Effect of bio materials and polymer modifiers on the performance properties of recycled asphalt binders

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Introduction

Asphalt roads' maintenance and construction work require massive amounts of non-renewable fossil-based products and natural aggregates annually. To mitigate environmental problems and to promote the transition to a circular and bio-based economy, the use of sustainable materials in asphalt pavement is in urgent demand [1]. Different waste materials, including recycled asphalt pavement (RAP) and bio-based products, have been attempted in asphalt construction [1]. In the recent past, wood-based by-products, and particularly lignin and Tall Oil Pitch (TOP) (residue from the distillation of crude tall oil, which is a by-product of the paper industry), have been tried to be used in asphalt materials as additives or to replace partially or completely the fossil-based binders [3]. Since their use allows to lower the overall environmental footprint of asphalt materials, generating in some cases carbon-neutral materials for paving construction, the industry is looking at the potential use of these bio-based materials to replace the fossil-based binder. And their use in combination with RAP could help in saving more natural resources. However, the performances of these bio-based binders highly depend on the source, the process used to obtain them, and the materials and additives used in combination with them [3].

Materials and methods

In the present work, a Bio-based polymer modified binder (Bio 25/55-55) was produced starting from a plain binder 30/45 and adding 5% of TOP and 3.5% of SBS to it. These quantities of TOP and SBS were decided to achieve the Penetration and Softening Point of a reference polymer modified binder 25/55-55 (Ref. 25/55-55). The blending protocol was based on ASTM D 4887. Moreover, bituminous blends composed with the Bio 25/55-55 and 50% RAP binder were produced. The RAP binder was extracted with a rotatory evaporator from a real RAP source (EN 12697-3). All the binders' traditional properties, such as Penetration and Softening Point, were evaluated with the Performance Grade (PG) (AASHTO M320). In addition, the performance properties at high, intermediate, and low temperatures were investigated with different testing protocols and aging conditions using the DSR and BBR. The complete testing plan with the research approach is reported in the flow chart in Figure 1.

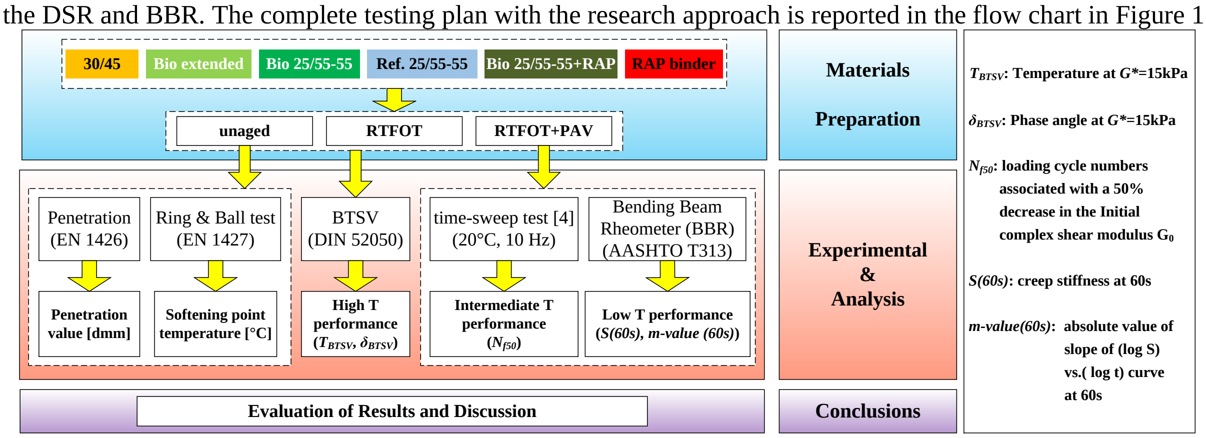

Figure 1. Research approach.

Results

The traditional properties are summarized in Table 1, and the overall performance properties in terms of rutting, fatigue, and thermal cracking, together with the PG, are summarized in Figure 2. The addition of TOP makes the binder 30/45 softer and more viscous, remarkably increasing the penetration and decreasing the softening point (Table 1). This trend is also true in the performance parameters. In particular, T_{BTSV} (Figure 2a) and $S(t)$ decrease significantly (Figure 2c); while δ_{BTSV} (Figure 2a) and *m-value* increases (Figure 2d). Moreover, from the BTSV results, the bio extended binder seems to be more sensitive to aging since the temperature differences between the aged and unaged conditions are higher than the plain binder 30/45. These effects in terms of PG imply that the bio extended binder loses one PG grade in the high temperature range but gains one PG grade in the low temperature domain. For fatigue, the addition of TOP considerably improves the material performance (Figure 2b).

When SBS is added to the bio extended, the bio-based binder becomes harder and less viscous, the penetration drastically reduces, and the softening point increases. These effects are also visible in the performance parameters: T_{BTSV} and $S(t)$ increase, while the δ_{BTSV} decreases. The *m-value* is slightly higher than the bio extended one. It is important to highlight that the chosen formulation of the Bio 25/55-55 can reach similar high and low temperature properties of the Ref. 25/55-55. Both the binders have, in fact, the same PG (Figure 2d). Regarding fatigue performances, incorporating SBS in the bio-extended binder has a great positive influence. However, the Bio 25/55-55 cannot reach the fatigue performances of the Ref. 25/55-55 in the range of the tested strain levels, but it shows better fatigue behavior for higher strain levels since the slope of its Wohler line is lower.

