Performance comparison analysis of cold recycled mixture of emulsified asphalt using 100% rap before and after the adding of cement

To cite this article: Yanan Li *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **300** 032023

Performance comparison analysis of cold recycled mixture of emulsified asphalt using 100% rap before and after the adding of cement

Yanan Li[1], Liang Fan[2], Hui Wei[2] and Yuzhen Zhang[1, *]

[1]China University of Petroleum, Qingdao, Shandong Province, 266580, China
[2]Shandong Transportation Research Institute, Jinan, Shandong Province, 250000, China

*Corresponding author e-mail: zhangyuzhen1959@163.com

Abstract. Cement can influence the performance of cold recycled mixture of emulsified asphalt (CRMEA) significantly. A comparative study on the performances of CRMEA before and after the adding of cement was carried out here. In this experiment, four types of emulsified asphalt were prepared by using four heavy-duty 70# asphalt as the raw materials. These emulsified asphalt were blended with 100% reclaimed asphalt pavement (RAP) when no cement was added or 1.5% cement was added. Specimens were made by the improved Marshall test method, and a series of performance characterizations were performed. Results demonstrate that the porosity of the CRMEA is increased after cement is added. The Marshall stability is improved under both 40°C and 60°C, and the Marshall stability under 60°C increases more pronounced compared with that under 40°C. In addition, the splitting strength increases and the bonding performance of CRMEA are enhanced with the addition of cemen.

1. Introduction

Asphalt pavement which has abundant advantages is extensively used in highway construction. Asphalt pavement suffers slow and continuous aging during the service period due to the influence by the water, UV and oxygen. Moreover, asphalt pavement is easy to develop many diseases like tracks and falling off of surface aggregates with the rapid increase of traffic load and number of heavy-load and overload vehicles. As a result, some asphalt pavements are destroyed far before the designed service life and the road maintenance workload is increasing continuously. According to statistical data, about 14% asphalt pavements in China needs large-scaled or small-scaled maintenances every year, which brings a considerable amount of RAP materials [1]. Traditional pavement maintenance methods mainly include direct adding a thick or thin asphalt concrete cover, reconstruction of destroyed pavement, and so on. These traditional methods have great defects. On the contrary, asphalt pavement regeneration technique has many advantages [2]. As one of asphalt pavement regeneration techniques, cold recycling technology of emulsified asphalt can reuse RAP materials into road maintenance and form an industrial chain conforming to the circular economy pattern. Moreover, the cold recycling technology of emulsified asphalt can avoid land occupation and environmental pollution of waste asphalt materials, reduce consumption of nonrenewable resources (e.g. aggregates and asphalt), and lower the cost for road construction and maintenance significantly. The survey of Federal Highway Administration reported that the asphalt recycling technique saves more than 50% of material cost, about 50% of asphalt consumption and about 25% of road construction costs compared with traditional techniques [3].

Some research pointed out that the properties of cold recycled mixture of emulsified asphalt or foamed asphalt was unsatisfying under heavy traffic loads [4]. Therefore, cement, lime and fly ash are used more and more as additives to improve performances of cold recycled mixture [5-7]. Most researches have verified the important role of cement in improving the initial strength and pavement performance of CRMEA recently, and the cement has become an indispensable additive in the cold recycling of emulsified asphalt [8-10]. Therefore, a comparative study on the performances of CRMEA using 100% RAP before and after the adding of cement was carried out in this paper.

2. Experimental

2.1. Materials

CRMEA is the mixture of RAP, new aggregates, emulsified asphalt, cement and water according to certain proportions. In this experiment, 100% RAP without new aggregate was applied. The RAP was collected from the overhaul milling materials of the Qingdao Jiaozhou Bay Highway. Experimental gradation was determined by combining requirements of Technical Specifications for Highway Asphalt Pavement Recycling [11] on design gradations of CRMEA and the practical size data of RAP. The results are shown in Table 1.

Table 1. Experimental gradation using 100% RAP

Sieve size/mm	0.075	0.15	0.3	0.6	1.18	2.36	4.75	9.5	13.2	16	19	26.5
Upper limit	8	—	21	—	—	50	65	80	—	—	100	100
Lower limit	2	—	3	—	—	20	35	60	—	—	90	100
Experimental gradation	3	4	6	9	15	27	50	74	85	92	97	100

For reducing influences of gradation difference on experimental results to the maximum extent, the RAP was firstly sieved to 12 grades by the sieve shaker according to the size from 0.075 mm to 26.5 mm and then the RAP stored separately by size are combined into experimental gradation according to the passing percent of each sieve size. In the experiment a slow-cleavage and slow-setting cationic emulsified asphalt made in the laboratory was used. The cement used the ordinary Portland cement with a strength grade of 32.5 and the water applied ordinary tap water in the laboratory.

