UNIKASSEL
VERSITÄT

EARN – Effects on Availability of Road Network

EARN background data

Sachgebiet Bau und Erhaltung von Verkehrswegen
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CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Service lifetime and availability of road materials and structures

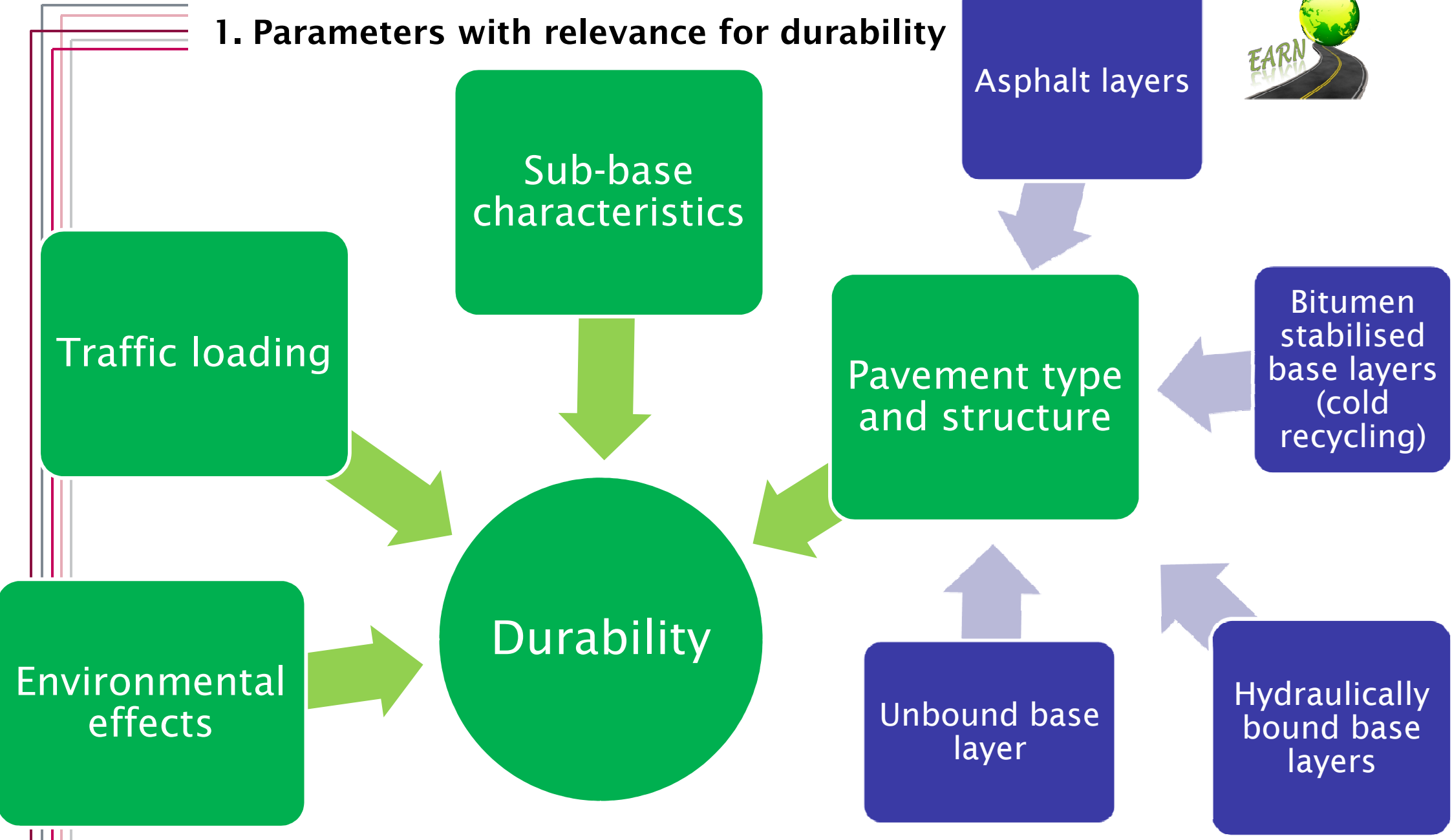
- **LCA study conducted during Re-Road:**
  - Durability has same effect as high recycling rate
  - Benefits of recycling can be reverted in case of reduced durability

- **Objectives and promised results: Empirical evaluation of effects on pavements durability**
  - Effect of high proportions of reclaimed road materials
  - Road works conditions (weather, season, day/night)
  - Materials with high contents of reclaimed and secondary materials
  - Warm-mix asphalt
  - Working time and availability effects of road maintenance

Methodology

1. **Synthesis of relevant parameters affecting pavements durability**
2. **Review of existing service lifetime estimations**
3. **Identification and analysis of databases for empirical assessment of durability effects of:**
   - RA use and
   - Construction work conditions

1. Parameters with relevance for durability



durability

Asphalt layers

- Type of mixture
- Aggregate grading
- Binder type
- Binder content
- Volumetric properties
- Additives
- RA quality and content
- Construction conditions
- Performance properties

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Pavement type and structure
- Flexible or rigid
- Number of layers
- Layer thicknesses
- Interlayer bonding

Bitumen stabilised base layers (cold recycling)
- … (see CoRePaSol project)

Environmental effects
- Temperature
- Sun exposure
- Humidity
- Frost-thaw cycles
- High-depth frosting

Durability

Unbound base layer
- Composition (grading, type of aggregates)
- Degree of compaction
- Moisture
- Bearing capacity

Hydraulically bound base layers
- Grading of aggregates
- Binder type
- Binder content
- Void content
- Stiffness
- Strength
- Construction conditions

…. Additives, e. g. for warm mix asphalt

Table 4. Summary of Warm and Half-Warm Systems (after D'Angelo et al. 2008; Zaumanis, 2010, Bonaquist, 2011 Rubio et al., 2012; Nicholls and James, 2012; Lewis et al., undated)

Product	Company	Description	Dosage of additive	Country used	Production Temperature or reduction ranges	Website
Zeolite additives						
Advera	PQ Corporation	Water containing Zeolite	0.25 % of mixture by mass	USA	(10-30) °C	www.pqcorp.com/products/AdveraWMA.asp
Aspha-Min	Eurovia and MHI	Water containing Zeolite	0.3 % of mixture by mass	Worldwide including France, Germany and USA	(20-30) °C	www.eurovia.fr/en/produit/135.aspx?print=y
Organic (Wax) additives						
Asphaltan A Romonta N	Romonta GmbH	Montan wax for mastic asphalt	(1.5-2.0) % of bitumen by mass	Germany	20 °C	www.romonta.de/ie4/english/romonta/i_wachse.htm
Asphaltan B		Refined Montan wax with fatty acid amide for rolled asphalt	(2-4) % by mass	Germany	(20-30) °C	
Sasobit	Sasol	Fischer-Tropsch wax	(2.5-3.0) % of bitumen by mass in Germany; (1.0-1.5) % of bitumen by mass in USA	Worldwide including EU, RSA and USA	(20-30) °C	www.sasolwax.us.com/sasobit.html
Sasolwax Flex		Fischer-Tropsch wax plus polymer (choice of type)	Unspecified		At least 28 °C	www.sasolwax.com/More_about_Sasolwax_Flex.html

- **2 Zeolite additives**
- **4 Organic (wax) additives**
- **2 Fatty acid derivatives**
- **7 Chemical additives**
- **2 Other specified additives**
- **2 Emulsions**
- **14 Foamed bitumen technologies**
- **2 Other processes**

In total, 35 WMA variations with distinct approaches

… how to generalise their effect on durability?

1. Parameters with relevance for durability

Asphalt layers
- Type of mixture
- Aggregate grading
- Binder type
- Binder content
- Volumetric properties
- Additives
- RA quality and content
- Construction conditions
- Performance properties

Sub-base characteristics
- Bearing capacity
- Sub-base
- ...isture/drainage

Traffic l...
- Tyre/axl...
- Axle nu...
- Traffic ...
- Axle co...

