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100% Recycled High Modulus Asphalt Concrete

Lily D. Poulikakos

October 2nd, 2019

High Performance Asphalt Materials Symposium, Waterloo, Canada

BHZ

AMMANN

Empa within the ETH Domain

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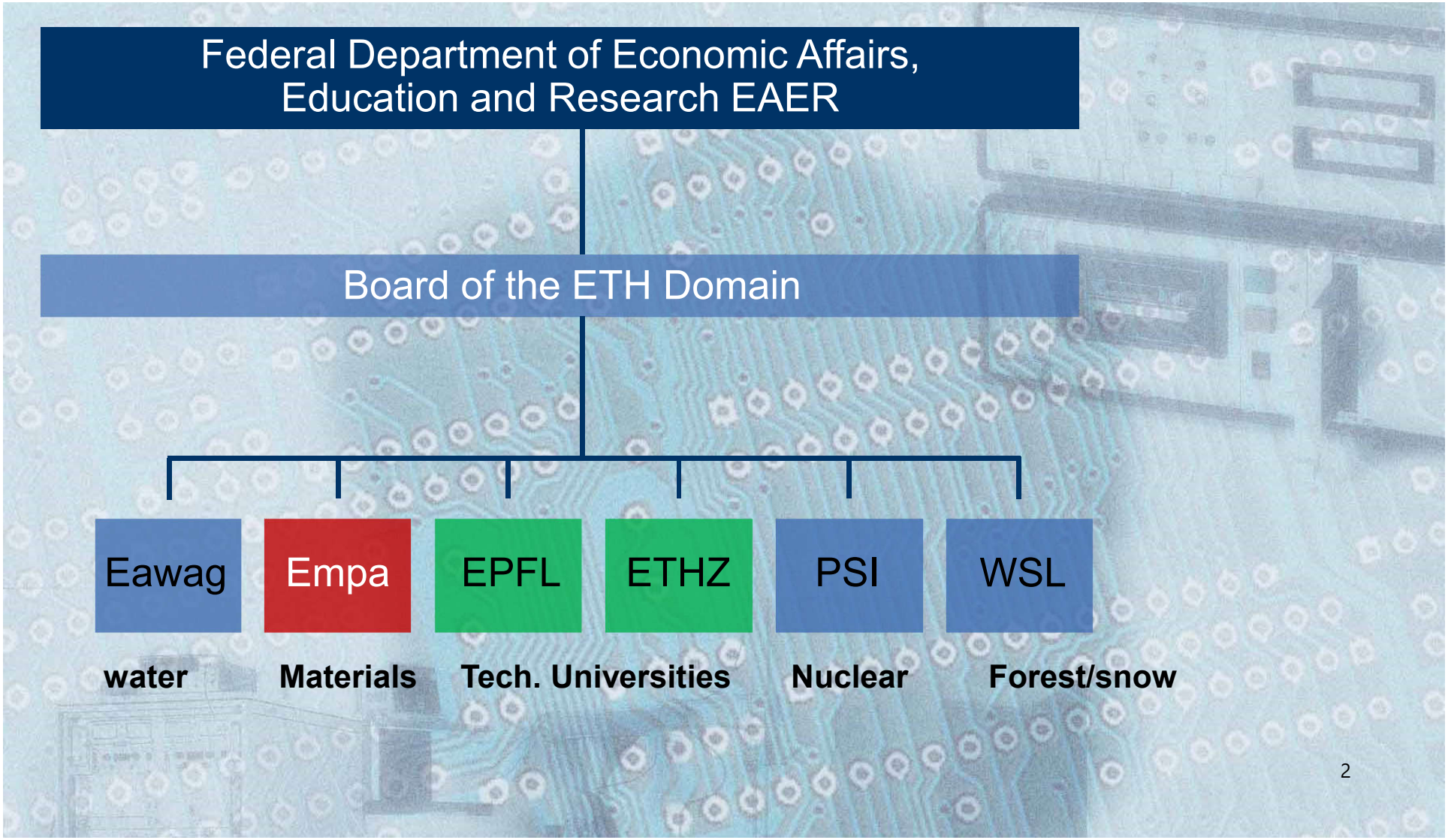

Empa in Numbers

3 Sites	Dübendorf, St. Gallen, Thun	
5 Departments	28	Laboratories
	950	Employees (860 FTE; about 30% Women)
	of which 28	Professors
	140	PhD Students
	40	Apprentices
	plus 200	Master Students & Interns
Budget	97	Mio. CHF Public Funding
	52	Mio. CHF Third Party Means
Scientific Output	> 500	Peer-reviewed ISI-Publications
	90	Seminars & Conferences at Empa-Academy
Third Party Projects	> 50	running Projects EU Framework Programmes
	> 90	running SNSF Projects
	80	running CTI Projects

