RAP pre-treatment for fast cold in-place recycling

Lin, P.; Liu, X.; Ren, S.; Li, Y.; Erkens, S.; Welvaarts, B.; Brouns, K.

DOI
10.1201/9781003387374-16

Publication date
2024

Document Version
Accepted author manuscript

Published in
Advances in Functional Pavements

Citation (APA)
Lin, P., Liu, X., Ren, S., Li, Y., Erkens, S., Welvaarts, B., & Brouns, K. (2024). RAP pre-treatment for fast cold in-place recycling. In Y. Zhang, G. Airey, M. Rahman, & H. Wang (Eds.), *Advances in Functional Pavements: Proceedings of the 7th Chinese-European Workshop on Functional Pavements, CEW 2023* (pp. 78-82). CRC Press / Balkema - Taylor & Francis Group. https://doi.org/10.1201/9781003387374-16

RAP Pre-treatment for Fast Cold In-Place Recycling

P. Lin, X. Liu, S. Ren, Y. Li, S. Erkens,
Civil Engineering and Geosciences, Delft University of Technology, Delft 2628CN, the Netherlands;

B. Welvaarts & K. Brouns

De Jong Zuurmond, Katijdeweg 20, 4153 RG Beesd, the Netherlands

ABSTRACT: Polyurethane-modified asphalt mixtures are a promising pavement material due to their superior performance. Delft University of Technology has developed a three-component polyurethane modified cold binder (PMCB) for fast in-place recycling, which has demonstrated improved durability and strength. However, moisture in reclaimed asphalt pavement (RAP) causes difficulties in using PMCB for in-place recycling. To address this issue, Calcium dioxide (CaO) was used to treat the wet RAP, followed by the addition of PMCB to prepare the asphalt mixture. In this research, the performance of the asphalt mixture was characterized using indirect tensile strength test before and after moisture conditioning and Cantabro test. The results showed that treating the wet RAP with CaO is a feasible way for fast in-place recycling using PMCB, which offers potential benefits for sustainable pavement construction.

1 INTRODUCTION

The polyurethane-modified asphalt mixture is an emerging pavement material due to its superior performance, with the thermosetting polyurethane dispersed in the continuous phase of bitumen(Cong *et al.* 2019, p.). The uniform distribution of polyurethane in the bituminous binder significantly enhances its tensile strength, resulting in excellent road performance and successful use in porous pavements(Chen *et al.* 2018). However, the high-temperature mixing requirement for polyurethane-modified bitumen limits its suitability for cold in-place recycling of reclaimed asphalt pavement (RAP) materials (Singh *et al.* 2006, Lu *et al.* 2019).

To overcome this limitation, a three-component polyurethane modified cold binder (PMCB) was developed at Delft University of Technology(Lin *et al.* 2022). The PMCB is in a liquid state at ambient temperature, and the three components can be mixed at a designed ratio in the field to trigger the condensation reaction of polyis°Cyanate and polyol, similar to that in polyurethane modified bitumen. However, RAP often contains water due to the need to protect the milling machine during the crushing and milling pr°Cess and can pick up additional moisture if exposed to rain, hindering the application of PMCB for fast cold in-place recycling(Ayazi *et al.* 2017). To address this issue, calcium oxide (CaO) was introduced to decrease the water amount in RAP and increase the temperature to accelerate the reaction of PMCB.

2 MATERIAL

2.1 *Polyurethane-modified bitumen binder (PMCB)*

A three-component PMCB was designed for the quick in-place recycling of reclaimed asphalt. The three-component PMCB can be mixed at the designed ratio at room temperature in the field (5 $^{\circ C}$~35 $^{\circ C}$) as the viscosity of the PMCB is not strongly affected by temperature. After homogeneously mixing, the polymerization reaction started, and PMCB transferred from the liquid state to the solid state in the following hours. Meanwhile, based and detailed information on base bitumen, PMCB and bitumen can be seen in Table 1.

Table 1 Basic physical properties of binder samples

Properties	Measurement
Base Bitumen	

Penetration at 25°C, 100g, 5s (0.1-mm)	76
Softening point (°C)	50.2
PG-Grade	PG 64-16
Viscosity @ 130 °C (Pa·s)	0.54
Polyurethane Modified Cold Bitumen (PMCB)	
Viscosity at beginning @ 15 °C (Pa.s)	1.62
Viscosity at beginning @ 25 °C (Pa.s)	1.58

2.2 *Polyurethane modified cold asphalt mixture (PMCM)*

To assess the performance of PMCB in mixtures, cylindrical specimens of polyurethane modified cold asphalt mixture (PMCM) were prepared using a Superpave gyratory compactor (SGC). The gradation of PA-16 asphalt mixture specimens adhered to the mid-value of the recommended gradation outlined in the specification (RAW-2015), as presented in **Table 2**.

Table 2 Gradation of PMCM mixture.