...type and ...

Bitumen stabilised base layers (cold recycling)
- ... (see CoRePaSol project)

Interim result:
Pavement durability is affected by a high number of parameters
⇒ detailed analysis of **general** material-specific service lifetime from laboratory and modelling assessment is not possible

Environmental effects
- Temperature
- Sun exposure
- Humidity
- Frost-thaw cycles
- High-depth frosting

Durability

Unbound base layer
- Composition (grading, type of aggregates)
- Degree of compaction
- Moisture
- Bearing capacity

...lically base layers
- ...g of aggregates
- ... type
- Binder content
- Void content
- Stiffness
- Strength
- Construction conditions

2. Review of existing service lifetime estimations

- **Who else needs to know about the durability of pavements?**

- **Pavement Management Systems**
  - Require service life estimations
  - Apply performance prediction models
  - Widely applied data available
  - Standardised approaches

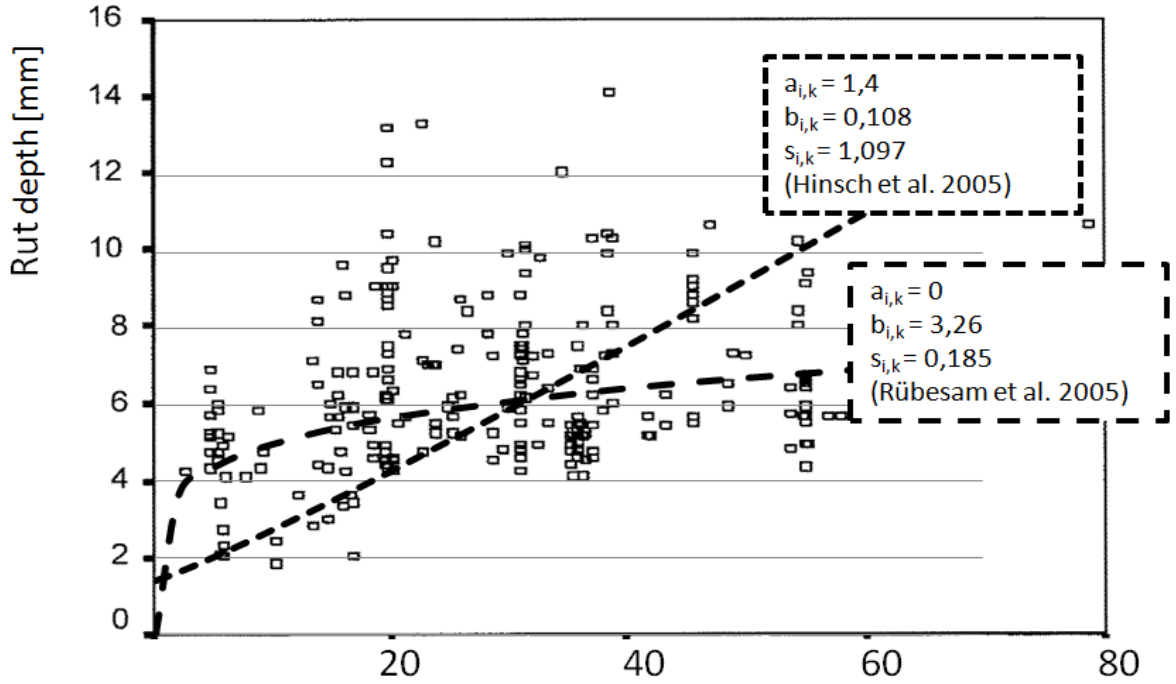
- **Network databases**

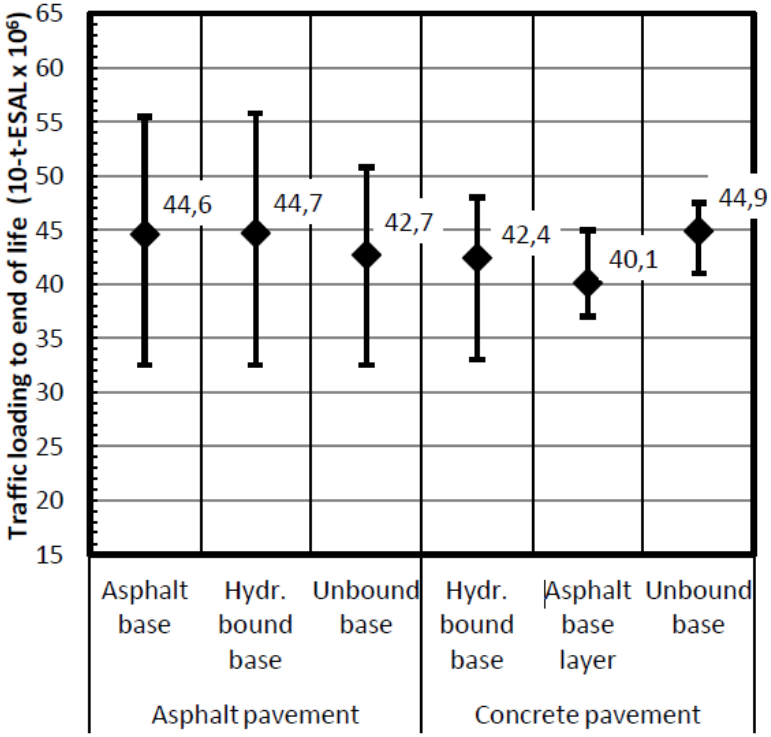
Life cycle assumptions in PMS

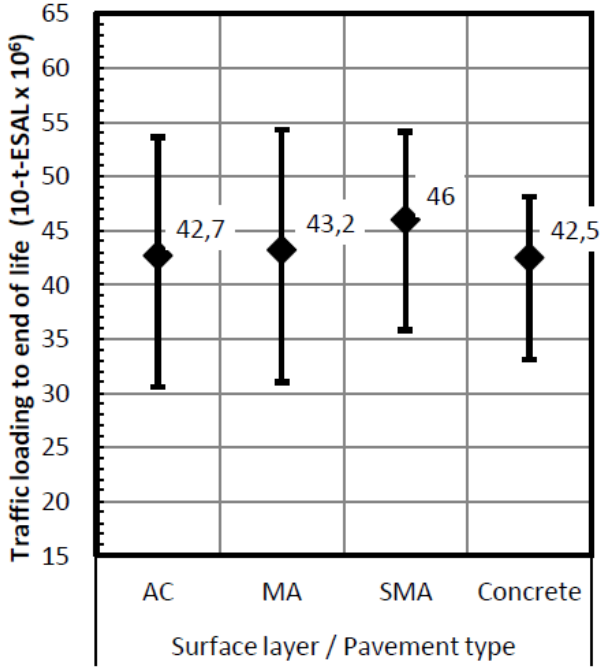
Road layer	Pavement material	Germany (FGSV, 2001)		Netherlands (IVON, 2012)		UK (SWEEP Pavements, 2013)	
		≥ 300 ESAL/day	< 300 ESAL/day	Right hand lane	Full width	surface life	structural life
Surface asphalt layers	Asphalt concrete (AC)	12	18	12	18	8	–
	Very thin layer asphalt concrete (BBTM)	–	–	–	–		
	Hot rolled asphalt (HRA)	–	–	–	–		
	Stone mastic asphalt (SMA)	16	22	11	17		
	Mastic asphalt (MA)	19	26	–	–		
	Porous asphalt (PA)	–	–	10	18		
Asphalt base layers	Asphalt concrete (binder layer)	26	30	–	–	–	20
	Asphalt concrete (base layer)	55	75	*	*		
	Other base layers						
	Hydraulically bound base layer	60	80	*	*		
	Unbound base layer	55	75	*	*		
Rigid pavement	Concrete surface layer	26	30	*	*	10	40
	Hydraulically bound base layer	55	70	*	*		
	Asphalt concrete base layer	50	65	*	*		
	Unbound base layer	45	60	*	*		
Maintenance materials	Slurry surfacing	6	8	–	–	8	–
	Micro-surfacing	5	8	–	–		
	Thin hot-mix asphalt layer on sealing	8	10	–	–		