Laboratory for Road Engineering

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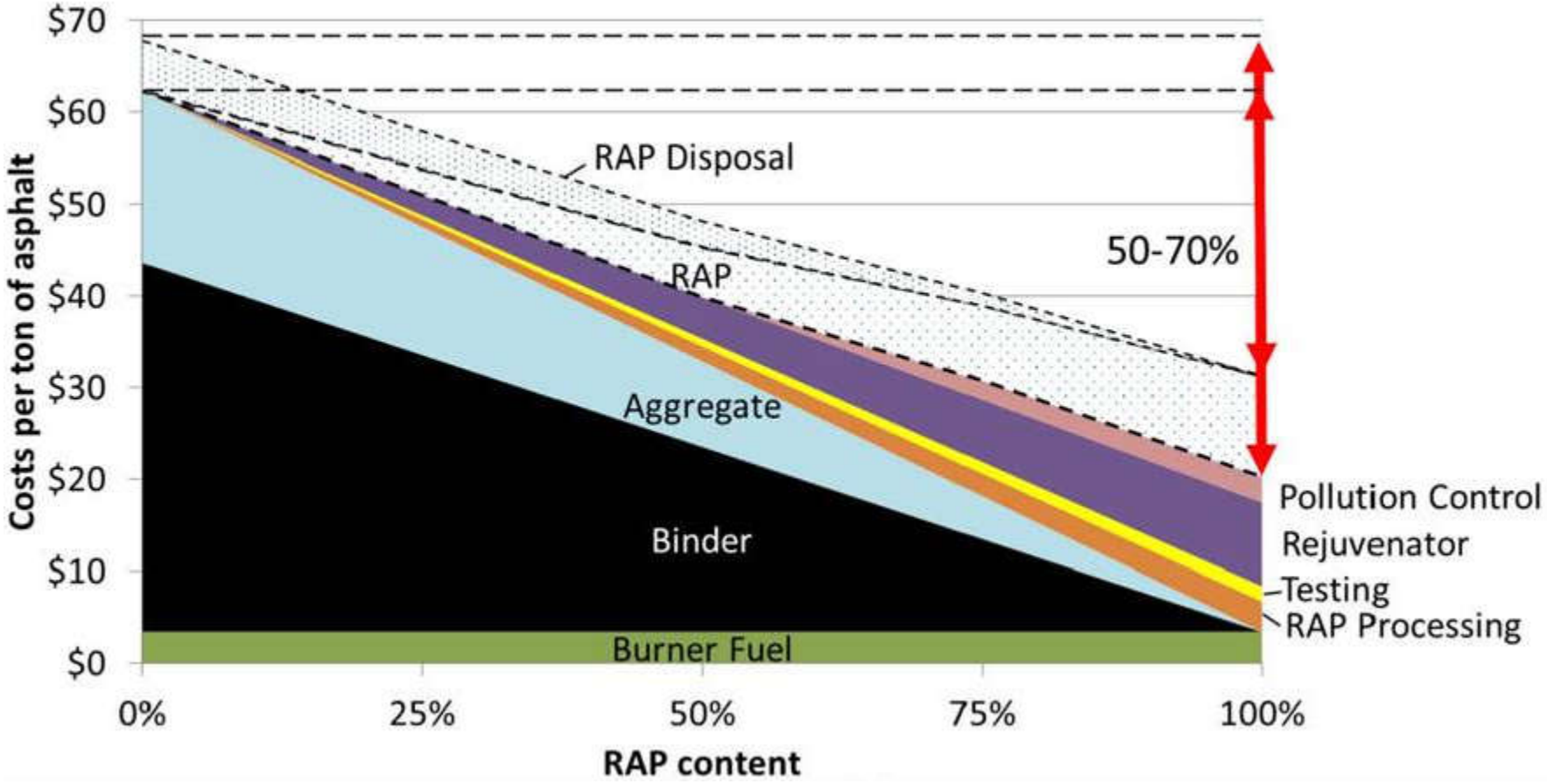
A multidisciplinary team (ca 20) consisting of engineers, chemists, post docs, PhD's, interns and technicians

Dr. Martins Zaumanis Dr. Maria Chiara Cavalli Dr. Martin Arraigada

Why use high amounts of RAP?



Zaumanis et al 2014

Multi scale evaluation of 100% RAP Mixtures

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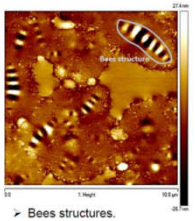
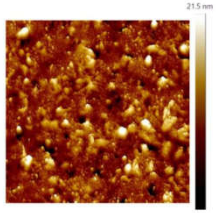
Microstructure

Virgin Binder 5070



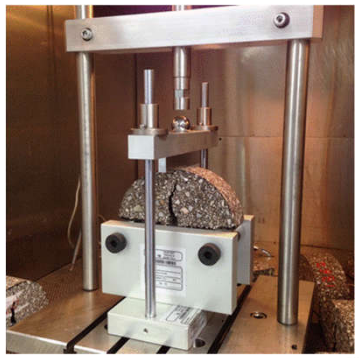
➢ Bees structures.

