THESSALONIKI 2021

Technische Universität Braunschweig

ISBS Institut für Straßenwesen TU Braunschweig

Experimental Investigation on Double Recycling of Asphalt Mixture for Pavement Applications

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Outline

- Introduction
- Materials and Experimentation
- Results and Analysis
- Summary and Conclusions

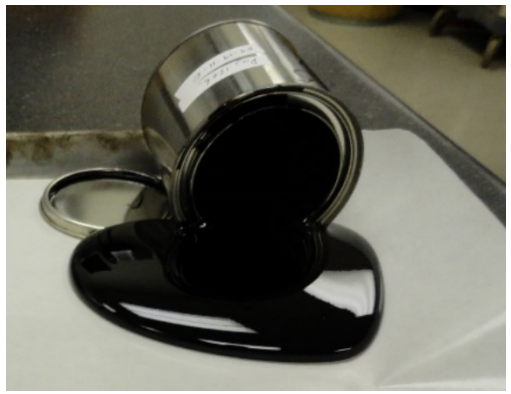
Introduction

- **Asphalt mixture** is the main road paving material
- In **Europe** and **north America** more than **90%** of roads are surfaced with asphalt mixture (NAPA & EAPA, 2011)

Asphalt mixtures:

- a particulate composites that contain **aggregate particles** of various sizes and shapes randomly distributed in a matrix made of **asphalt bitumen/binder.**

Introduction

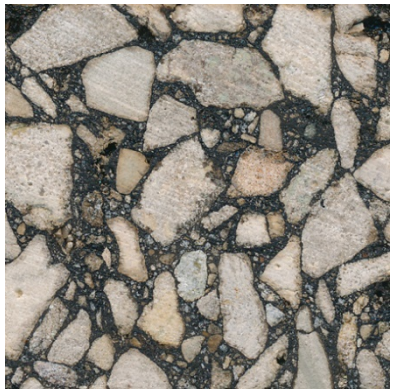


Asphalt
Bitumen/Binder

+

Aggregates

=



Asphalt
Mixture

TABLE 4A. WARM MIX ASPHALT (WMA)

PRODUCTION OF WARM MIX ASPHALT IN THE PERIOD 2013 - 2019 (in million tonnes)

For this table Warm Mix Asphalt is defined as mixtures produced by using special techniques and/or additives to reduce the production temperature.
The production temperature is between 100°C and 150°C

Country	All available Reclaimed Asphalt in 2019 in tonnes
Austria	1.800.000
Belgium	1.637.000
Croatia	210.000
France	8.074.000
Germany	13.400.000
Great Britain	6.050.000
Hungary	105.000
Italy	9.500.000
Norway	1.173.000
Romania	612.500
Slovakia	165.600
Slovenia	150.000
Spain	1.486.000
USA	88.000.000

More than

70 million

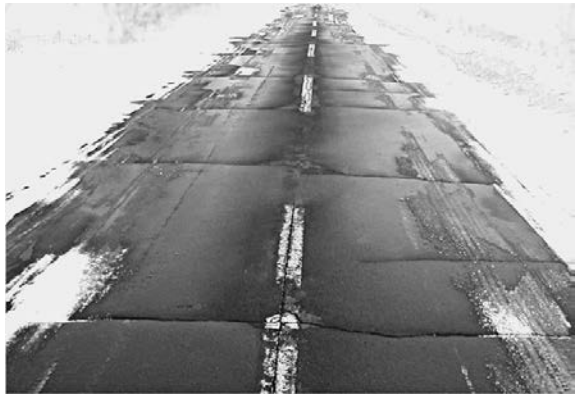
Country	2013	2014	2015	2016	2017	2018	2019
Austria	0,000	0,000	0,000	0,000	no data	no data	no data
Belgium	no data	no data	<0,05	no data	<0,050	0,100	0,200
Croatia	0,000	0,040	0,060	0,060	no data	no data	no data
Czech Republic	0,030	0,001	0,020	0,007	0,070	0,080	0,001
Denmark	0,120	0,200	0,200	0,250	0,340	0,330	0,320
Estonia	no data	no data	0,008	no data	no data	no data	no data
Finland	0,000	0,120	0,240	0,310	0,430	0,310	0,200
France	3,550	4,023	4,552	4,324	3,824	3,728	4,305
Great Britain	<1,000	<1,000	no data	<0,300	<1,000	<1,000	>1,000
Hungary	0,020	0,038	0,070	0,208	0,210	0,000	0,180
Luxemburg	0,000	0,007	0,007	0,007*	no data	no data	no data
Netherlands	0,060	0,133	0,100	0,100*	0,060	0,790	0,790*
Norway	0,380	0,540	0,592	0,502	0,869	1,339	1,740
Portugal	no data	no data	no data	no data	no data	no data	0,100
Slovakia	no data	no data	0,014	0,035	0,050	0,030	0,035
Slovenia	0,000	0,000	0,000	0,000	0,050	0,002	no data
Spain	0,086	0,140	0,140	0,060	0,200	0,180	0,380
Sweden	0,500	0,700	0,700	0,700*	no data	no data	no data
Switzerland	0,870	0,388	no data	no data	no data	no data	0,500
Turkey	no data	no data	0,080	0,151	0,077	0,000	0.000
USA	69,000	103,000	109,000	106,000	133,000	143,000†	72,000
Ontario-Canada	no data	0,750	0,900	0,750	no data	no data	no data
South Africa	0,150	0,150	0,200	0,200	no data	no data	no data