The addition of 50%RAP in the Bio 25/55-55 stiffens the material, significantly lowering the penetration value but not affecting the softening point. The T_{BTSV} increases and both the BTSV parameters take a position along the blending line. Moreover, the addition of RAP remarkably increases the *S(t)*. At the same time, the *m-value* shows a slight decrease compared to the Bio 25/55-55, and in fact, the resulting low PG is one grade less in comparison to all the other binders. Regarding the intermediate temperature performances, as expected, the addition of RAP causes a significant worsening of the fatigue response. This effect could also be attributed to the higher initial complex shear modulus of the blend containing RAP.

Table 1. Penetration [dmm] and softening point [°C] of the binders.

Binder Type	Penetration	Softening Point	Binder Type	Penetration	Softening Point
30/45	37	57.6	Ref. 25/55-55	43	59.1
Bio extended	88	46.2	Bio 25/55-55+RAP	19	64.0
Bio 25/55-55	41	62.6	RAP binder	12	73.2

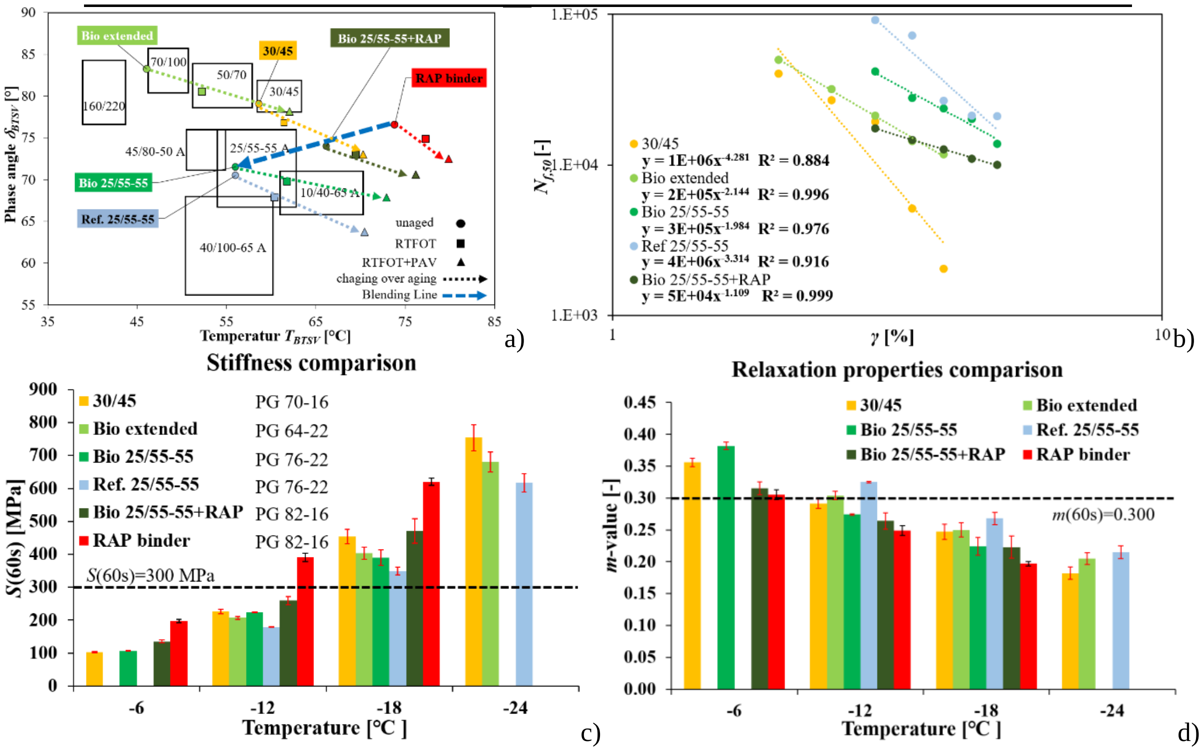

Figure 2. Performance properties: a) in the high temperature range, BTSV plane; b) in the intermediate temperature range, Wöhler curves; c) in the low temperature range, S(60s); d) m(60s)

Conclusions

Results showed that the chosen formulation of Bio 25/55-55 was able to achieve similar rutting and thermal cracking performances of the Ref. 25/55-55. It was not able to reach similar performances for the investigated strain levels for fatigue resistance, but it seems to have better fatigue properties for higher strain levels. Moreover, the addition of RAP in the Bio 25/55-55 showed better high temperature properties and slightly lower fatigue and thermal cracking resistance. It can be concluded that a bio polymer modified binder with a proper formulation can achieve similar performance properties to a reference polymer modified binder providing a valid alternative to fossil-based binder. Further studies on the possibility of adding a higher percentage of TOP are under experimental investigation.

References

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