RAP Binder



➢ No "bees".

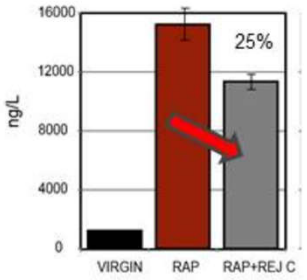
Macro-scale



Mega-scale

µm **mm** **m** **km**

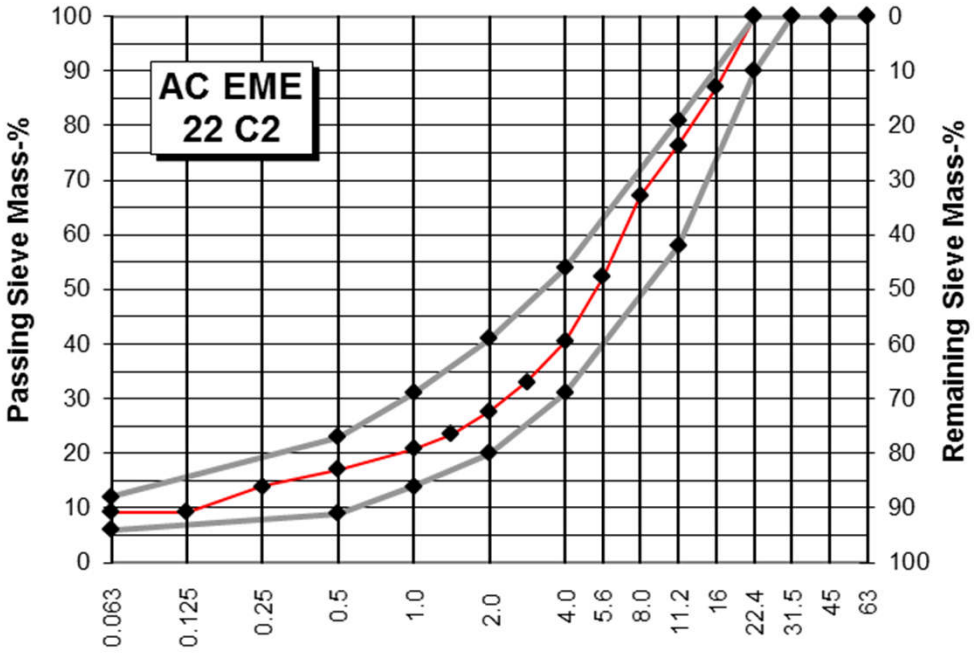
Unaged samples



PAH

EME: Enrobés á Module Elevé

	Binder Pen	RAP M%	BC M%	VC V%
AC EME C1	15/20	30	5 (≥4.6)	3.1 (3…6)
AC EME C2	10/20	35	5.6 (≥5.2)	2.2 (1…4)



- Developed in France
- Improve mechanical properties of asphalt concrete to provide high modulus, good fatigue behavior and excellent rutting resistance.
- Base and binder courses and allow reducing pavement layer thickness or increasing pavement life span.
- High content of hard (and often polymer-modified) binder, low air void content
- Application of performance-based testing requirements for fatigue, modulus and rutting resistance.

Why is 100% RAP relevant for HMAC?

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Well documented in literature:

- RAP binder is aged thus naturally provides the required hard-grade binder for HMAC;
- High RAP mixtures chronically demonstrate low air voids;
- Performance-based mixture design is recommended for high-RAP mixtures because of unknown binder blending, relatively little field performance experience and potential for cracking.

Objective: investigate the potential to design HMAC mixtures from 100% reclaimed asphalt pavement and validate the results using vehicle load simulator

Source: Zaumanis, M., Arraigada, M., Poulikakos, L. D. Design of 100% Recycled High-Modulus Asphalt Concrete, Eurobitumen 2020, submitted

Swiss Standards: Performance

2PB-TR

Minimum values from current Swiss Standards				
		Type of mix	Complex Modulus	Fatigue resistance, ε_6, at 10°C, 25Hz
			S_{min} at 15°C, 10 Hz	[micro strains, µm/m]
			[MPa]	
Existing Swiss Standard		AC EME C1	≥ 11000	≥ 100
[SN 640 431-1b-NA]		AC EME C2	≥ 14000	≥ 130

European Standards (Stiffness and Fatigue)