2.2. Methods

RAP of experimental gradation were stirred evenly in a small mixing pot in the laboratory. Subsequently, the water was added to stir the aggregate by 90 s until the aggregate surface was wet completely. Then the emulsified asphalt was added and stirred by another 90 s, specimens were molded by the improved Marshall test method at last, 4 specimens in each group.

2.2.1. Determination of water content. With references to Test Methods of Soils for Highway Engineering [12] the optimal water content corresponding to the chosen experimental gradation was determined by a geotechnical test. The results are shown in Figure 1.

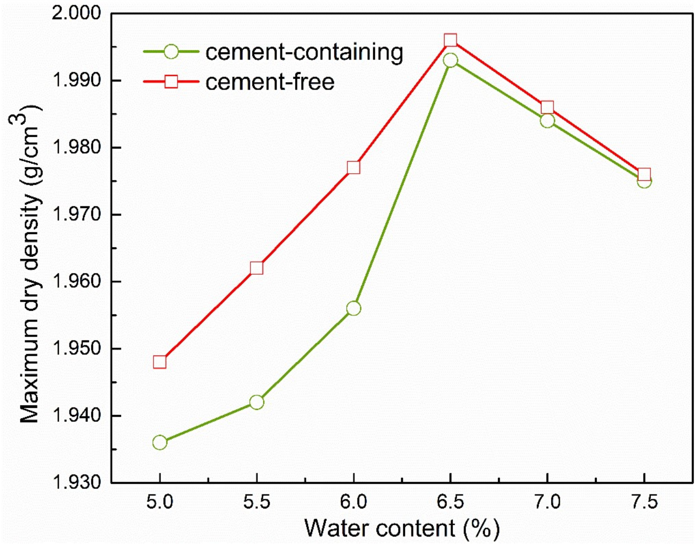

Figure 1. Relationship between maximum dry density and water content

According to experimental results, the water content was determined 6.5% no matter whether cement was added or not.

2.2.2. Determination of emulsified asphalt content. The cement content and water content were determined 1.5% and 6.5%, respectively. Specimens with different emulsified asphalt contents including 2.0wt%, 2.5wt%, 3.0wt%, 3.5wt%, 4.0wt%, 4.5wt%, 5.0wt% and 5.5wt% were prepared by the abovementioned method. Marshall stability tests and indirect tensile tests of these specimens were carried out by the T0709 and T0716 methods in Standard Test Methods of Bitumen and Bituminous Mixture for Highway Engineering [13]. The results are presented in Figure 2.

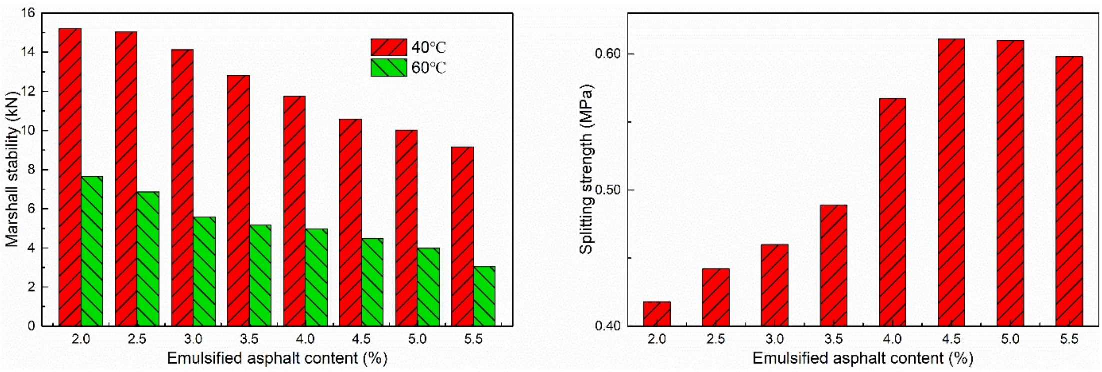

Figure 2. Determination of emulsified asphalt content

Both the Marshall stability under 40°C and 60°C decreases gradually with the increase of emulsified asphalt content. However, the splitting strength of the 15°C increases gradually but it remains basically stable after the emulsified asphalt content exceeds 4.0wt%. According to specifications of Technical Specifications for Highway Asphalt Pavement Recycling [11] on Marshall stability and splitting strength of CRMEA used as the subsurface layer, taking into account engineering practices the emulsified asphalt content was determined 4.0wt%.

3. Results and discussion

Four types of heavy-duty 70# asphalt were used as the matrix asphalt and the emulsified asphalt content was chosen 4%, through which four types of emulsified asphalt were prepared and labeled as A, B, C and D. Properties of these four types of emulsified asphalt were analyzed, and the results demonstrate that all four types of emulsified asphalt can meet requirements in Technical Specifications for Highway Asphalt Pavement Recycling [11].