†Of which 72,1 Mt were produced at reduced temperature and 70,9 Mt at HMA temperature but with WMA technology

EAPA
(Asphalt in Figures, 2019)

Introduction

Asphalt bitumen/binders and asphalt mixtures are **temperature susceptible** materials. **Fatigue and thermal cracking** is a significant distress in asphalt pavements built in cold climates.



Low T
Thermal
Cracking

Intermediate T
Fatigue
Cracking

High T
Permanent
Deformation

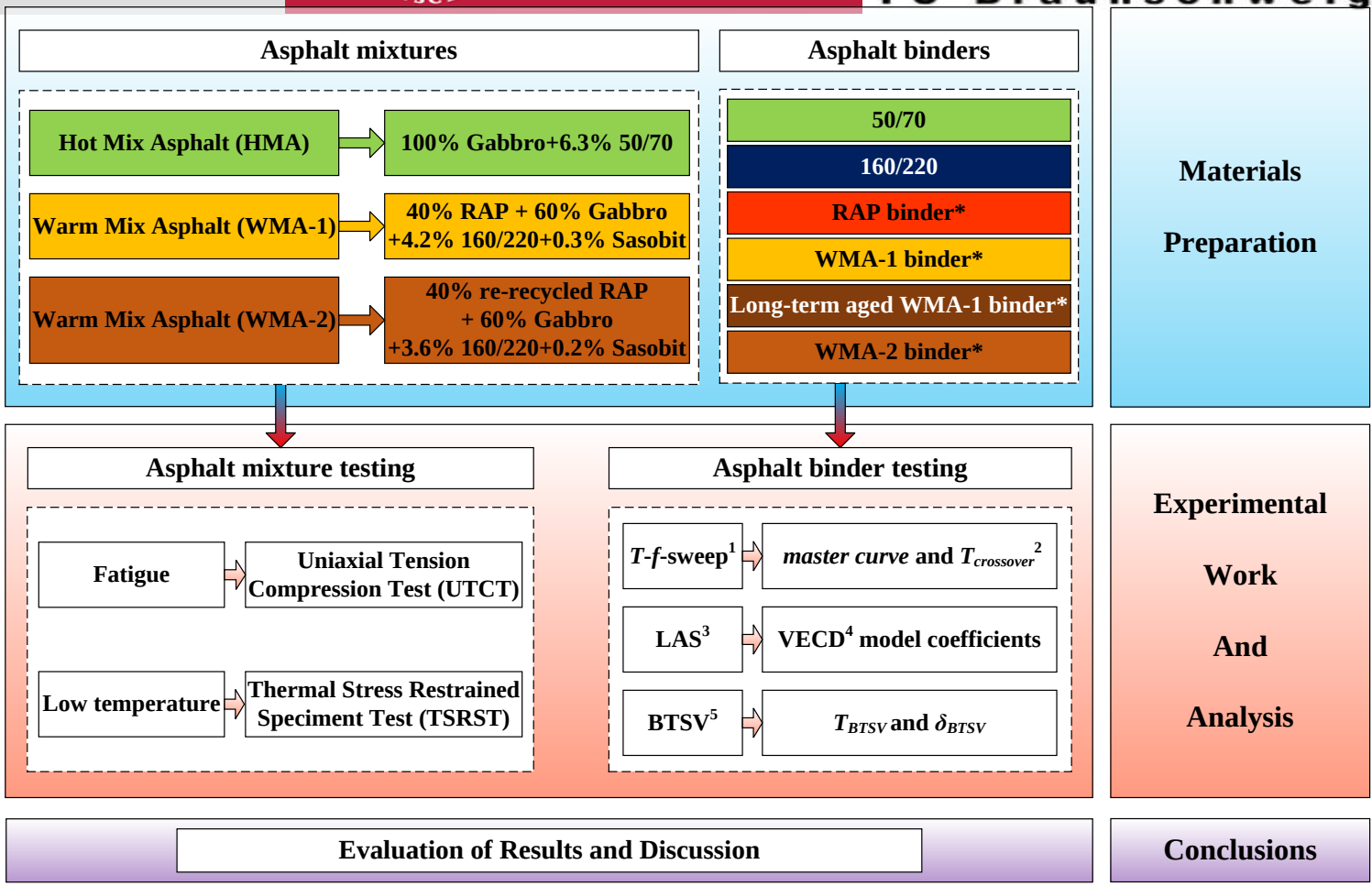
After field aged or laboratory aged, the asphalt binders are getting harder and more stiffness; hence, the low temperature properties of asphalt mixture should be studied.