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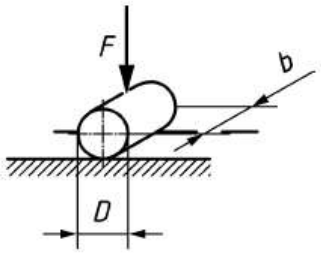
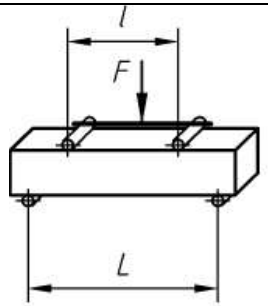
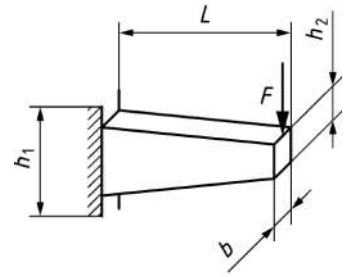
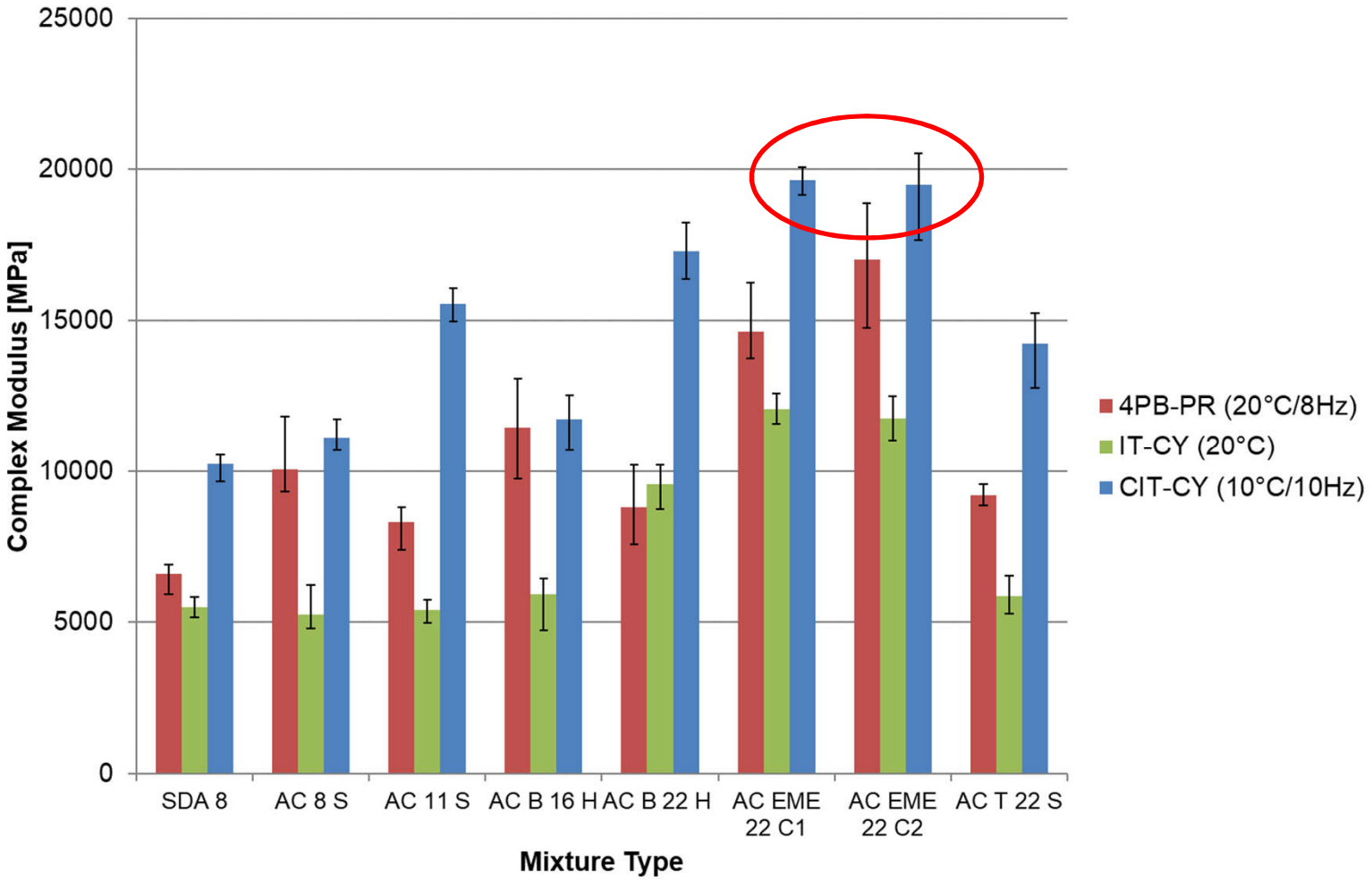
Type of loading	Designation	Schematic diagram
Indirect tensile test with cylindrical specimen (Pulse and sinusoidal loading form)	IT-CY and CIT-CY	
Four point bending test with prismatic specimen	4PB-PR	
Two point bending with trapezoidal specimen	2PB-TR	

Source: EN 12697-24 und -26

Complex Modulus



L.D. Poulikakos, Standardization requirements for the Swiss annex to EN for complex modulus and resistance to fatigue. Project Nr. VSS 2014/502, (2019) FB 1660.

