Construction and Building Materials 98 (2015) 315–324

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Rheological characteristics investigation of high percentage RAP binders with WMA technology at various aging states

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HIGHLIGHTS

- This study is to explore rheological properties of the high percentage of RAP binder.
- Viscosity, failure temperature, rutting and fatigue resistances of binders were tested.
- RAP source affected the performance properties of combined asphalt binders.
- WMA additive could offset the effect of RAP binder on the rheological properties.
- Additional RAP could improve the rutting resistance and reduce fatigue resistance.

ARTICLE INFO

Article history:
Received 15 June 2015
Received in revised form 13 August 2015
Accepted 18 August 2015
Available online 27 August 2015

Keywords:
Reclaimed asphalt pavement
Warm mix asphalt
Rutting resistance
Fatigue resistance
Aging state

ABSTRACT

The application of reclaimed asphalt pavement (RAP) is very promising and the research activities focusing on this subject is numerous in recent year. However, how to increase the percentage of RAP in the surface layer mixtures of asphalt pavement and meet or exceed the standards is challenging to the state highway agencies in the USA. The objective of this study is to explore the rheological properties of the high percentage (up to 50%) of RAP binder with three base binders in terms of five RAP binder content, two RAP binder sources, one HMA and one warm mix additive (WMA) technologies at three aging states. The viscosity, failure temperature, rutting resistance, fatigue resistance of various asphalt binders were tested in this study. The results indicated that the combined binders after a short term aging and a long term aging procedures still satisfied the requirement of asphalt binder set by Superpave binder specifications. In addition, increasing the RAP binder concentration could improve the rutting resistance of asphalt binder but a reduction in the fatigue resistance was noticed. However, the WMA additive could offset these properties of combined binder. Moreover, the results indicated that the RAP source typically affected the performance properties of combined asphalt binder and should be investigated individually.

1. Introduction

The recycling of old asphalt pavement materials to produce new pavements with considerable savings in material, money, and energy is very promising recent years. Aggregate and binder from existing asphalt pavements are valuable materials and easy to recycle even though these pavements have reached the end of their service lives. Reclaimed asphalt pavement (RAP) has been used with virgin aggregates and binders to produce new asphalt pavements for many years, proving to be both economical and effective in protecting the environment. Furthermore, mixtures containing RAP have been found, for the most part, to perform as well as the virgin mixtures with respect to rutting resistance [1–4]. National Cooperative Highway Research Program (NCHRP) Report 452 report provides basic concepts and recommendations concerning the components of mixtures, including new aggregate and RAP materials [5].

Currently, crushing and screening technologies allow processing of RAP in a more consistent and uniform manner. In addition, hot mix plants are routinely able to handle higher amounts of RAP. As a result, it is now possible to consistently produce hot mix asphalt (HMA) mixtures containing 25% to over 50% RAP. Such a high RAP content mixtures have the potential to significantly reduce the cost of HMA paving while conserving natural resources [1–3].

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http://dx.doi.org/10.1016/j.conbuildmat.2015.08.114
0950-0618/

Table 1
Rheological properties of base binders at three aging states.

Binder type	Source	Aging states						
		Unaged			RTFO	PAV		
		Viscosity (135 °C) (cP)	Failure temp. (°C)	$G^*/\sin\delta$ (64 °C) (kPa)	$G^*/\sin\delta$ (64 °C) (kPa)	$G^*/\sin\delta$ (25 °C) (kPa)	Stiffness (−12 °C) (MPa)	m-Values (−12 °C)
PG 64-22	A	465	65.6	1.23	3.70	3529	178	0.306
PG 64-22	B	650	68.5	2.13	4.16	2157	144	0.349
PG 58-28	B	315	60.2	1.38 (58 °C)	3.88 (58 °C)	3595 (19 °C)	249 (−18 °C)	0.281 (−18 °C)
RAP binder I	–	–	94.8	52.3	–	5680	–	–
RAP binder II	–	–	97.6	64.3	–	4050	–	–

