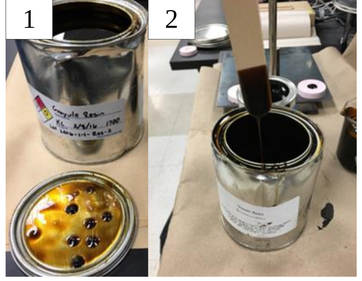

Guayule Resin: (1) at room temperature; (2) at 135°C

A Threshold to Utilize Guayule Resin as a New Binder in Flexible Pavement Industry

"Potential of solutions regarding environment, economics, and sustainability"

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OBJECTIVE:

Could we answer the following questions?

Does guayule resin have the potential to:

1. Replace asphalt cement (AC) in the asphalt pavement industry at specific grades (by itself or by adding an enhancer (e.g., crumb rubber modifier (CRM))?
2. Work as a new bio-based additive to AC or asphalt-rubber (AR)?

BACKGROUND

Guayule resin, as one of guayule whole shrub derivatives, is inevitably extracted with guayule natural rubber (the only current valuable guayule derivative) production.

Each 1kg of produced rubber is corresponding to about 1kg of resin, at least.

There is almost no current value of this resin, just a byproduct (i.e., still under research).

The only obstruction against utilizing Guayule Rubber, via previous hundred years, it is not economically affordable in its production cycle.

The solution to open the door towards this valuable source of natural rubber is yielding high-value byproducts including resin to be commercially attractive .

Yes, some researchers see that guayule byproducts such as resin, bagasse, wax, seed, and leaves have the potential to involve about 25% to 50% saving in the guayule rubber production process

As a result, guayule resin utilization in the flexible pavement industry could be an opportunity to gain two aspects: (1) get a benefit from a byproduct (cheap material) in such a massive industry like flexible pavement, in addition to (2) equilibrate the production cost of guayule extractables.

Why guayule resin?

- Guayule resin is an asphalt-like material (viscoelastic – mainly hydrocarbons)
- Present physical properties similar to asphalt at specific grades
- Bio-based material and byproduct at the same time (i.e., renewable unlike asphalt). Subsequently, in asphalt industry it has the potential to provide binder solutions regarding environment, economics, and sustainability.

MATERIALS & SAMPLING

Materials

- Asphalt cement, AC (PG52-28) – Source: Conoco Philips Terminal in Granite City
- Guayule Resin (BGR) – Source: Bridgestone Americas Center from Research and Technology (BART)
- Crumb rubber modifier (CRM 30-40), i.e., retained between mesh#30 and mesh#40 – Source: Liberty Tire Recycling

Sampling

- 15 designated binders [divided into six subsets: Neat AC, Neat BGR, AC+BGR, BGR+CRM, AC+CRM, and AC+BGR+CRM]. All of them were studied (OB vs. RTFO), whereas eight selected binders proceeded with PAV.

For blending:

- ❑ High shear Mixer (HSM-100LCI-T)
- ❑ Heating system (heating mantle (Glas-Col 100C M112) and temperature control unit (Digi-Sence TC9100))

For testing

- ❑ Rotational Viscometer (RV)
  - ➢ unaged binders' dynamic viscosity
- ❑ Dynamic Shear Rheometer (DSR)
  - ➢ unaged and RTFO aged binders' elevated temperature grades, short term aging
  - ➢ PAV binder's intermediate grade, long term aging
  - ➢ G*/Sin(δ) master curves for unaged binders
- ❑ Bending Beam Rheometer (BBR)
  - ➢ PAV binder's low temperature grade
- ❑ Rolling Thin Film Oven (RTFO)
  - ➢ Simulating the short term aging
- ❑ Pressure Aging Vessel (PAV)
  - ➢ Simulating long term aging