HMAC Design and Test Results

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Parameter	C1-A	C1-B	C1-C	Required/ Ref
RAP 0/5.6, %	-	13.3	10.5	-
RAP 5.6/11, %	-	20.5	21.0	-
RAP 0/11, %	32.8	-	-	-
RAP 11/22, %	66.5	64.8	66.3	-
Filler, %	-	2.6	-	-
Virgin bitumen, %	0.7	1.75	2.1	-
Natural bitumen, %	0.07	-	-	-
Total binder content (RAP+virgin), %	4.70	5.14	5.58	**≥4.60**
Estimated binder penetration, 0.1×mm	16	21	21	**15-25**
Richness modulus	2.87	3.11	3.57	**≥2.70**
Richness modulus @ 85% binder activation	2.39	2.70	2.87	**-**
Air voids, %	**2.2**	**2.0**	**2.0**	**3.0-6.0**
Modulus, MPa @ 10°C, 10Hz	25,151	22,646	20,850	**≥19,000**
Fatigue strain at 10^6 cycles ε_6 @ 10°&10Hz, μm/m	13.9	46.7	45.8	**≥50**
Proportional rut depth @30,000 cycles, %	-	-	6.8*	**≤5.0**

*sample preparation differed from the standard method, likely resulting in by approx. 40 % higher rut depth

Mix design optimizations: significant increase in fatigue resistance and reduction of modulus

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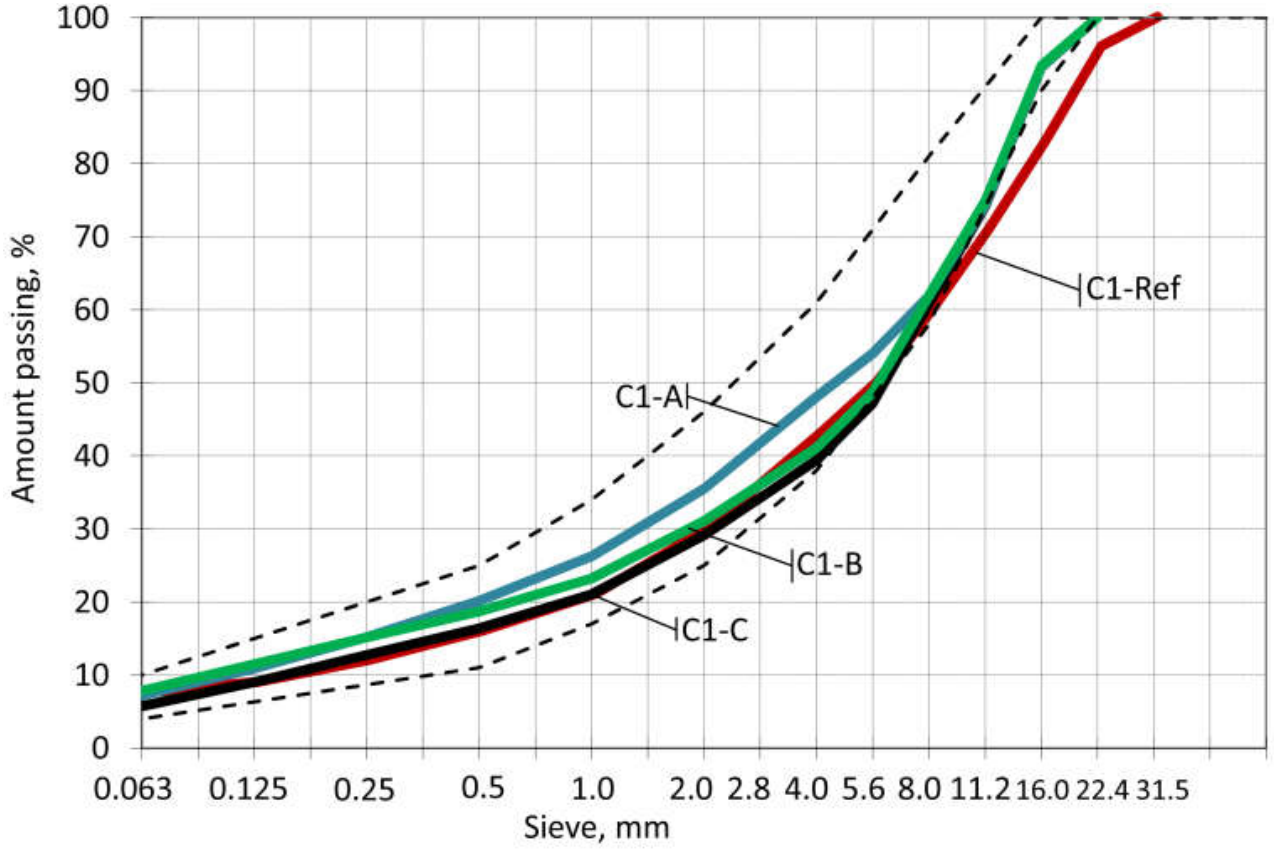
100% RAP HMAC



