-cycle assessment (Cradle-to-gate) CRM vs. HMA

- Comparison of applied CRAB pavement with „standard" HMA pavement for 2 road sections

Germany, 2006

Standard: HMA (base layer)
- 96,5 % aggregates
- 3,5 % bitumen

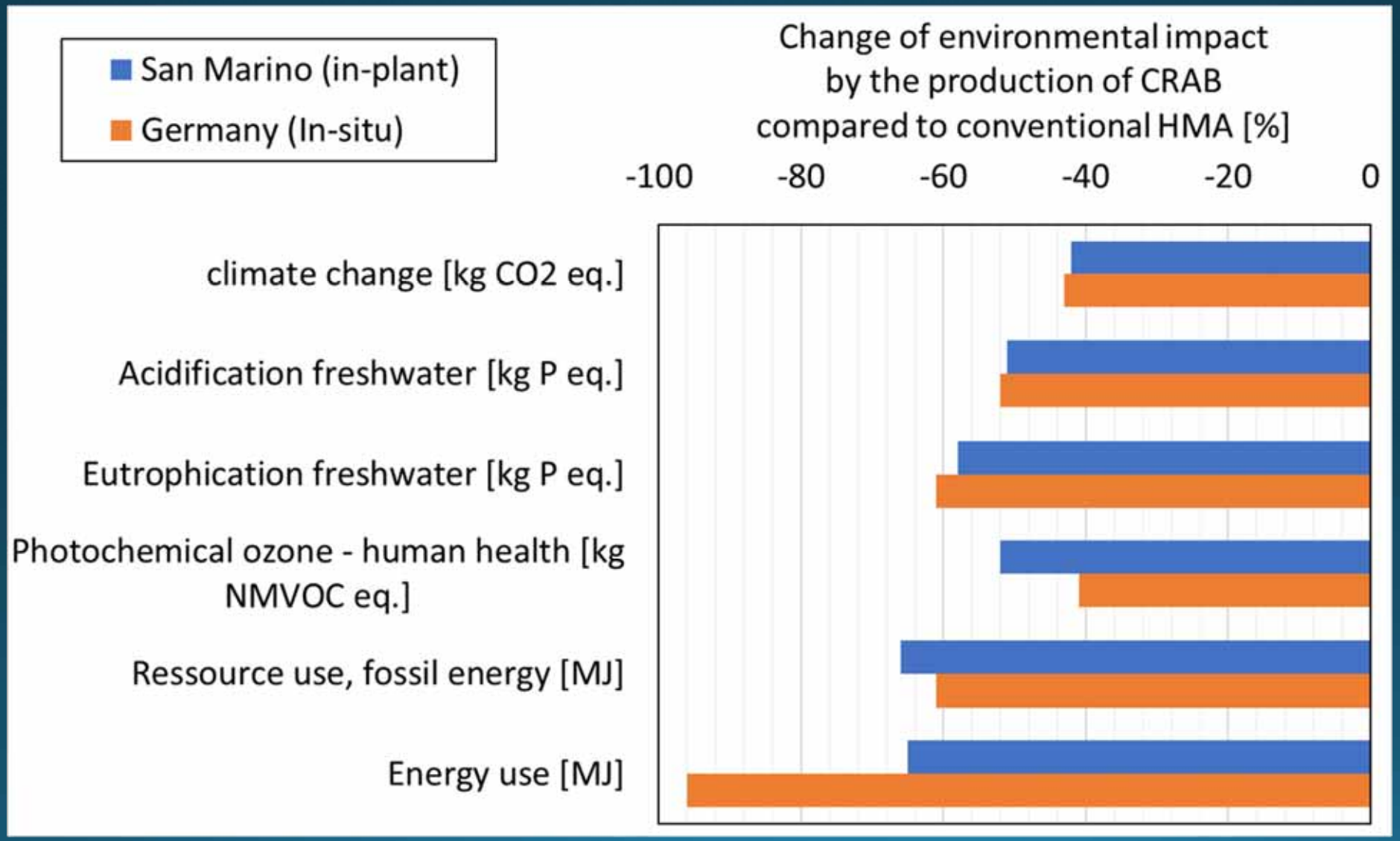
CRM:
- 92 % Reclaimed Asphalt
- 4 % bitumen (emulsion)
- 4 % cement