PMS background data

- **High scatter in model trimming data**
  - Result of high number of parameters affecting the pavement performance & life
  - High risk for mistakes for individual road structures
  - Applicable only on network level





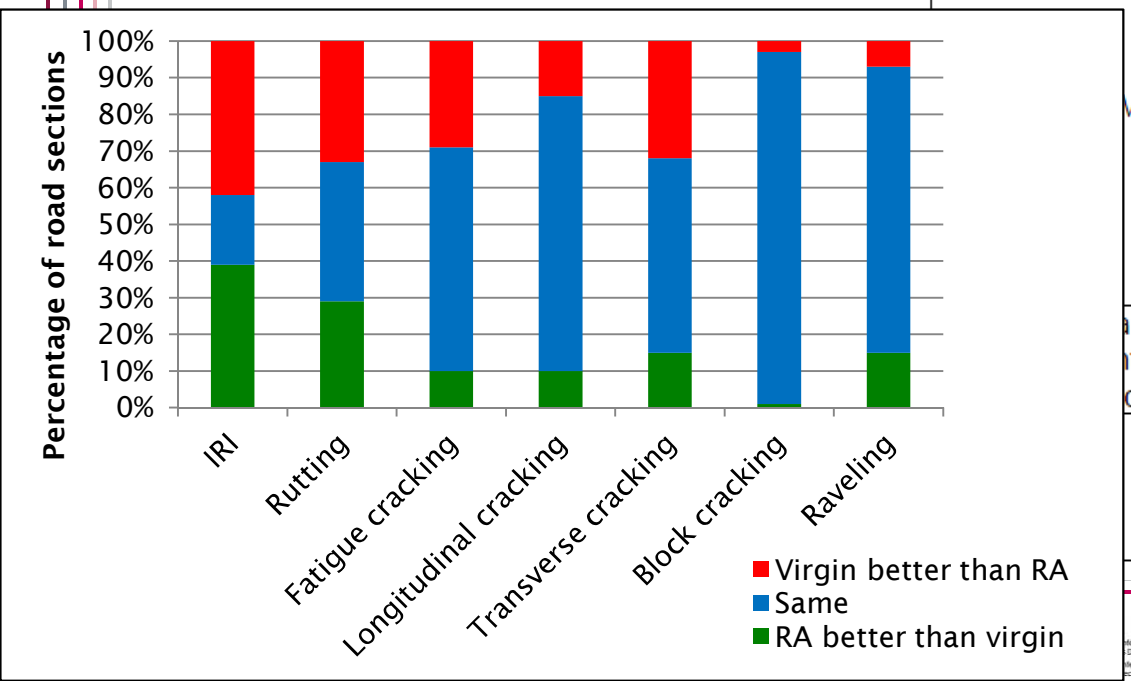


Available data on durability effect of RA

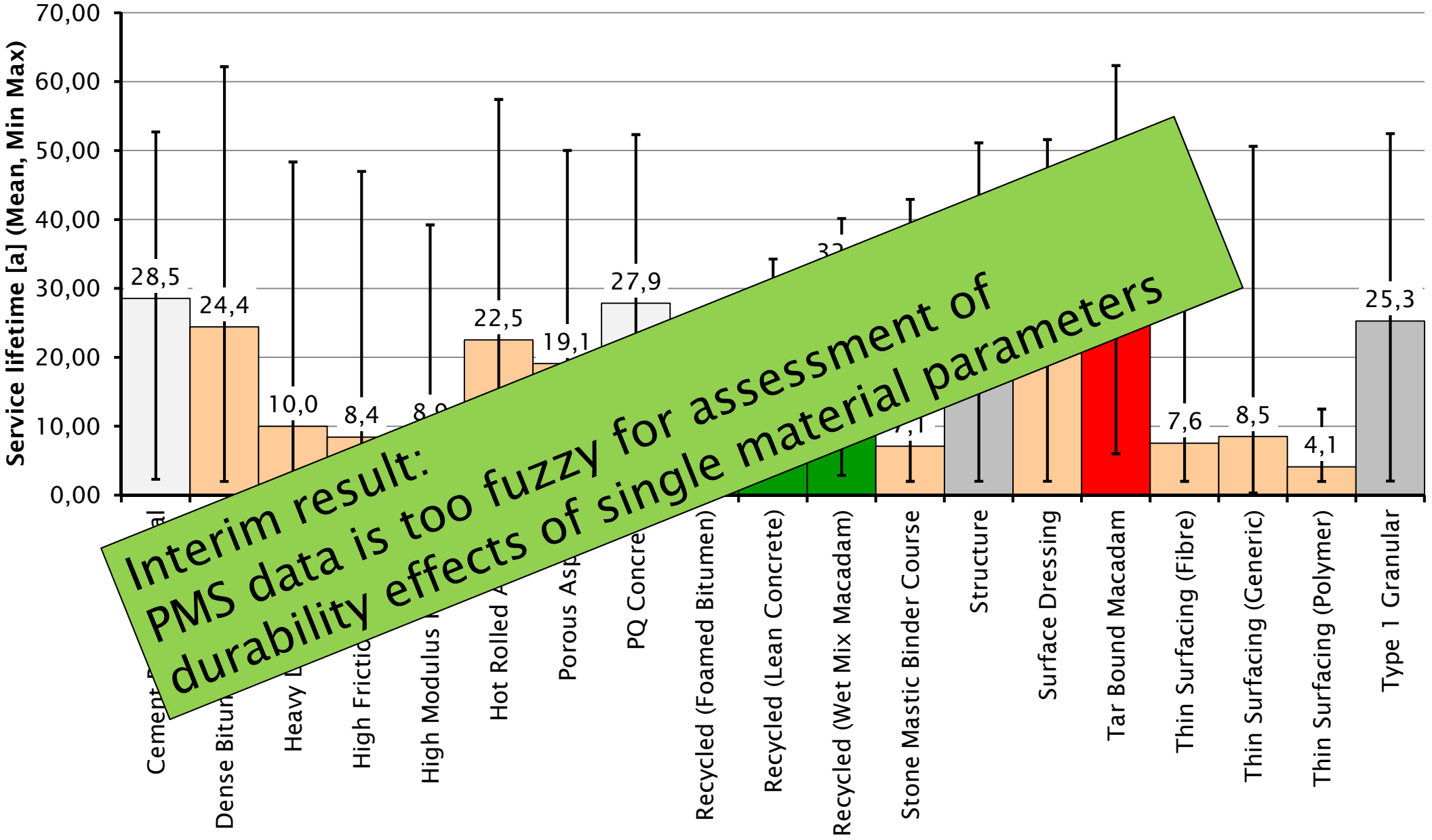
- **Direct-Mat project:**
  - Majority of laboratory and full-scale studies result in same or better performance when RA is applied
- **West *et al*. (2011):**
  - Cracking risk is higher for mixtures with RA

Mixture type		*HMA with x % RA has the same or better properties than comparable mix without RA*		*HMA with x % RA has worse properties than comparable mix without RA*	
		Laboratory study	*Full-Scale study*	*Laboratory study*	*Full-Scale study*
Surface course asphalt	AC	20%(DRF4.2) 40%(DRF4.6) 50%(DRF4.1)			
	SMA	20%(DRF4.162) 30%(DRF4.14) 30%(DRF4.51)		30%(DRF4.162)[3]	
	ACTL		30%(DRF4.229)		
Binder course asphalt	AC	25%(DRF4.2); 30%(DRF4.15); 30%(DRF4.155);		30%(DRF4.155)[1]	
Base course asphalt	AC	30%(DRF4.12); 15%(DRF4.154)			
	HRA				
	MA	30%(DRF4.222) 30%(DRF4.224) 35%(DRF4.160) 40%(DRF4.158) 45%(DRF4.159) 40%(DRF4.163) 50%(DRF4.225) 50%(DRF4.51) 70%(DRF4.181) 70%(DRF4.223) 100%(DRF4.228)	45%(DRF4.159)	30 % (DRF4.222)[3] 70%(DRF4.223)[3] 50%(DRF4.225)[4]	45%(DRF4.159)[2]
	lysis / t ce		(DRF4.161) 30%(DRF4.164) 20%(DRF4.165)		