Research Objective

Evaluate the possibility of using 40% **re-recycled (double recycled)** RAP together with **Warm Mix Asphalt (WMA)** technology.

Based on experimental works on:

- Asphalt mixtures
- Asphalt binders



WMA 1: WMA prepared with 40% RAP
WMA 2: WMA prepared with 40% re-recycled RAP
***T-f*-sweep[1]:** Temperature frequency sWeep
$T_{crossover}$[2]**:** crossover temperature
LAS[3]: Linear Amplitude Sweep Test
VECD[4]: Visco-Elastic Continuum Damage
BTSV[5]: Bitumen-Typisierung-Schnell-Verfahren (Binder-Fast-Characterization-Test)
binders with * are extracted from the corresponding mixtures

Materials and Experimentation

Materials

Table 1. Asphalt mixtures

	HMA	WMA-1	WMA-2
Recycled level	virgin	RAP	re-recycled RAP
Aggregates	100% Gabbro	60% Gabbro + 40% original RAP	60% Gabbro + 40 % re-recycled RAP
Binder type	50/70	4.2% 160/220	3.6% 160/220
Binder content [%]	6.3	6.2	6.2
Additives	-	0.3% Sasobit	
Density [g/cm³]	2.56	2.54	
Air void [%]	1.7	1.5	

artificially aged WMA-1 mixture after 35h of PAV aging

Materials and Experimentation

Experimental work for asphalt mixtures

- Fatigue-Uniaxial Tension Compression Test (UTCT) (Isailović et al., 2016)
- Thermal-Thermal Stress Restrained Specimen Test (TSRST) (EN 12697-46, 2012)

