Investigation on the performance properties of asphalt mixtures prepared with RAP and WMA additives at binder and mixture levels

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In consideration of both economic and environmental benefits, recycled materials, such as Reclaimed Asphalt Pavement (RAP), have been commonly used in pavement construction for decades (Büchler *et al.*, 2018). On one hand, a number of research efforts have been conducted to evaluate the possibility of using a high amount of RAP in the pavement construction, leading to a wide acceptance on the use of RAP up to 40% in content (Poulikakos *et al.*, 2017; Büchler *et al.*, 2018; Wang *et al.*, 2019). On the other hand, only limited studies focused on the combined use of RAP with other techniques or materials, for example, the Warm Mix Asphalt (WMA) technology for the mixture design and paving. In this study, the possibility of using a high amount of RAP together with WMA technologies to achieve similar performance properties compared with the conventional Hot Mix Asphalt (HMA) was experimentally investigated. The original idea of this research develops and expands from the interlaboratory work proposed by the RILEM technical committee (TC) entitled Asphalt Pavement Recycling 264-RAP-TG2 (RILEM, 2015). This TC was originally proposed in 2015, its objective is to enhance the fundamental understanding of the interactions between recycled asphalt (RA) materials and new fresh materials in asphalt paving mixtures, and the combination of RAP with various technologies and sustainable materials. In this paper, the recycled asphalt (RA) mixture, with an NMAS equals to 11.2 mm, provided by the RILEM committee was used as reference material. The following steps were conducted to evaluate the possibility of combined use of RAP and WMA at both mixture and binder scales. The entire research approach with detailed experimental information can be found in Figure 1.

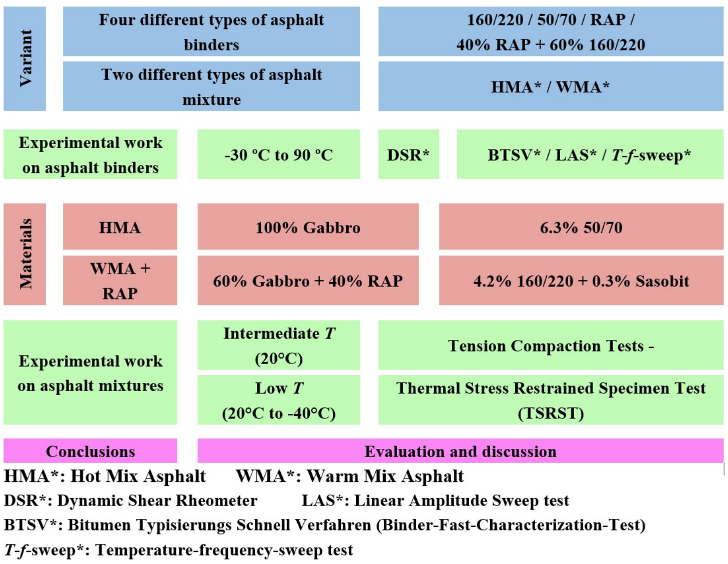

Figure 1. Flow chart

Regarding the asphalt binders, two unmodified asphalt binders, 50/70 and 160/220, were used together with the asphalt binder extracted and recovered from the RAP mixture (EN 12697-3, 2013). Next, 40% of RAP binder was mixed with 60% binder 160/220, since the mixed materials have similar penetration value with binder 50/70. Then, conventional tests, such as penetration (EN 1426, 2015) and softening point (EN 1427, 2015), were conducted on these four different asphalt binders. Finally, rheological tests, 'Binder-Fast-Characterization-Test BTSV' (AL BTSV, 2017), Temperature-frequency sweep tests (*T-f* sweep) and Linear Amplitude Sweep (LAS) (AASHTO TP101, 2012), were also performed with the Dynamic Rheometer (DSR). It should be noticed that no WMA technology was used for the asphalt binders. In the case of asphalt mixture, the conventional HMA mixtures were first prepared with 50/70 binder and fresh aggregates, this material was used as the reference material. RA materials, fresh aggregates, soft unmodified asphalt binder 160/220 and the WMA additives Sasobit were mixed and compacted together; 40 % of RAP materials were used in the new component by weight. Since the oxidation and aging process in the RAP materials lead to a harder and brittle asphalt binder, which ultimately induced better high temperature properties when RAP is used (Poulikakos et al., 2017; Büchler et al., 2018), only the intermediate and low temperatures properties were experimentally investigated in this study. At intermediate temperature (20 C), Tension Compaction Test (EN 12697-24, 2018) was used to evaluate the fatigue properties while at low temperature, the Thermal Stress Restrained Specimen Test (TSRST) (EN 12697-46, 2012) was applied to assess the thermal properties of these two mixtures.

Part of the experimental results is displayed in Figure 2 and Table 1 for asphalt binders and asphalt mixtures, respectively. In Figure 2, master curves were generated based on the *T-f*-sweep test results for all the asphalt binders. It can be seen that RAP binder mixed with 160/220 binder have very similar rheological properties with the fresh 50/70. The other experimental results based on DSR parameters confirmed this finding.

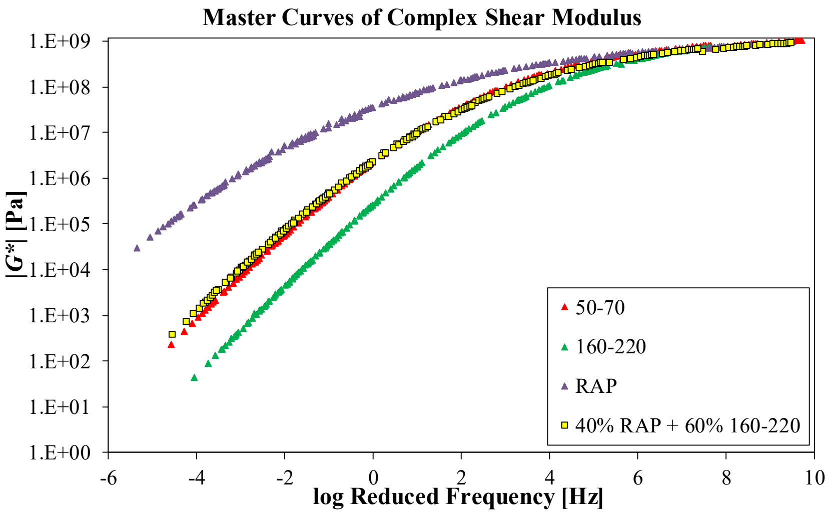

Figure 2. Master curves comparison between different asphalt binders

Table 1. Fatigue and thermal properties between conventional HMA and WMA mixtures.

Fatigue Properties (Tension-Compaction Tests)			Thermal Properties (TSRST)		
Amplitude-sweep	HMA	WMA	Cooling tests	HMA	WMA
E-Modulus initial [MPa]	5814	6322	Fracture temperature T_F [ºC]	-23.3	-25.0
Loading cycles N_{f50} [-]	12397	12684	Fracture stress σ_F [MPa]	4764	4774
N_{macro}	9830	11675			

In Table 1, it can be concluded that mixture prepared with RAP and WMA technology have better fatigue and thermal properties compared with the conventional HMA mixture. This is especially true for the low temperature properties. This research provides evidence on the possibility of combined using up to 40% of RAP and WMA technology for pavement construction. Nevertheless, various RAP materials with different WMA technologies need to be evaluated with respect to the general understanding of the reaction between RAP and fresh materials.

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