Asphalt Mixture	Quality percentage of passing following sieves [mm (%)]						
	22	16	11.2	8	5.6	2	0.063
PA-16	100	96.5	77.5	42.5	22.5	15	6

To investigate the feasibility of using PMCB in moist conditions with the aid of CaO, a series of mixture specimens were prepared and outlined in **Table 3**. The RAP materials were collected from the field and sieved to create PMCM specimens containing nearly 100% RAP with varying binder content. The benchmarks included PA16-RAP+Bit and PA16-Agg+Bit. Based on extraction test results, the bitumen content in the RAP was found to be 4.2%, and thus, an additional 1.3% virgin bitumen was added to supplement the bitumen content in PA16-RAP+Bit. PA16-Agg+Bit, on the other hand, was prepared with fresh aggregate and base bitumen to represent fresh porous asphalt mixture.

Table 3 Composition of tested mixture samples

Sample	Solid materials (100%)				Liquid materials		
	RAP (%)	Fresh Aggratge (%)	Filler (%)	CaO (%)	Water (%)	Bitumen (%)	PMCB (%)
PA16-Agg+Bit	0	95	5	0	0	5.5	0
PA16-RAP+Bit	100	0	0	0	0	1.3	0
PMCM-5.0%	95	0	0	5	5	0	5
PMCM-5.5%	95	0	0	5	5	0	5.5
PMCM-6.0%	95	0	0	5	5	0	6
PMCM-7.0%	95	0	0	5	5	0	7

3 REULTS AND ANALYSIS

3.1 *Indirect tensile strength test results*

In order to determine the optimum binder content for PMCM samples, the indirect tensile test (ITT) was conducted at 15 ºC according to the specification (NEN-EN 12697-23). The area under this curve represents the dissipated work G when the PMCM sample is completed failure. The peak force P represents the maximum loading capacity of the sample. It should be noted that the optimum PMCB binder content is investigated based on the PMCM mixture utilized with wet RAP materials and treated with 5% of CaO.

To investigate how binder content affects the mechanical response of PMCM specimens, PMCM specimens with varying binder content were prepared and subjected to an indirect tensile test. The ITS and dissipated work results at 15°C are presented in Figure 1. The results showed that increasing the PMCB binder content had a positive impact on the mechanical response of PMCM mixture specimens, with an increase in indirect tensile strength and dissipated work. When the PMCB binder content was over 5.5%, the ITS of PMCM outperformed that of PA16-

Agg+Bit, indicating that the tensile strength of PMCM specimens was superior to that of representative hot mixed asphalt mixture. However, even at a PMCB binder content of 7%, the dissipated work of PMCM did not perform as well as PA16-Agg+Bit.

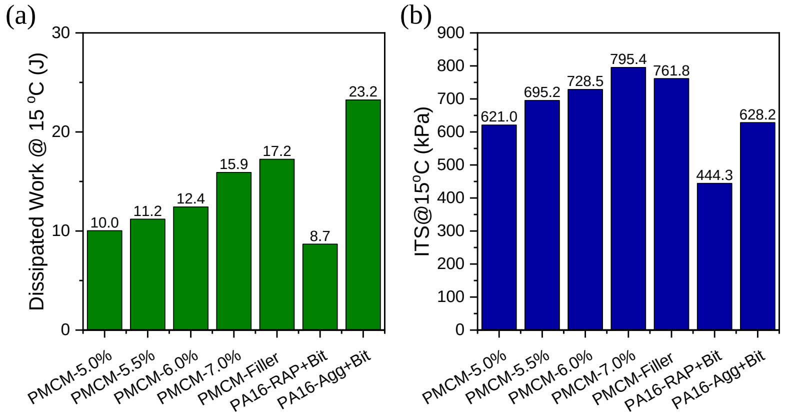

Figure 1 Influence of binder content on the indirect tensile strength and dissipated work at 15 ℃

3.2 *Indirect tensile strength ratio results*

Indirect tensile strength ratio (ITSR) can be used to evaluate the effect of water on asphalt mixtures. The tests were conducted according to EN 12697-12.

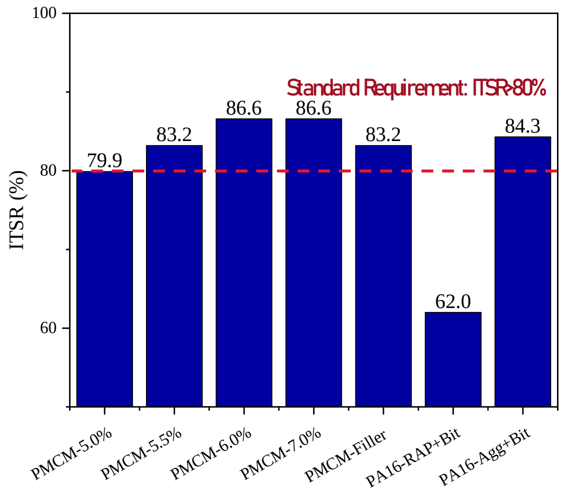

Figure 2 Indirect tensile strength ratio of recycled asphalt mixture

Figure 2 displays that the ITSR of PMCM and PA16-Agg+Bit surpass the standard requirement (80%) when the PMCB binder content exceeds 5.5% with the assistance of CaO. However, the ITSR of PA16-RAP+Bit falls below the standard requirement, indicating that 100% RAP hot recycling encounters water stability issues. In contrast, PMCM can meet this requirement when the PMCB binder content exceeds 5.5%. Furthermore, when the PMCB binder content reaches more than 6%, the moisture damage resistance of PMCM even outperforms that of porous asphalt with fresh aggregate and base bitumen.