San Marino, 2020

Standard: HMA (base layer)
- 94,5 % aggregates
- 5,5 % bitumen

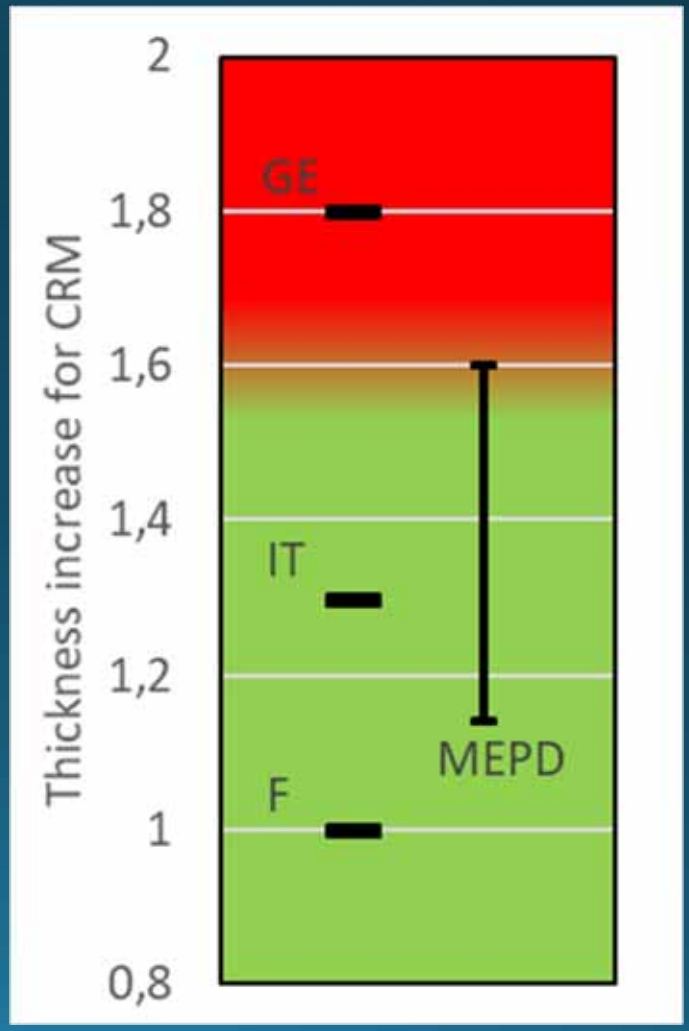
CRM:
- 88,8 % Reclaimed Asphalt
- 5 % aggregates
- 4,5 % bitumen (emulsion)
- 2 % cement

Change in environmental impact by using CRM instead of HMA base layer



Combining CO_2-reduction to pavement design

- Compared to HMA production, CRM inhibits less than 60 % of CO_2eq.
- However, pavement designs indicate, that higher layer thickness is required and results in more material consumption
- Resulting LC-benefit by using CRM will be reached, when thickness surplus is less than +67 % (Thickness factor less than **1,6**)
- Pavement designs indicate, that lower thickness surplus is required



Thank you very much for your Attention!

Acknowledgements

- CRABforOERE-Team:
  Marius Winter, Davide Lo Presti, Gaspare Giancontieri, Henrik Bjurström, Björn Kalman, Vincent Gaudefroy, Pierre Hornych, Andrea Graziani, Chiara Mignini, Gabriella Buttitta, Konstantinos Mantalovas
- FE 07.0239-Team:
  Marius Winter, Martin Radenberg, Matthias Staschkiewicz, Ludger Vienenkötter

The presented results are based on research results funded by CEDR and German Federal Ministry of Transportation