[1] higher moisture sensitivity
[2] more cracking
[3] reduced fatigue resistance
[4] reduced rutting resistance



HAPMS database

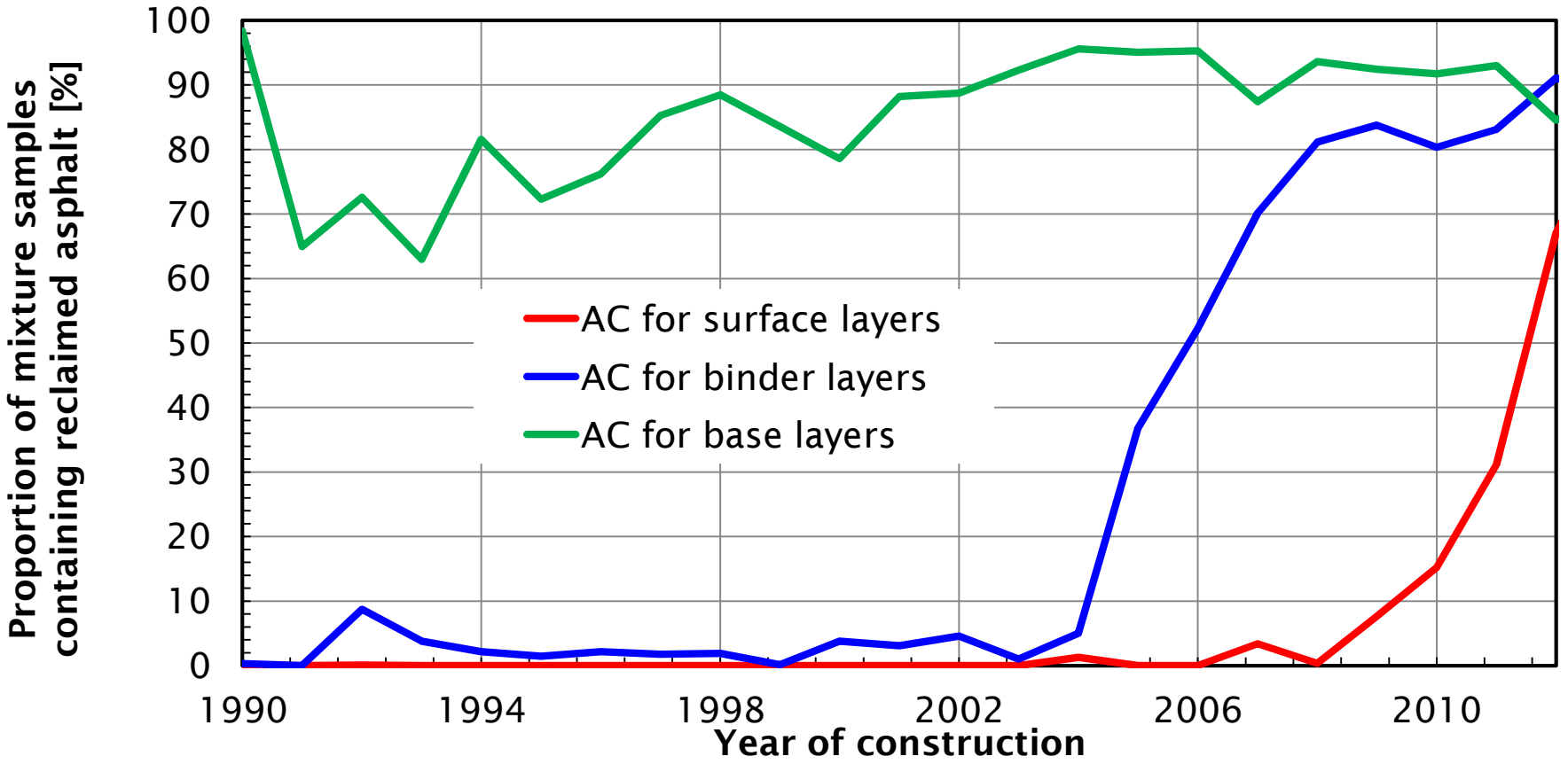


Asphalt mixtures and surface condition data in Lower Saxony

- **Asphalt mix database in Lower Saxony**
  - 80.000 asphalt mixture data from contractual compliance tests
  - Accurate binder properties, mix composition, binder content, type of aggregates, use of RA, …
  - Data implemented by test laboratories
  - Less accuracy regarding site location (manual localisation necessary for each dataset)
- Surface performance data
  - Input for PMS models
  - Regular assessment of surface properties
  - Directly linked to actual pavement location

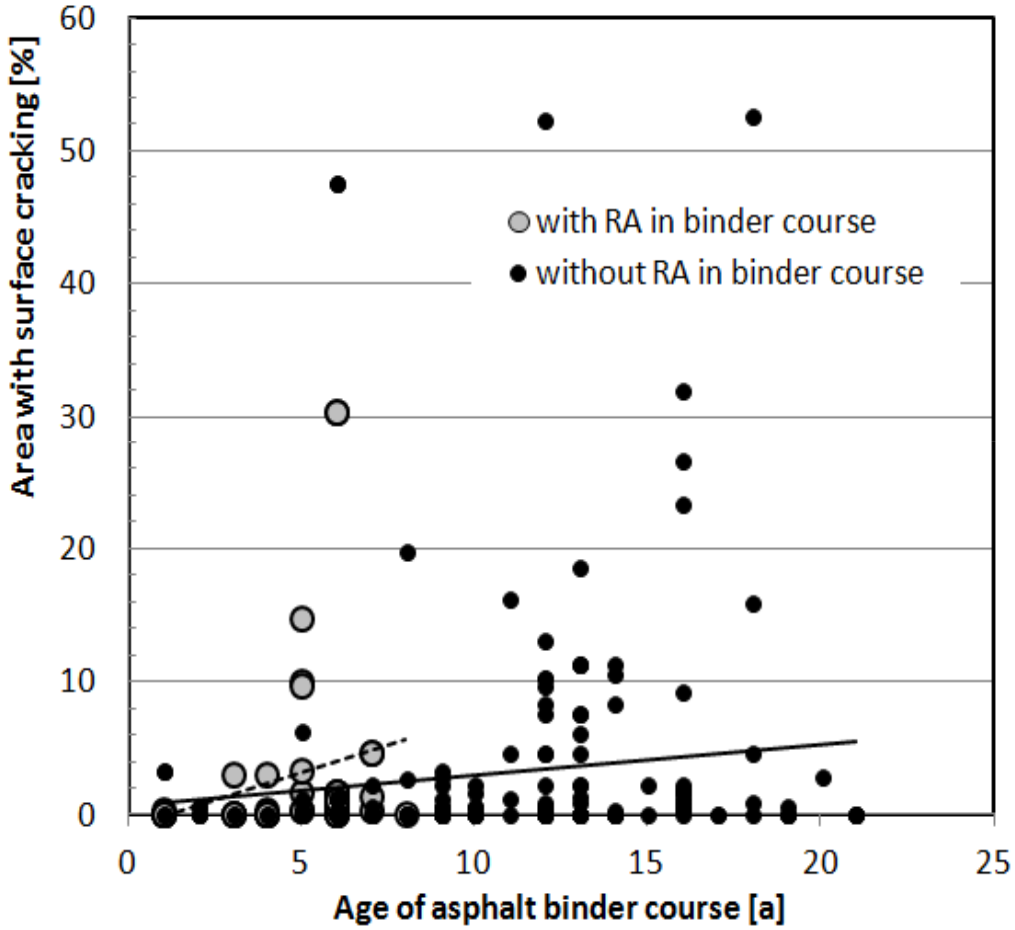
Niedersächsische Landesbehörde für Straßenbau und Verkehr