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Fatigue Performance

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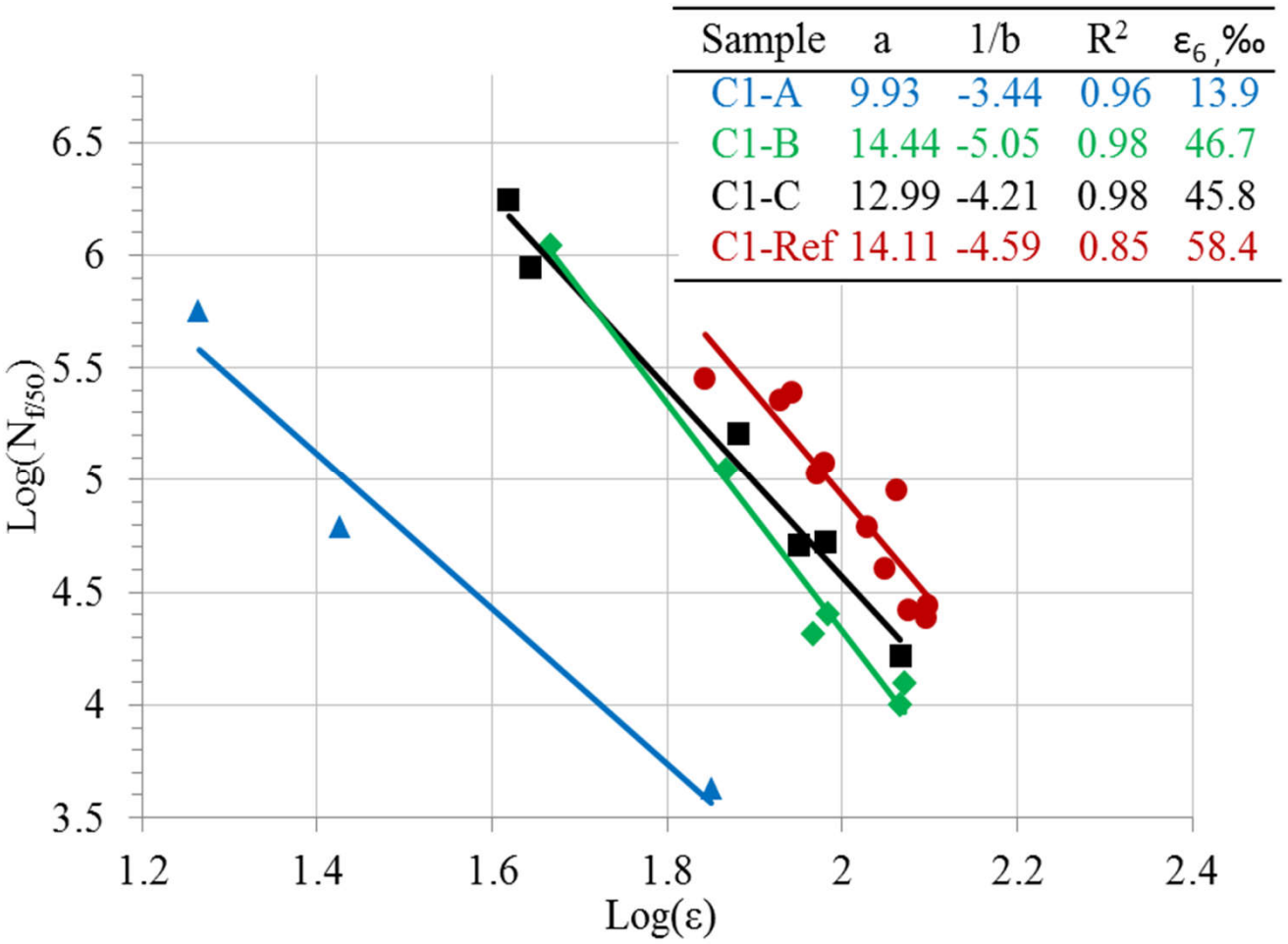

