engineering proceedings

MDPI

Abstract

Evaluation of binder-aggregate adhesion in hot-recycled asphalt mixtures as a function of the production temperature†

Edoardo Bocci [1,*], Emiliano Prosperi [2] and Maurizio Bocci [2]

[1] Università eCampus, via Isimbardi 10, 22060 Novedrate (CO), Italy; edoardo.bocci@uniecampus.it
[2] Department of Construction, Civil Engineering and Architecture, Università Politecnica delle Marche, via Brecce Bianche, 60131 Ancona, Italy; e.prosperi@pm.univpm.it (EP); m.bocci@univpm.it (MB)
* Correspondence: edoardo.bocci@uniecampus.it; Tel.: +39 338 467 7744
† Presented at IOCI2022, 7-9 June 2022.

Keywords: asphalt concrete; reclaimed asphalt; hot recycling; adhesion; temperature.

When recycling reclaimed asphalt (RA) in new hot-mix asphalt (HMA), the temperature of the mix components (mainly virgin aggregate, RA and virgin bitumen) can vary in a wide range [1]. Higher temperatures of the virgin aggregate allow the mobilization of a higher amount of the binder in the RA. However, this implies a more severe short-term aging of the virgin bitumen and poorer properties of the aged-virgin bitumen blend, due to the lower virgin bitumen/RA bitumen ratio [2]. On the contrary, the adoption of lower temperatures has the opposite effect (lower mobilization of the RA binder but higher performance of the bituminous blend). In addition, the reduction of material heating results in a lower bitumen viscosity, which may determine lower compactability and lower adhesiveness. Previous studies showed that a reduction of 30 °C in the mixing temperature of HMA containing RA does not imply a significant increase of the air voids content but allows improving the material performance against cracking, fatigue, and rutting [3]. Moreover, the lower mixing temperature also preserves the effectiveness of the rejuvenating agent [4]. To have a deeper understanding of this phenomenon, the adhesive properties between binder and aggregate were investigated through the simulation of a hot recycled HMA production in the laboratory, adopting two mixing temperatures.

The objectives of the research were: (i) evaluating how the binder adhesive properties changes when varying the content of aged bitumen; (ii) assessing if the adhesion is higher on virgin aggregate or on RA particles, coated with aged bitumen; (iii) understanding how the blending temperature influence the binder-aggregate adhesion.

To this aim, binder bond strength (BBS) tests were carried out using a self-aligning PATTI (Pneumatic Adhesion Tensile Testing Instrument) device, according to AASHTO TP-91. The experimental program provided 2 types of substrates, simulating virgin limestone aggregate and RA, 3 RA/virgin binder proportions (20/80, 35/65 and 50/50), 2 types of rejuvenator in the binder (coded with the letters A and B), 2 bitumen application temperatures (140 °C and 170 °C), and 5 repetitions. In particular, a 50/70 penetration bitumen was used as virgin binder. To reproduce the RA substrate, the virgin bitumen at 170 °C was spread on hot limestone plates with an average thickness of about 10 μm. Then, the plates were aged in the oven at 135 °C for 4 h and 85 °C for 120 h, according to AASHTO R30. The same 50/70 virgin binder was aged in the laboratory using RTFOT (163 °C for 85 min) and PAV (100 °C and 2.1 MPa for 20 h) devices to reproduce the RA bitumen. The aged and virgin binders were blended with ratios 20/80, 35/65 and 50/50 to investigate different mobilization rates of the RA bitumen. In this step, 9% by aged bitumen weight of rejuvenator (A or B) was added. The binder blending and pull-stub gluing were carried out at 140 °C or 170 °C. The BBS tests were performed at 25 °C.

Citation: Last name, F.; Last name, F.; Last name, F. Title. *Eng. Proc.* **2022**, *x*, x. https://doi.org/10.3390/xxxxx

Published: date

Figure 1 shows the measured values of pull-off tensile strength (POTS).