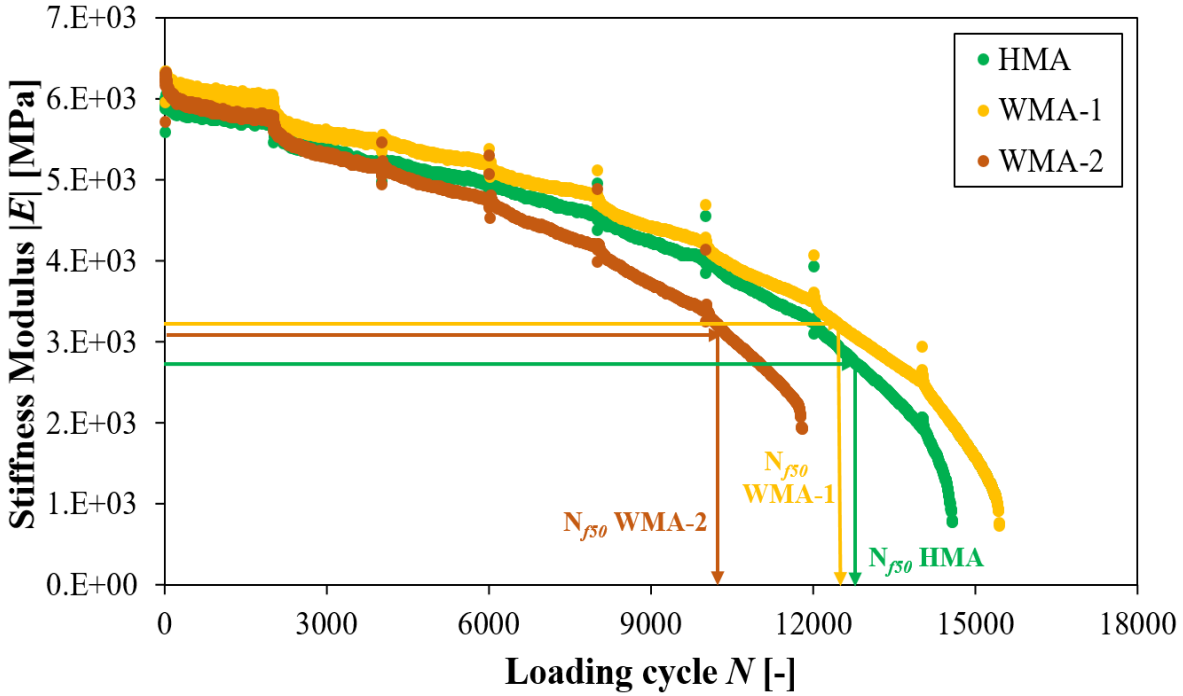
Experimental work for asphalt binders

- Rheological properties - Temperature-frequency (t-f) sweep tests (EN 14770-08, 2012; Farrar et al., 2015)
- Fatigue properties - Linear Amplitude Sweep (LAS) (AASHTO TP101, 2012)
- High temperature properties - Binder-Fast-Characterization-Test (BTSV) (DIN 52050, 2018)

Isailović, I., Cannone Falchetto, A., Wistuba, M. P. (2016). *Energy dissipation in asphalt mixtures observed in different cyclic stress-controlled fatigue tests*. In 8th RILEM International Symposium on Testing and Characterization of Sustainable and Innovative Bituminous Materials, 693-703. Springer, Dordrecht.
Farrar, M., Sui, C., Salmans, S., Qin, Q. (2015). *Determining the low-temperature rheological properties of asphalt binder using a dynamic shear rheometer (DSR)*. Technical white paper FP08. No. DTFH61-07-D-00005, Fundamental Properties of Asphalts and Modified Asphalts, III.

Results and Analysis – mixtures

UTCT results



	HMA	WMA-1	WMA-2
E_0 [MPa]	5813.925	6321.815	6145.089
N_{f50} [-]	12397	12684	10420
N_{macro} [-]	5732	6404	5810
ER_{max} [MPa]	4.04E+10	4.31E+10	3.74E+10
initial deformation [mm]	0.0093	0.0093	0.0102