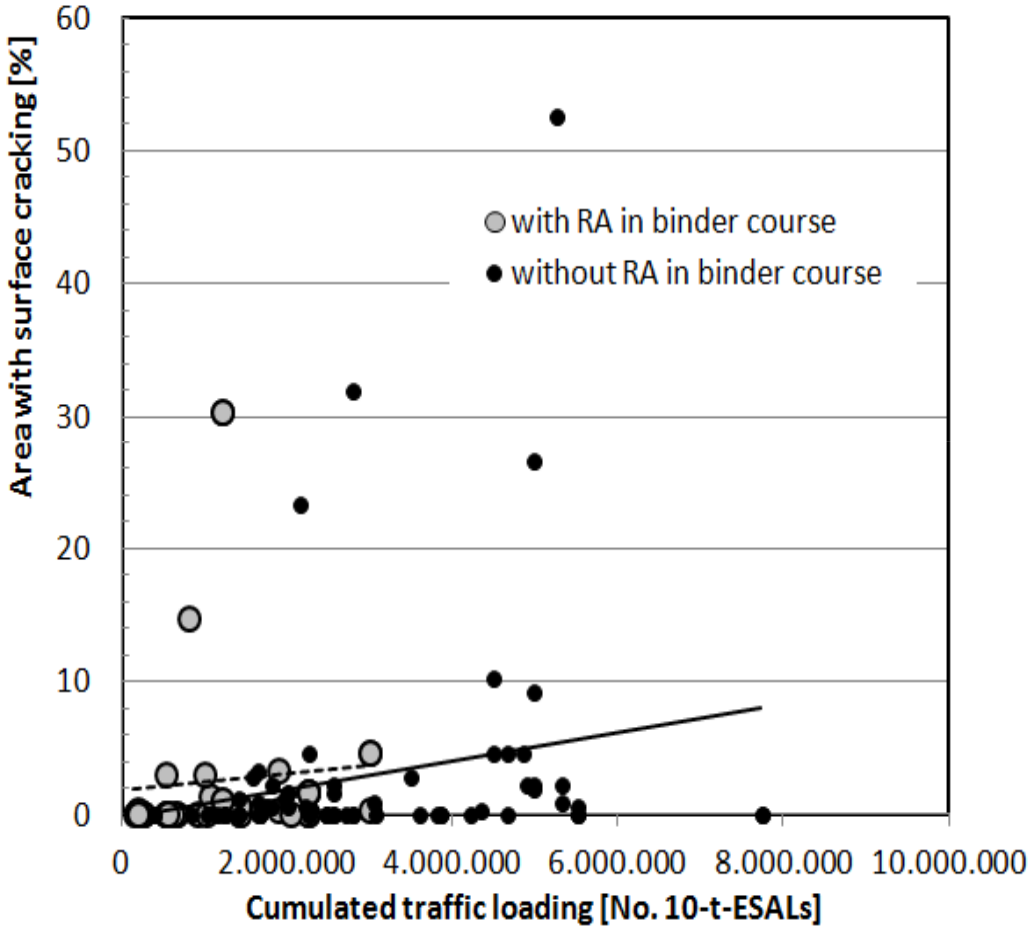
Proportion of AC mixtures with RA (1990 -2013)



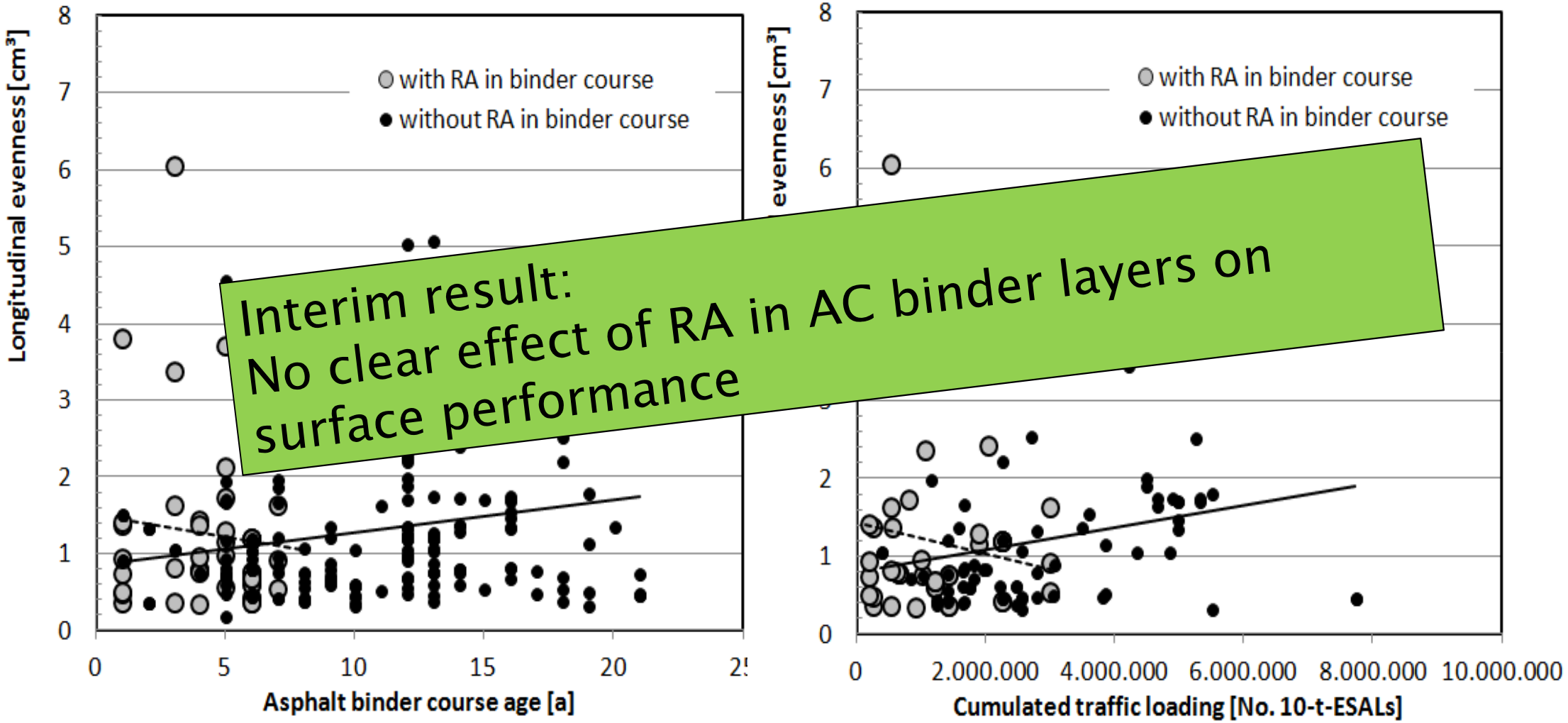
- **Majority of base layer asphalt contains RA**
- **Minority of surface layer asphalt contains RA**
- **For quantitative assessment of RA effect on performance, binder courses seems to be best for evaluation**

Effect of RA in binder course on cracking





Effect of RA in binder course on evenness



Interim result:
No clear effect of RA in AC binder layers on surface performance

Durability effects of consruction site conditions

- **Weather effects**
  - Constraints for pavement works according to national specifications
- **Paving season effect**
  - Consequence of insufficient compaction and missing interlayer bonding
  - Proportion of insufficient compacted asphalt layers versus construction date
  - Proportion of insufficient interlayer bonding versus construction date