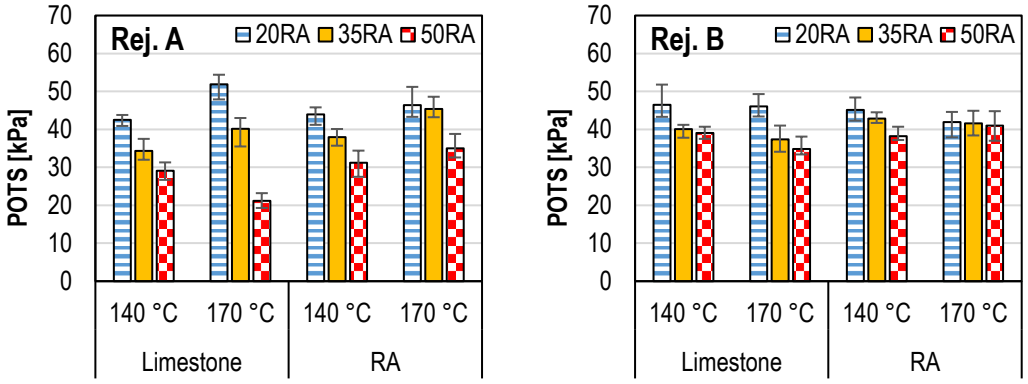

Figure 1. Pull-off tensile strength (POTS) values.

It can be immediately noted that the adhesive properties of the binder decreased when increasing the aged bitumen content from 20% to 50%. As the BBS tests provided quite dispersed data, a statistical analysis was carried out through t-test. The α values obtained when comparing the POTS of the blends with 20% and 35% of RA bitumen and the blends with 35% and 50% of RA bitumen were respectively 1.2×10^{-6} and 6.1×10^{-7}, confirming the decreasing trend of POTS with aged bitumen content. Moreover, the graphs in Figure 1 show that, for high RA bitumen contents (35% and 50%), the adhesion on the RA substrate was higher than on the limestone substrate (α = 0.004). Between the two rejuvenators, the type B allowed obtaining higher POTS values for high RA bitumen contents (35% and 50%), as confirmed by α = 0.008. Differently, the bitumen application temperature (140 °C or 170 °C) did not significantly influence the POTS (α = 0.50). This indicates that the increase of adhesiveness that can be obtained at higher temperature was approximately balanced by the more severe aging underwent by the binder. However, as in site the lower mixing temperature implies the lower mobilization of the RA binder, thus a lower RA/virgin bitumen proportion, from the experimental results it can be stated that the reduction of the mix temperature is beneficial for the adhesion between the binder and both the virgin and the pre-coated RA aggregates.

The promising findings of the research encourages further studies on hot-recycling of RA at reduced mixing temperatures, also adopting warm mix asphalt solutions.

Author Contributions: Conceptualization, E.B. and M.B.; methodology, E.B.; formal analysis, E.P.; investigation, E.P.; data curation, E.B.; writing—original draft preparation, E.B.; writing—review and editing, E.P.; supervision, M.B. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest

References

1. Ma, X.; Leng, Z.; Wang, L.; Zhou, P. Effect of Reclaimed Asphalt Pavement Heating Temperature on the Compactability of Recycled Hot Mix Asphalt. *Materials* **2020**, 13, 3621. https://doi.org/10.3390/ma13163621
2. Lo Presti, D.; Vasconcelos, K.; Orešković, M.; Menegusso Pires, G.; Bressi, S. On the Degree of Binder Activity of Reclaimed Asphalt and Degree of Blending with Recycling Agents. *Road Mater Pavement* **2020**, 21(8), 2071-2090. https://doi.org/10.1080/14680629.2019.1607537
3. Marsac, P.; Bocci, E.; Cardone, F.; Cannone Falchetto, A.; Carbonneau, X.; Zaumanis, M.; Carter, A.; Rubio-Gámez, M.C.; Del Sol Sánchez, M.; Dave, E.V.; Tebaldi, G. International Evaluation of the Performance of Warm Mix Asphalts with High Reclaimed Asphalt Content. *RILEM Bookseries* **2022**, 27, 19-25. https://doi.org/10.1007/978-3-030-46455-4_3
4. Prosperi, E.; Bocci, E.; Bocci, M.: Evaluation of the Rejuvenating Effect of Different Additives on Bituminous Mixtures Including Hot-Recycled RA as a Function of the Production Temperature, *Road Mater Pavement* **2021**. https://doi.org/10.1080/14680629.2021.2002179