TSRST results

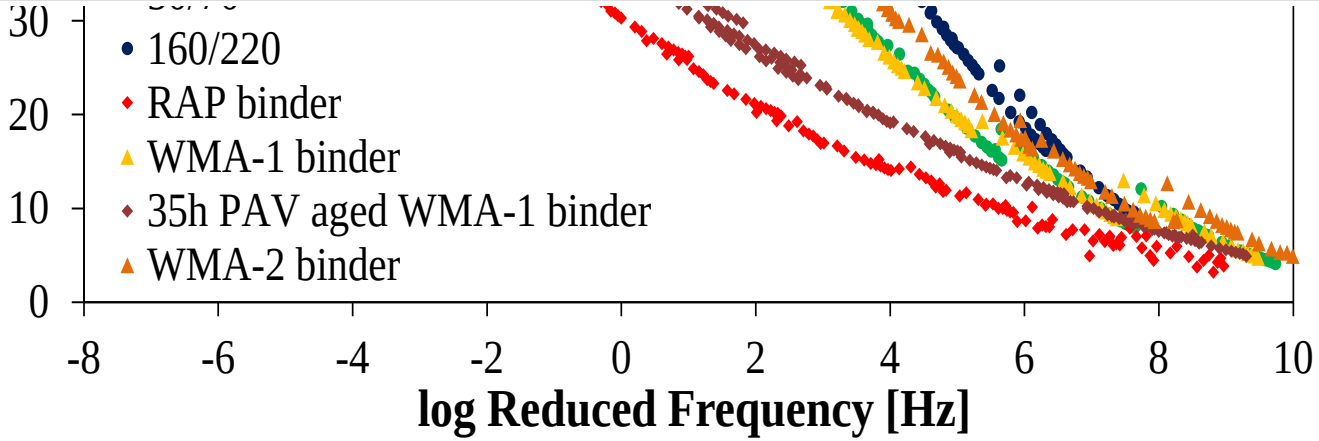
	HMA	WMA-1	WMA-2
fracture temperature T_F [°C]	-23.3	-25.0	-27.3
thermal strength σ_{cry} [MPa]	4.764	4.775	4.632

Overall similar fatigue behavior and slightly better thermal cracking properties were found in mixtures prepared with re-recycled RAP and WMA technologies.

Results and Analysis – binder

Rheological properties

Asphalt Binders	*G-R* parameter	Crossover temperature parameter	
	Glover-Rowe (Pa)	$T_{\delta=45^\circ}$	G^*(MPa)
50/70	488.00	6.6	34.334
160/220	1.43	-6.0	44.829
RAP binder	691543.16	25.7	22.435
WMA-1 binder	501.32	7.2	32.972
35h PAV aged WMA-1 binder	621451.65	23.8	31.525
WMA-2 binder	382.43	5.8	30.865



Asphalt binders in **both WMA mixtures** present **similar rheological properties** to the target **virgin 50/70 binder**.

Results and Analysis – binder

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LAS results

	A	B	N_{f50}
50/70	1.36E+05	-2.844	10107 [2.5% strain level] 1408 [5.0% strain level]
160/220	0.86E+05	-2.286	10454 [2.5% strain level] 2144 [5.0% strain level]
extracted WMA-1 binder	1.35E+05	-3.181	7317 [2.5% strain level] 807 [5.0% strain level]
extracted WMA-2 binder	1.39E+05	-3.428	8234 [2.5% strain level] 1055 [5.0% strain level]