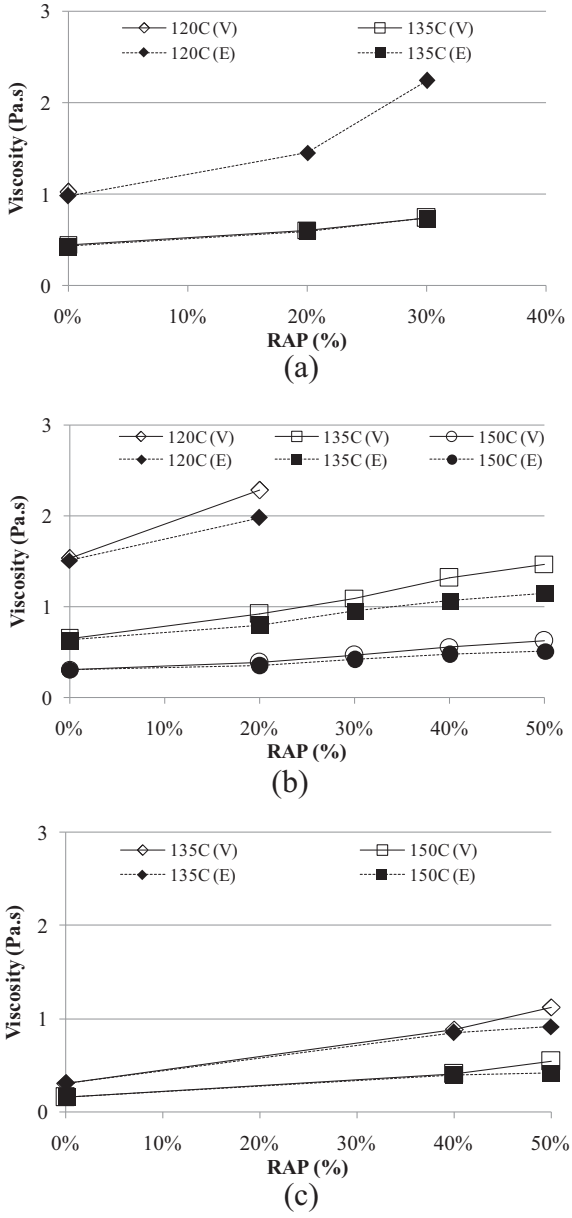

Fig. 1. Viscosity values of the binders with RAP I at various temperatures. (a) Binder A, (b) Binder B and (c) Binder C.

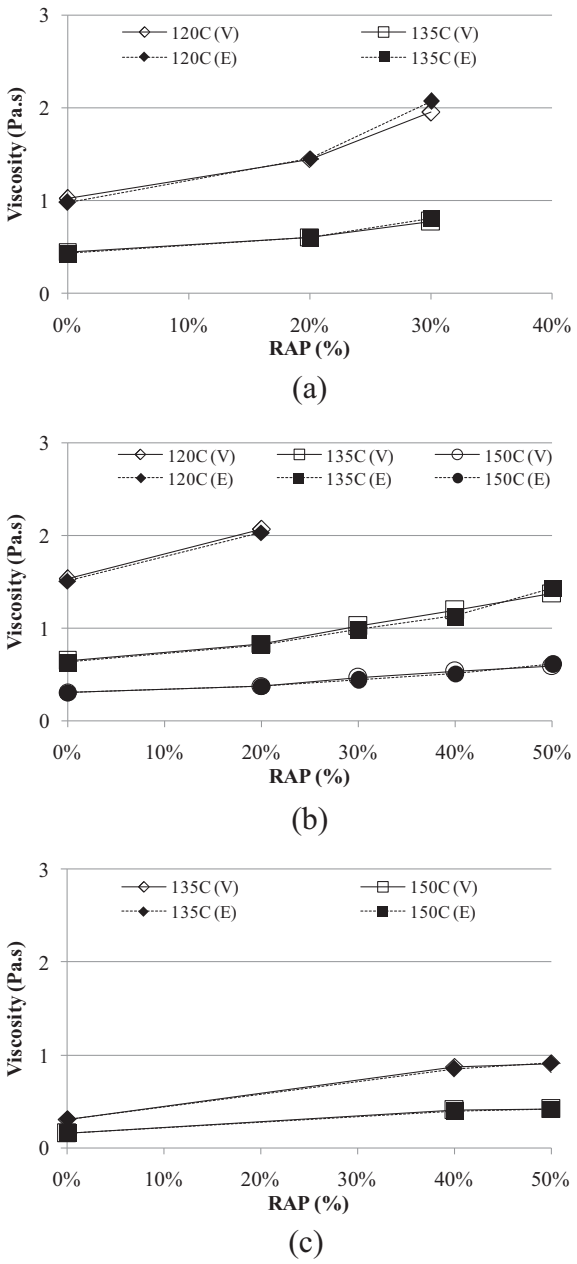

Fig. 2. Viscosity values of the binders with RAP II at various temperature. (a–c) Binders A, B, and C.

If a higher percentages of RAP, between 30% and 50%, could be used competently while still constructing pavements which meet or exceed all current standards, the cost savings to the states, and therefore to the taxpayers, would increase [6–8]. Su et al. determined that using up to 40% RAP in airport surface courses was feasible in Japan [9]. Celauro et al. determined that up to 50% RAP could be used in base, intermediate, and surface courses