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Validation: MMLS3

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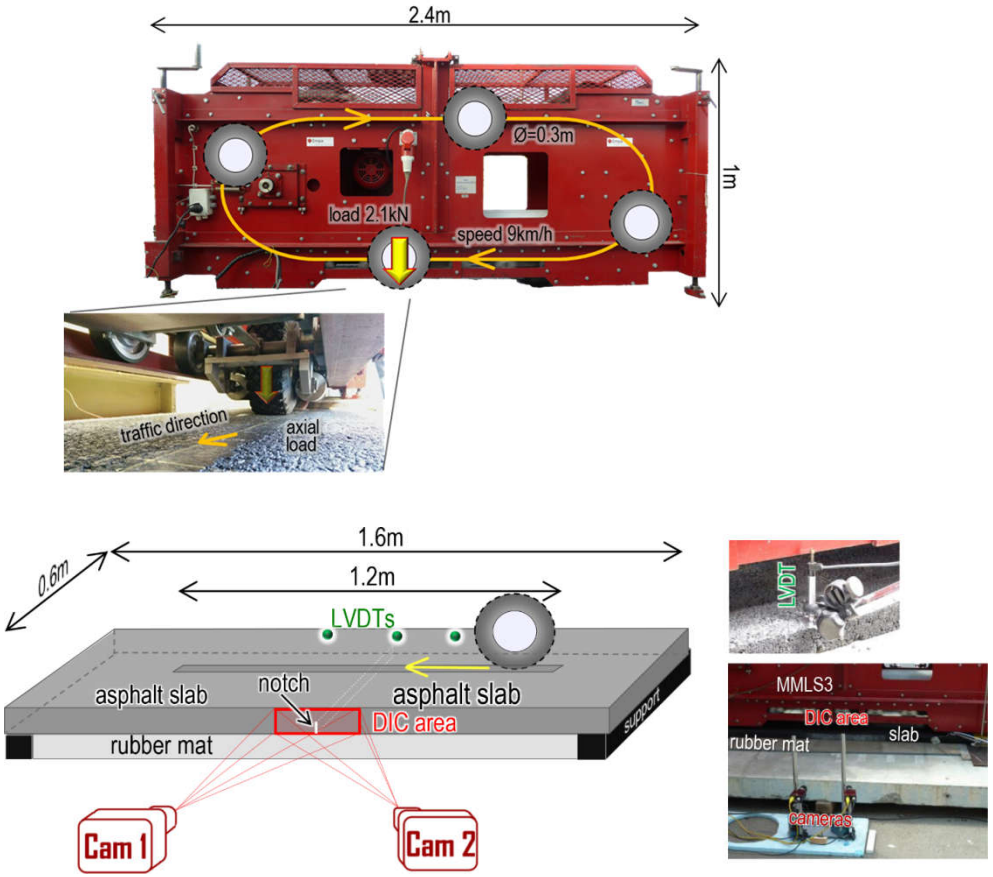
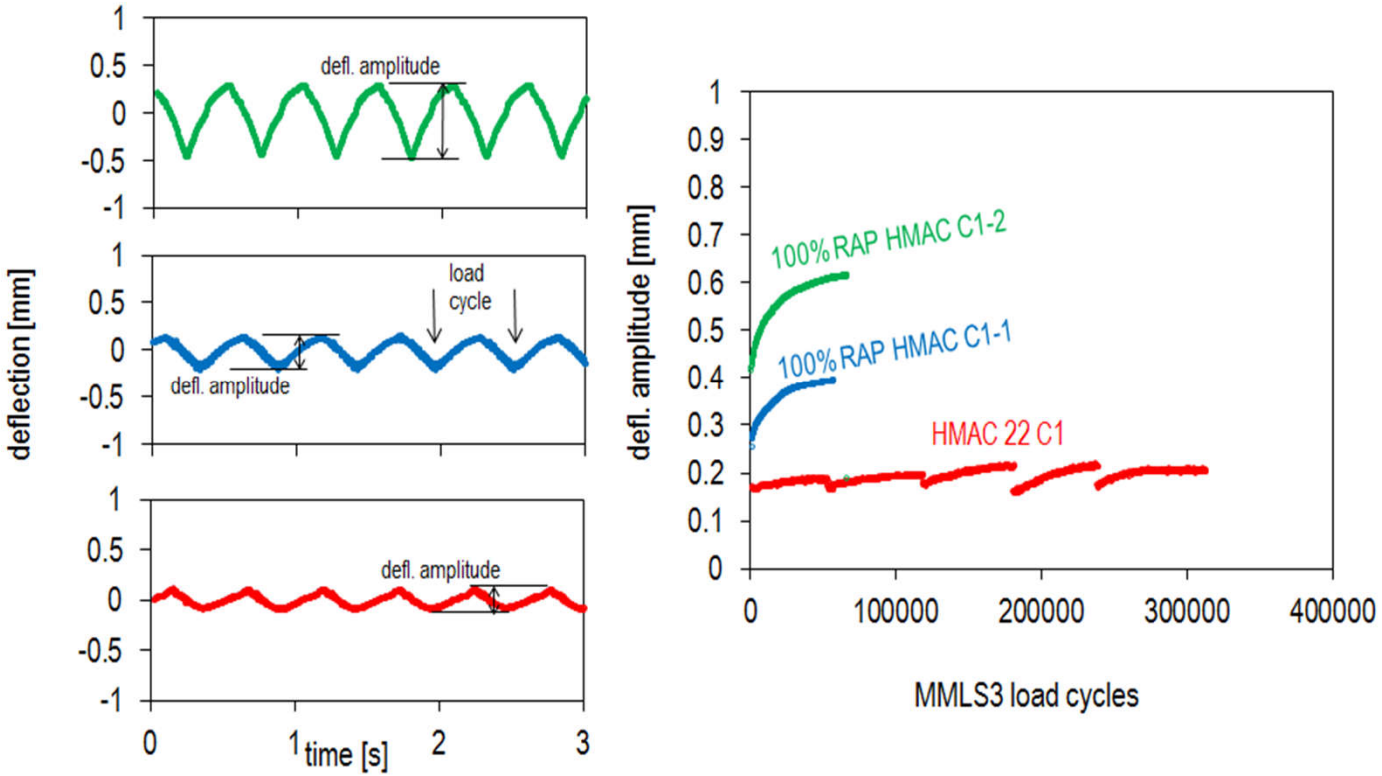