Allowed weather conditions for pavement works

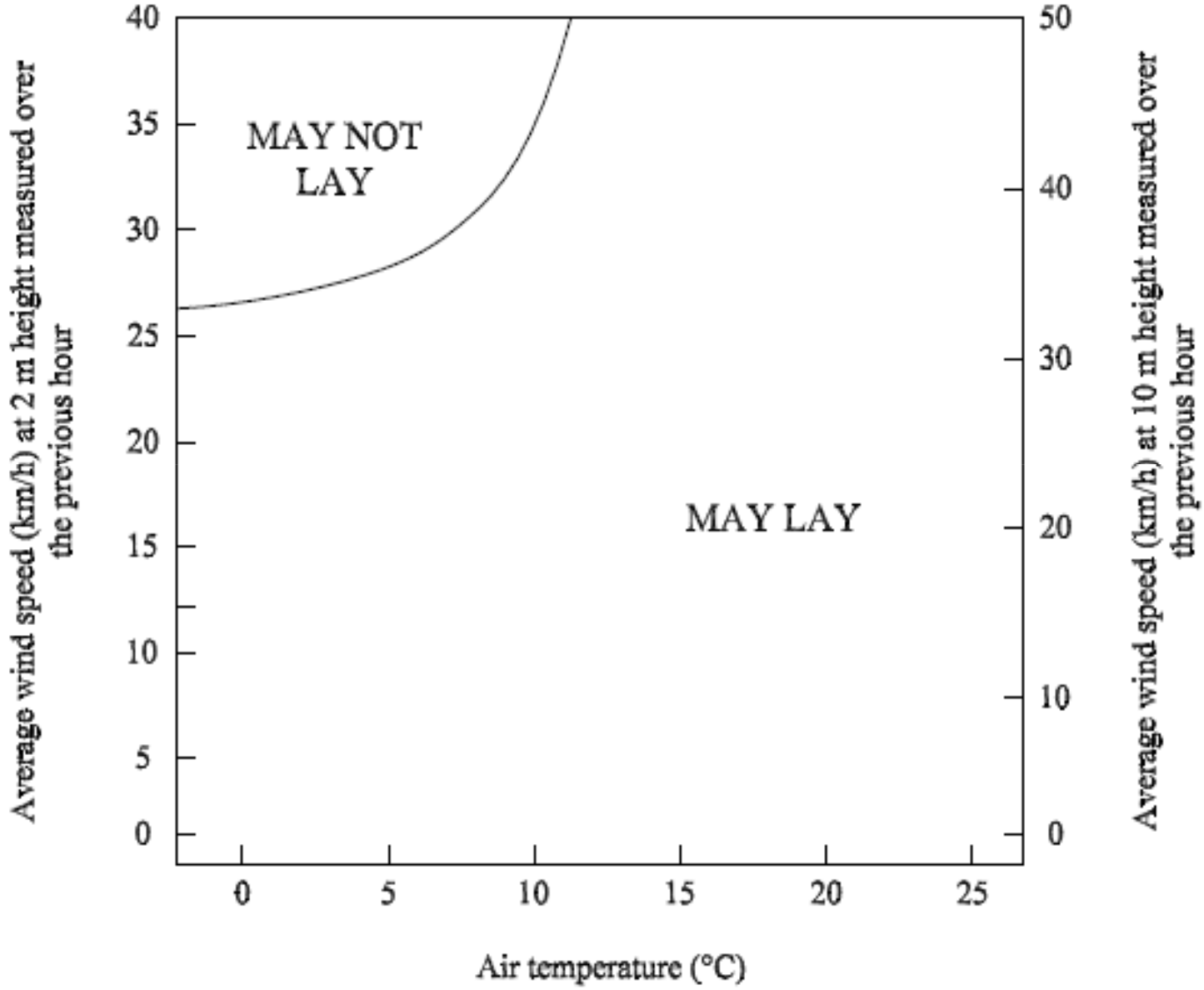
Country	Minimum allowed air temperature for paving of							Rainfall
	AC base layer	AC binder layer	asphalt surface ≥ 30 mm	asphalt surface < 30 mm	PA	MA ≥ 30 mm	HRA & PCC	
Germany	-3 °C	0 °C	+5 °C	+ 10 °C	+10 °C*	0 °C	-/-	allowed, no closed water film
The Netherlands	-**	-**	-**	-**	$T_{air} \geq W+5$ (°C)***	-**	-**	
UK and Ireland	Combination of wind and rainfall for layers less than 50 mm to Figure 14						0 °C	-/-

* Paving of PA is restricted at high wind velocities (not further defined)

** There are no specific requirements for other types of asphalt pavements than PA. However, the contractor is obliged to monitor and report on the conditions during construction and indicate how the quality of the paving work was ensured.

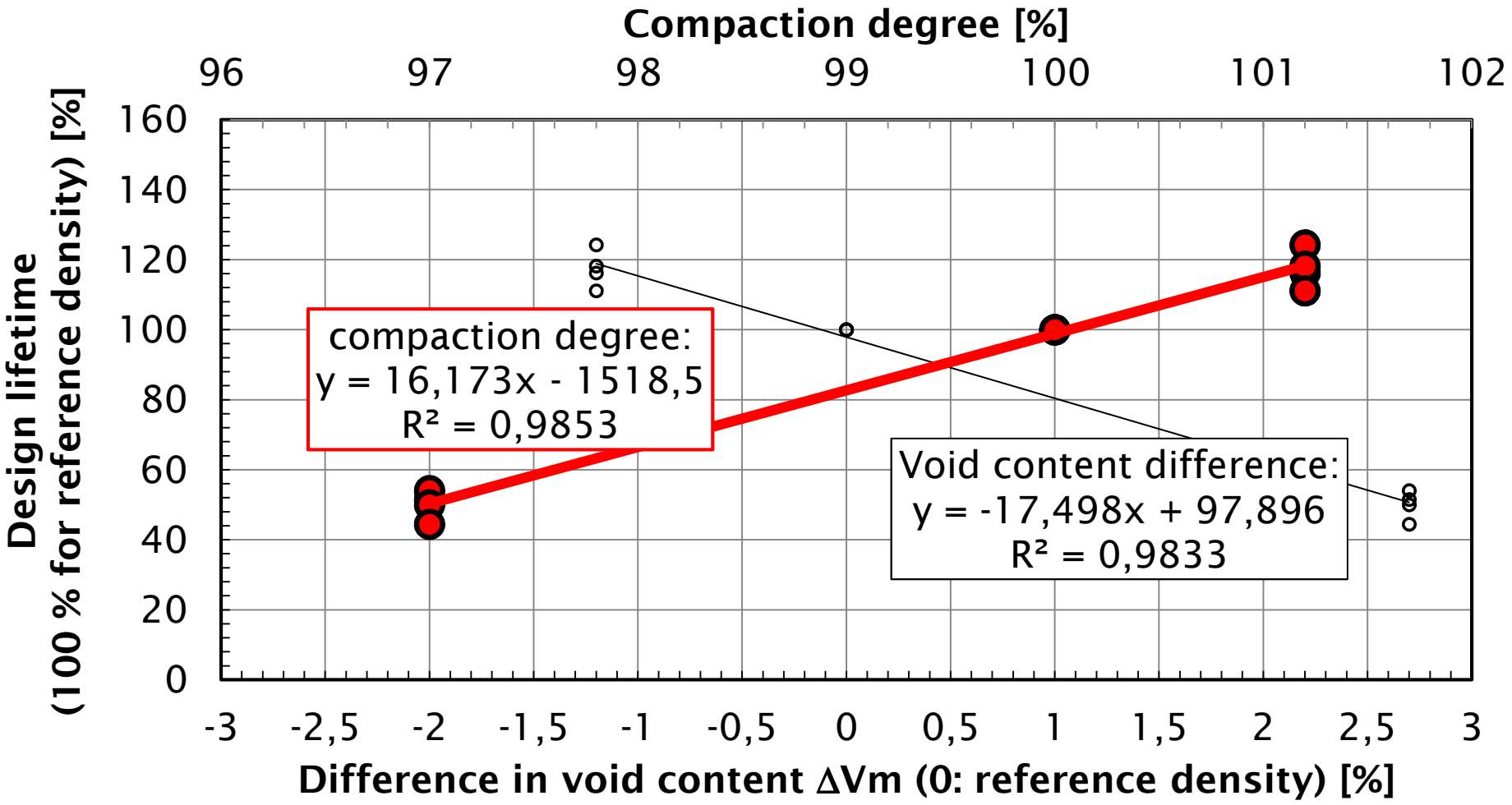
*** PA pavements can only be constructed when the air temperature is above 5°C plus the wind velocity (T is the air temperature in °C; W is the wind velocity in m/s).