RAP binder failed at relative low strain level due to very high stiffness

Results and Analysis – binder

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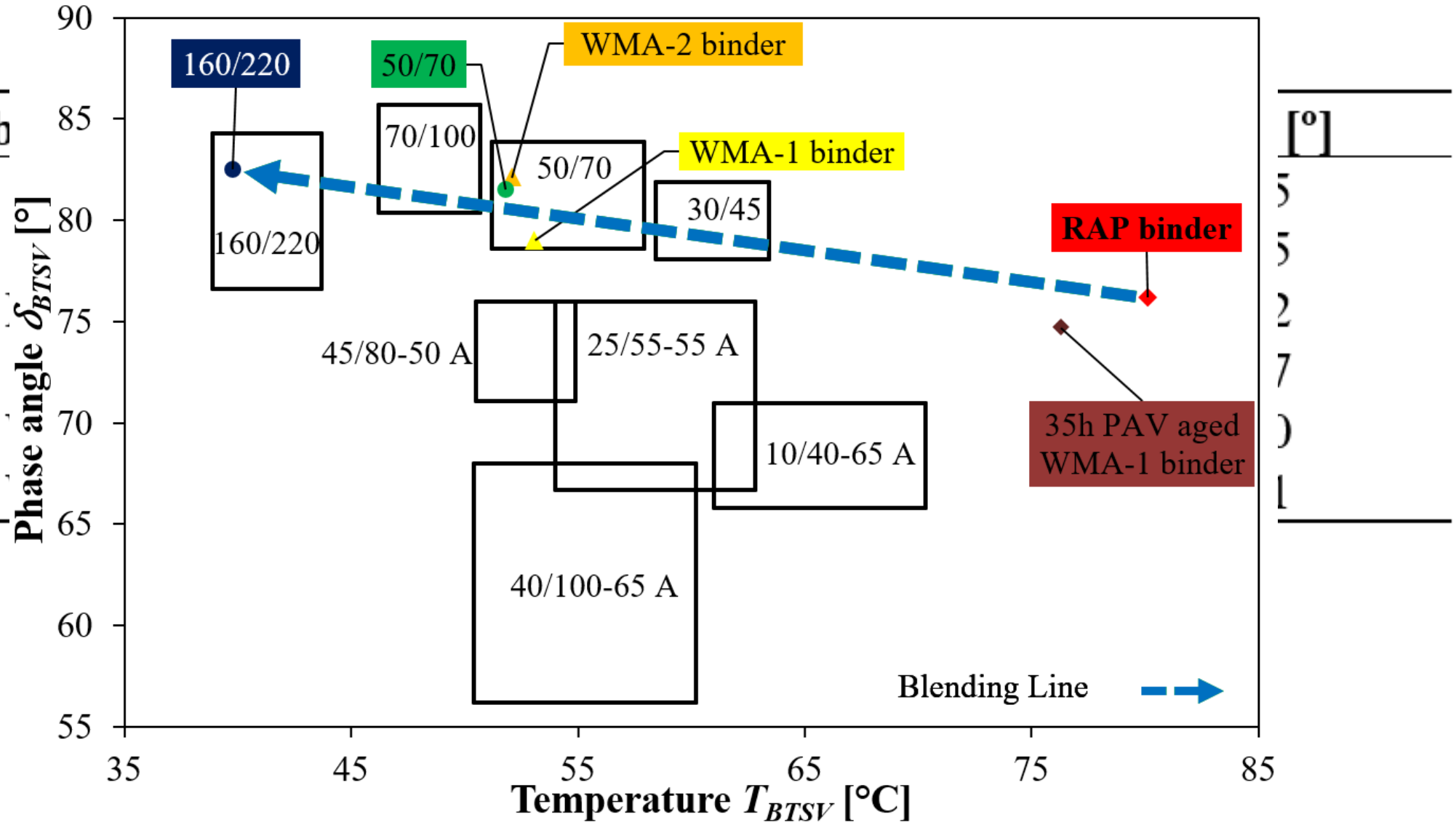
BTSV results

Asphalt b	[°]
50/70	5
160/220	5
extracted	2
35h PAV	7
extracted	0
extracted	1



Summary and Conclusions

The possibility of using a re-recycled RAP, up to 40%, in combination with the Warm Mix Asphalt (WMA) technology for designing surface layer mixture was experimentally investigated.

- Aged asphalt binder can be rejuvenated by using a very soft fresh binder, 160/220.
- Similar fatigue and low temperature behavior were observed for reference HMA and two WMA mixtures prepared with different generations of RAP.
- Similar rheological characteristics, including fatigue and high temperature properties, can be achieved for the extracted binder in both WMA mixtures compared with the reference virgin binder.

Name: ***Journal of Traffic and Transportation Engineering (English Edition)***

Editors-in-chief: Prof. Richard Kim (North Carolina State University, USA)
Prof. Aimin Sha (Chang'an University, China)

Sponsored by: Chang'an University

CN: 61-1494/U

ISSN: 2095-7564

Started from: 2014

Issue: Bimonthly

Language: English

Publisher: KeAi /Elsevier

Indexed by: Ei, ESCI, Scopus, CSCD, CSTPCD, DOAJ

Email: jtte2014@126.com jtte@chd.edu.cn

Website: http://www.sciencedirect.com/science/journal/20957564 http://jtte.chd.edu.cn

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Name: ***Journal of Road Engineering***

Editors-in-chief: Prof. Aimin Sha (Chang'an University, China)
Prof. Fwa Tien Fang (National University of Singapore, Singapore; Chang'an University, China)

Sponsored by: Chang'an University

CN: 61-1520/U

Issue: Quarterly

Start from: Late 2021 (expected)

Language: English

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