- one-third scaled accelerated pavement testing device
- testing under the loading of repetitive rolling tires.
- Slabs: 1.6mX 0.6mX 8 cm
- laboratory-mixed loose material which was short-term aged for 4 hours at 150°C.

Source: Zaumanis, M., Arraigada, M., Poulikakos, L. D. Design of 100% Recycled High-Modulus Asphalt Concrete, Eurobitumen 2020, submitted

MMLS3 Traffic simulator



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Summary and Conclusions

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- The design principle of HMAC is a good match for using high RAP content, because of the requirement to test mixture performance instead of relying mostly on volumetric properties
- In order to improve fatigue performance, 100% recycled mixtures required higher binder content than normally found in HMAC mixtures. This is likely because of not fully activated RAP binder.
- At Lab scale could fulfil most requirements;
- MMLS3: the RAP mixture was much more brittle than the reference mixture
- Need appropriate lab-scale techniques
- Properties of RAP play a crucial role: need RAP from high performance roads for HMAC

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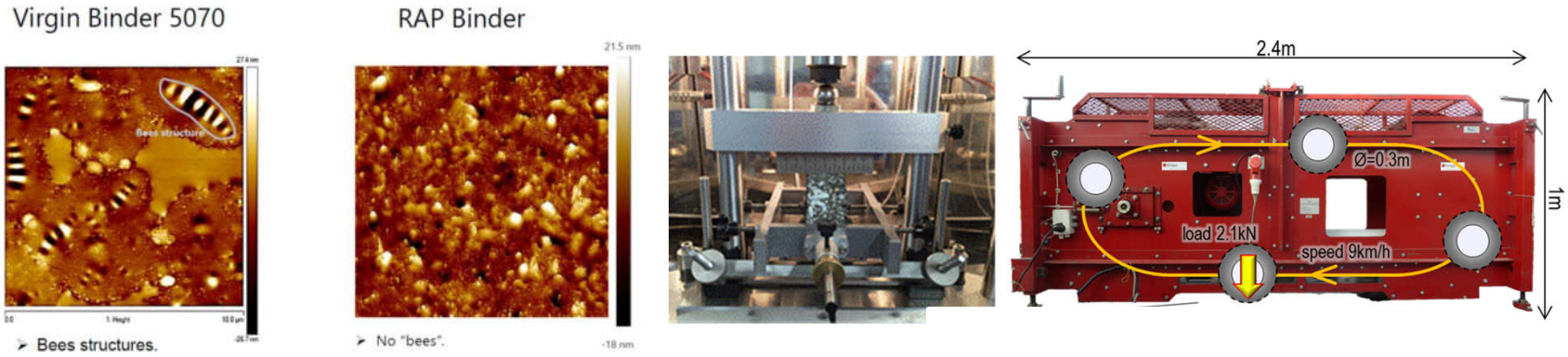
Thank you for your attention



Micro scale

mm- scale

m-scale

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