Allowed weather conditions for pavement works

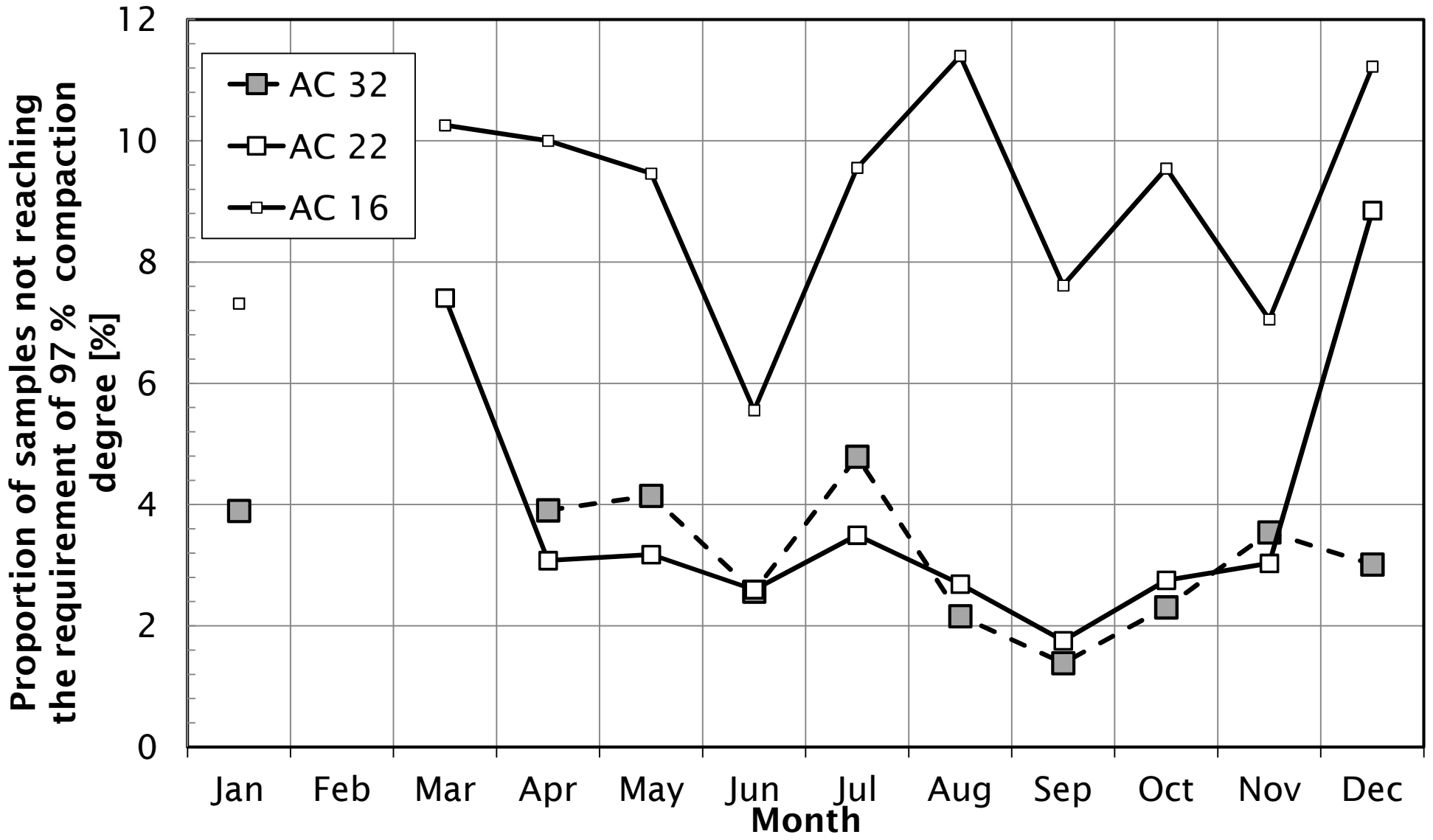


Effect of compaction quality on calculated lifetime

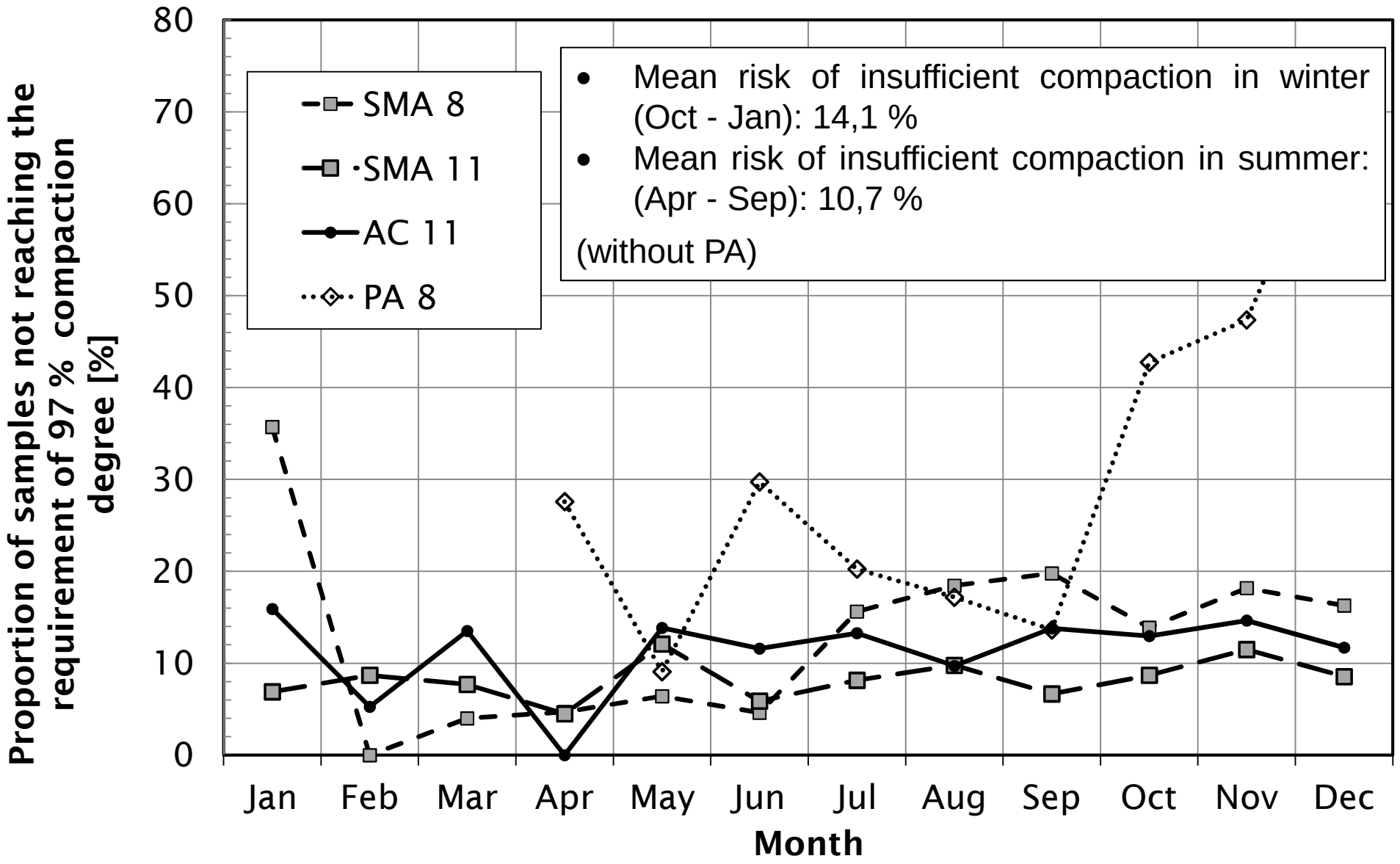
Based on lifetime calculations by applying German mechanistic-empirical pavement design guide