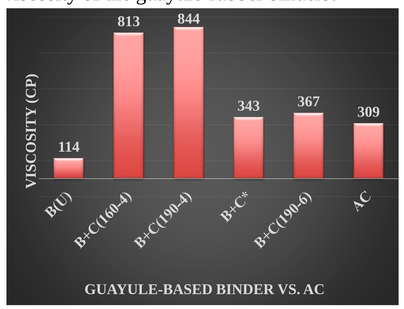
Designated Binders

Subset	Designated Binder	Binder Label	Proportions AC	Proportions BGR	Proportions CRM	Interaction Time, hr	Interaction Speed, rpm (Hz)	Interaction Temp., C	Test Conditioning
Neat BGR	Neat BGR(Unconditioned)	B(U)	__	__	__	__	__	__	OB, RTFO, PAV
	Neat BGR-3000-190(4hr)	B(4)	__	__	__	4	3000 (50)	190	OB, RTFO, PAV
	Neat BGR-3000-190(6hr)	B(6)	__	__	__	6	3000 (50)	190	OB, RTFO, PAV
BGR+CRM	BGR-CRM(10:2)-3000-160(4hr)	B+C(160-4)	__	10	2	4	3000 (50)	160	OB, RTFO, PAV
	BGR-CRM(10:1)-3000*	B+C*	__	10	1	6	3000 (50)	160, 190	OB, RTFO, PAV
	BGR-CRM(10:2)-3000-190(4hr)	B+C(190-4)	__	10	2	4	3000 (50)	190	OB, RTFO, PAV
	BGR-CRM(10:1)-3000-190(6hr)	B+C(190-6)	__	10	1	6	3000 (50)	190	OB, RTFO, PAV
AC+BGR+CRM	AC-BGR-CRM(5:5:2)-3000-190(4hr)	A+B+C(4)	5	5	2	4	3000 (50)	190	OB, RTFO
	AC-BGR-CRM(5:5:1)-3000-190(6hr)	A+B+C(6)	5	5	1	6	3000 (50)	190	OB, RTFO
	AC-BGR-CRM(7.5:2.5:1)-3000-190(6hr)	7.5A	7.5	2.5	1	6	3000 (50)	190	OB, RTFO
	AC-BGR-CRM(2.5:7.5:1)-3000-190(6hr)	2.5A	2.5	7.5	1	6	3000 (50)	190	OB, RTFO
Neat AC	Neat AC	AC	__	__	__	__	__	__	OB, RTFO, PAV
AC+BGR	AC-BGR(5:5)-3000-190(2hr)	A+B	5	5	__	2	3000 (50)	190	OB, RTFO
AC+CRM	AC-CRM(10:2)-3000-190(4hr)	A+C(4)	10	__	2	4	3000 (50)	190	OB, RTFO
	AC-CRM(10:1)-3000-190(6hr)	A+C(6)	10	__	1	6	3000 (50)	190	OB,RTFO

* 4hr interaction at 160 °C; hence, extra 2hr at 190

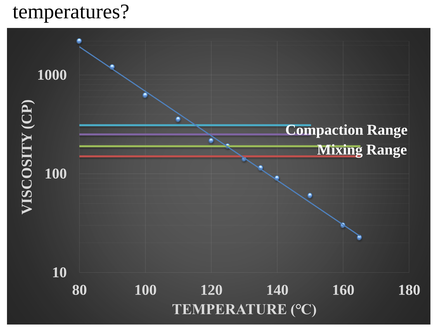
RESULTS (Following questions' answers in "FINDINGS", in order from A to G)

(A) Do CRM concentrations & interaction time and temperature affect the dynamic viscosity of the guayule-rubber binders?



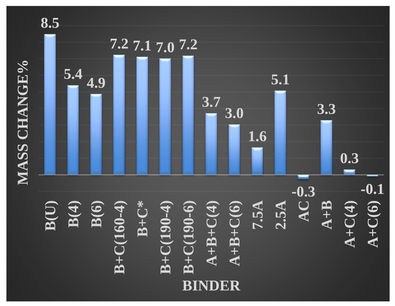
Dynamic Viscosity of Guayule-Based Binders vs. AC at 135°C

(B) Compared to the neat asphalt viscosity, could BGR present lower mixing and compaction temperatures?



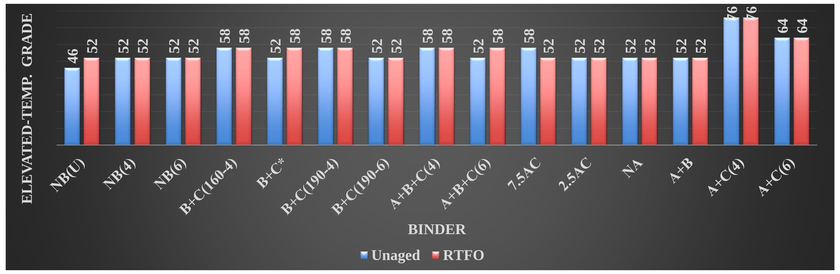
Neat BGR(Unconditioned) Viscosity-Temperature Relationship & Mixing and Compaction Ranges

(F) Compared to the neat asphalt mass loss, could BGR provide an acceptable mass loss?



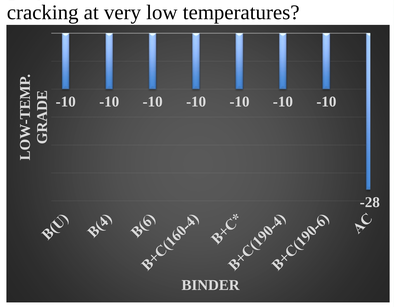
Mass Change% for All Designated Binders by RTFO Method

(C) Does BGR age the same way of AC using the scale of AC Standard regarding the elevated temperature grade?