3.3 *Cantabro test results*

The Cantabro loss test was conducted to evaluate the raveling resistance of the porous asphalt specimen, according to the specification NEN-EN 12697-17. Prior to the start of testing, the specimens shall be stored on a flat surface at room temperature (20 °C) for three days from their manufacture time. The scheme of the Cantabro loss test can be seen in Figure 3.

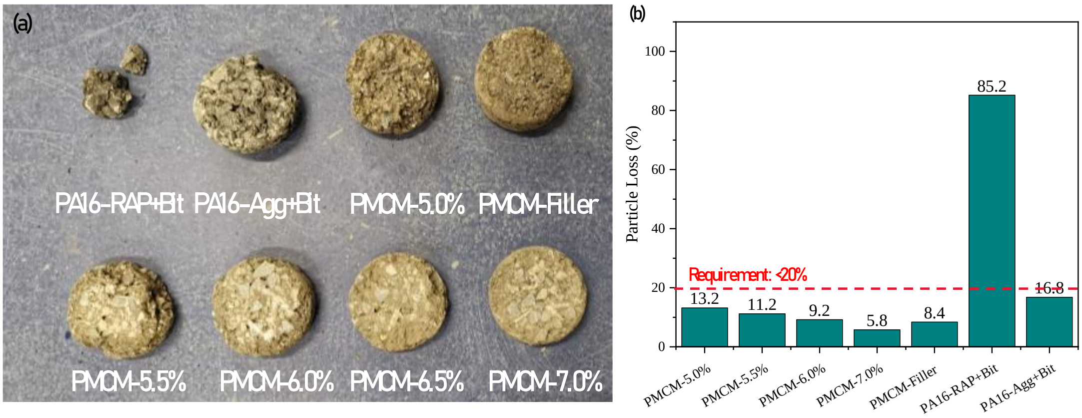

Figure 3 Cantabro particle loss ratio of recycled asphalt mixture

The results in Figure 3 demonstrate that the PA16-RAP+Bit asphalt mixture with 100% RAP has a significant issue with raveling resistance, as indicated by a particle loss value of 85.2%. Even for the PA16-Agg+Bit mixture, the particle loss value is still relatively high at 16.8%, which is close to the required standard of 20%. In contrast, the particle loss ratio of PMCM specimens decreased as the PMCB content increased. The PMCM specimen with a PMCB content of 5.5% showed the lowest particle loss value of only 11.2%, which is well below the required 20% in the specification. These findings suggest that PMCM samples have an advantage in raveling resistance compared to hot recycled asphalt mixtures.

4 CONCLUSIONS

Based on the ITS, ITSR, and Cantabro loss test results, treating the wet RAP with CaO is a feasible way for fast in-place recycling using PMCB, which offers potential benefits for sustainable pavement construction. 5.5% of PMCB binder is recommended as the optimum amount for the RAP utilized in this study.

5 PREFERENCES

Ayazi, M.J., Moniri, A., and Barghabany, P., 2017. Moisture susceptibility of warm mixed-reclaimed asphalt pavement containing Sasobit and Zycotherm additives. *Petroleum Science and Technology*, 35 (9), 890–895.

Chen, J., Yin, X., Wang, H., and Ding, Y., 2018. Evaluation of durability and functional performance of porous polyurethane mixture in porous pavement. *Journal of cleaner production*, 188, 12–19.

Cong, L., Yang, F., Guo, G., Ren, M., Shi, J., and Tan, L., 2019. The use of polyurethane for asphalt pavement engineering applications: A state-of-the-art review. *Construction and Building Materials*, 225, 1012–1025.

Lin, J., Wei, T., Hong, J., Zhao, Y., and Liu, J., 2015. Research on development mechanism of early-stage strength for cold recycled asphalt mixture using emulsion asphalt. *Construction and Building Materials*, 99, 137–142.

Lin, P., Liu, X., Erkens, S., Welvaarts, B., and Brouns, K., 2022. Investigation of Polyurethane Modified Cold Bitumen for Fast Cold In-Place Recycling. *Transportation Research Record*, 03611981221115727.

Lu, G., Liu, P., Wang, Y., Faßbender, S., Wang, D., and Oeser, M., 2019. Development of a sustainable pervious pavement material using recycled ceramic aggregate and bio-based polyurethane binder. *Journal of Cleaner Production*, 220, 1052–1060.

Singh, B., Gupta, M., and Kumar, L., 2006. Bituminous polyurethane network: Preparation, properties, and end use. *Journal of applied polymer science*, 101 (1), 217–226.