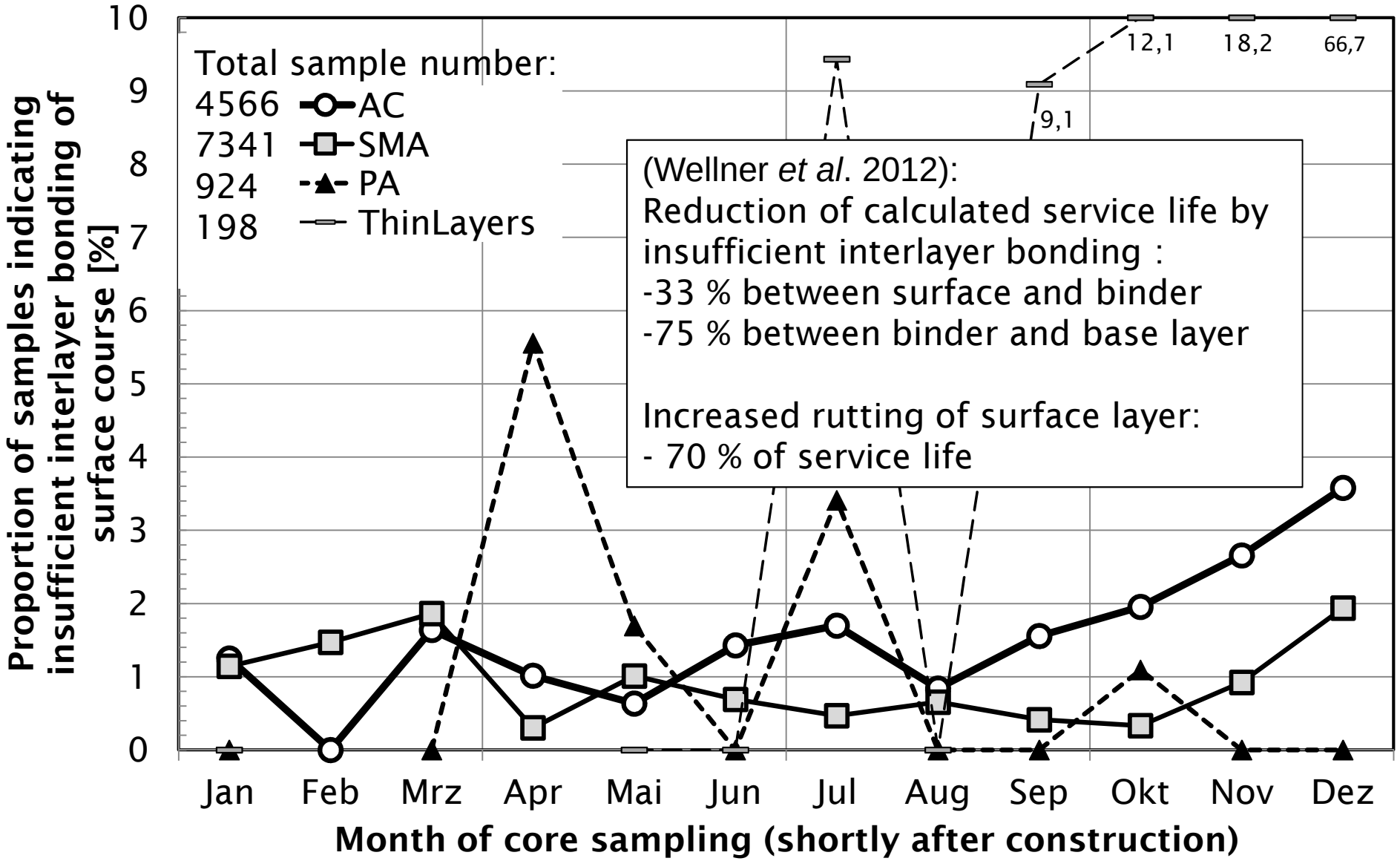
Data base analysis: Seasonal effect on compaction degree



Data base analysis: Seasonal effect on compaction degree



Data base analysis: Seasonal effect on interlayer bonding



Results summerised in EARN D3

Deliverable D3:
Effects of constituent materials, recycled and secondary sources materials and construction conditions on pavements durability derived from literature and site data review

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Conclusions from background data analysis (1)

General

- **Pavement durability is affected by high number of parameters**
  - Detailed analysis of general material-specific service lifetime from laboratory and modelling assessment not possible
- **Reliable databases combining detailed on pavement structure and materials and long-term performance data not available**
  - Empirical data sources are limited in number and accuracy

However…

Regarding the application of RA in hot-mix asphalt

- **Empirical data identifies negative effect but with a large scatter**
- **Most international literature shows adequate material durability performance**
- **Some studies identified reduced durability**
  - Additional procedures (mix design, mix production) increases risk of reduced durability
  - Increased demand for high-quality approach in all productions stages

Conclusions from background data analysis (2)

Regarding new additives and mix designs (e. g. WMA)

- **Additional additives will increase demand for quality by additional risks (e.g. incompatibilities to specific binders)**
- **Feasible laboratory conditioning procedures are required in order to allow the estimation of long-term properties during the mix design**
- **Laboratory test results with site-adapted laboratory tests will enable LCA and LCCA for single projects**

Regarding construction conditions

- **Construction season effect by adverse weather conditions**
  - Slightly increase the risk for insufficient compaction and interlaying bonding
  - Significant reductions of pavement and/or road material service lifetime.
  - Service lifetime decrease of -2,2 % for pavements constructed in autumn/winter months (October to January)
    - > *-1,7 % by non-sufficient compaction*
    - > *-0,5 % by insufficient interlayer bonding*

References

Mollenhauer, K, A Ipavec, L Gaspar, P Marsac, K Mirski, f Batista, M L Antunes, C McNally and R Karlsson (2011). Synthesis of national and international documents on existing knowledge regarding the recycling of reclaimed road materials in asphalt. DIRECT-MAT Deliverable D6. EC no. 218656. 2011.

Rübesam, J, L Hellmann, D Staroste, and J Stoltz (2005). Untersuchungen zur Wirtschaftlichkeit und bautechnischen Bewährung von Fahrbahnbefestigungen aus Asphalt und Beton auf bestehenden Bundesautobahnen (Investigations of the profitability and structural dependability of asphalt and concrete carriageway pavement on existing interstate highways). Forschung Straßenbau und Straßenverkehrstechnik. 914/2005. BMVBS, Bonn.

Walther, A, M Wistuba and K Mollenhauer (2010). Analysis of asphalt mix performance properties considering the discrepancy between mix design and in-field realization – Part II: Effect on asphalt pavement design. Proceedings of 11th International Conference on Asphalt Pavements. Nagoya.

Wellner, F, S Werkmeister and D Ascher (2012). Auswirkung der Alterung und des Schichtenverbundes auf den Beanspruchungszustand von Asphaltbefestigungen (Effect of ageing and interlayer bonding on the loading conditions of asphalt pavements). Straße und Autobahn 7.2012. pp. 430 - 437.

West, R, J Michael, R Turochy and S Maghsoodloo (2011). Use of Data from Specific Pavement Studies Experiment 5 in the Long-Term Pavement Performance Program to Compare Virgin and Recycled Asphalt Pavements. Transportation Research Record No. 2208, pp. 82-89. Washington D. C. 2011.