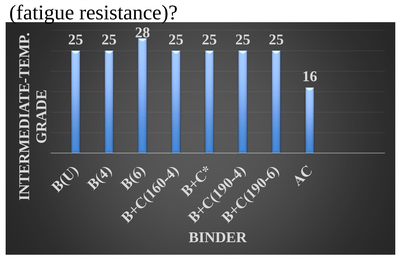
Elevated Temperature Grade of All Designated Binders (Unaged vs. RTFO Binders

(G) According to AC standard, could guayule-based binders resist the thermal cracking at very low temperatures?



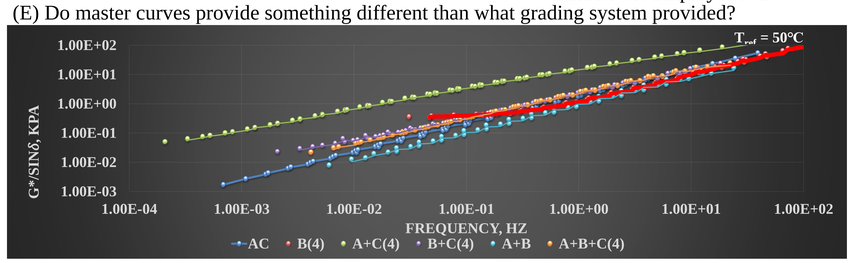
Low Temperature Grade of Guayule-Based Binders vs. Employed AC

(D) Could BGR provide an acceptable binder regarding the intermediate temperature grade (fatigue resistance)?



Intermediate Temperature Grade: Guayule-Based Binders vs. AC

(E) Do master curves provide something different than what grading system provided?



G*/Sin(δ) Master Curves of Different-Material-Involved Binders

FINDINGS

(Answering the offered questions upon results)

(A) Yes – significant effect – Neat BGR viscosity is 114cP, compared to 309cP for AC (at 135°C) increased to about three times with 10%CRM and about 7-8 times with 20%CRM.

(B) Yes – at 170±20cP, BGR has a mixing temperature range of 124.5°C-129°C. At 250±30cP, it has a compaction temperature range of 116°C-119.5°C.

(C) Yes – Applying the AC specs on the guayule-based binders indicated a resultant elevated temperature grade of unaged binder (corresponding to G*/Sin(δ) of 1 kPa) reasonably compared to the attributed one to the RTFO aged binder (corresponding to G*/Sin(δ) of 2.2 kPa).

(D) Yes – All guayule-based binders achieved 25°C as intermediate-temperature grade except for B(6), 28°C, while AC produced 16°C – significant difference. However, all guayule-based binders accomplished at least the minimum requirements concerning Superpave specs except for B(6) indicating the more the BGR heat treated the more the aromatics it lost.

(E) Yes – Even though, all trends almost seem to be normal with considering the grading system, Neat BGR provided the so-called ascending sag curve (ASC) – Yes, it seems to have a lower trend than others at higher frequencies, but at lower frequencies it significantly provides a much better performance than others. That could take our thinking in the future to direct our research towards how to exploit BGR in low frequency applications (e.g., parking lots and traffic queues).

(F) No – unfortunately guayule-based binders yielded a high mass loss when applying the AC specs – Justifying that BGR has very low molecular weight components that are easily evaporate during the short term aging simulation (RTFOT) – Further investigation is required in the future.

(G) Relatively, no – Whether Neat BGR or CRM-modified BGR binders resulted in a low temperature grade of -10 °C, but at least BGR has the potential to provide binders acceptable at specific grades upon the location of utilization.

CONCLUSIONS

- BGR could provide binders with lower viscosity than the corresponding AC (reflecting more construction, cost savings and workability).
- 20% of CRM enhanced BGR by about one grade, compared to about 4 grades for AC.
- Master curves exposes the significance of guayule that could be exploited at very low traffic speed applications (e.g. parking lots and traffic queues).
- Mass loss was observed significantly high, compared to AC. However, mass change is a debatable issue; determined ±1% by specs for AC regarding the environmental aspect which is not the same hazards regarding bio-binders. Furthermore, many studies created upon bio-binders resulted in high mass losses as well.
- Upon BBR testing, results indicate a pass at 0°C testing temperature for all guayule-based binders. However, all did not pass at lower temperatures. Adding 10% or 20%CRM do not denote a positive behavior of the designated binders at low temperatures.
- Ultimately, the guayule resin has the potential as a bio-material to break through the asphalt (flexible pavement) industry as it has the potential to contribute with economic, environmental and sustainable aspects.
- Furthermore, chemical and further physical testing could help improve the related interactions to accomplish better performance in the future.

ACKNOWLEDGMENTS

We would like to show our gratitude to Bridgestone Corp for creating guayule resin that we worked on in addition to their assistance for information we requested.

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Any perspectives, outcomes, discussions, and conclusions expressed in this study are those of writer(s).