Based on above experimental methods, water content and emulsified asphalt content were determined 6.5% and 4.0%, respectively. Four types of emulsified asphalt were blended with RAP to make specimens. The effect of cement on performances of CRMEA were analyzed by a series of tests.

3.1. Porosity

The Porosity of prepared specimens was tested by the T0705 method in Standard Test Methods of Bitumen and Bituminous Mixture for Highway Engineering [13]. The results are displayed in Figure 3.

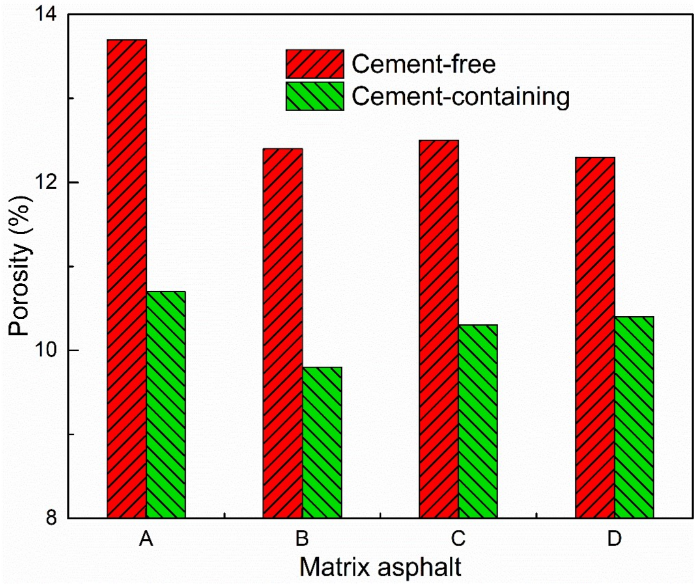

Figure 3. Effect of cement on porosity

It can be seen that the porosity of CRMEA with 1.5% cement is 2%-3% lower than that without cement. This is because the hydration reaction of cement and demulsification of emulsified asphalt are performed simultaneously during stirring of mixture and curing of specimens. The hydration products and the thin asphalt film interweaved into a space network structure and this space network structure was wrapped around RAP, decreasing the porosity of specimens.

3.2. Marshall stability

The Marshall stability of prepared specimens was tested by the T0709 method in Standard Test Methods of Bitumen and Bituminous Mixture for Highway Engineering [13]. The results are displayed in Fig 4.

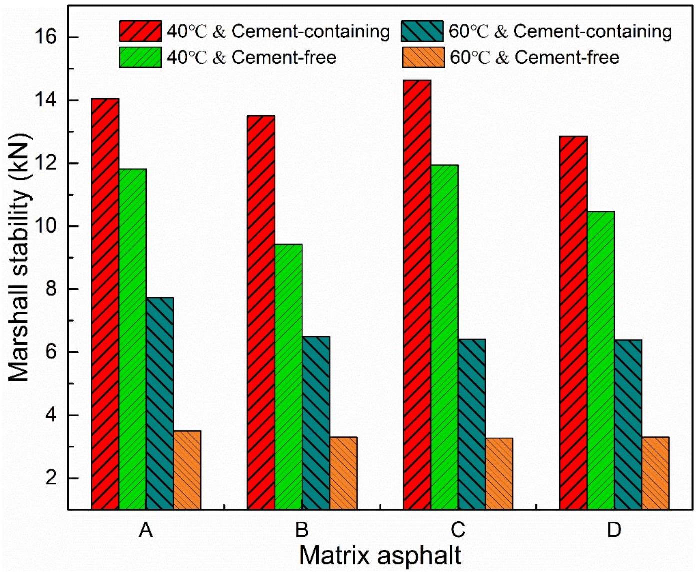

Figure 4. Effect of cement on Marshall stability

Fig.4 shows that Marshall stabilities of CRMEA with 1.5% cement under 40°C and 60°C are higher than those specimens without cement. In addition, the Marshall stability of specimens with cement under 60°C is even double that of specimens without cement. This is because the cluster hydration products can form synergistic effects with the asphalt film to increase the stability of mixture under the existence of cement [14]. From this perspective the cement content shall be increased to some extent when engineering requires high initial strength of asphalt pavement. While some study argued that excessive cement content would decrease the fatigue performance of the mixture. Generally, cement content shall be controlled within 2.0% [15].

3.3. Splitting Strength

The Splitting strength of prepared specimens was tested by the T0716 method in Standard Test Methods of Bitumen and Bituminous Mixture for Highway Engineering [13]. The results are displayed in Figure 5, where DSS stands for dry splitting strength and WSS stands for wet splitting strength.

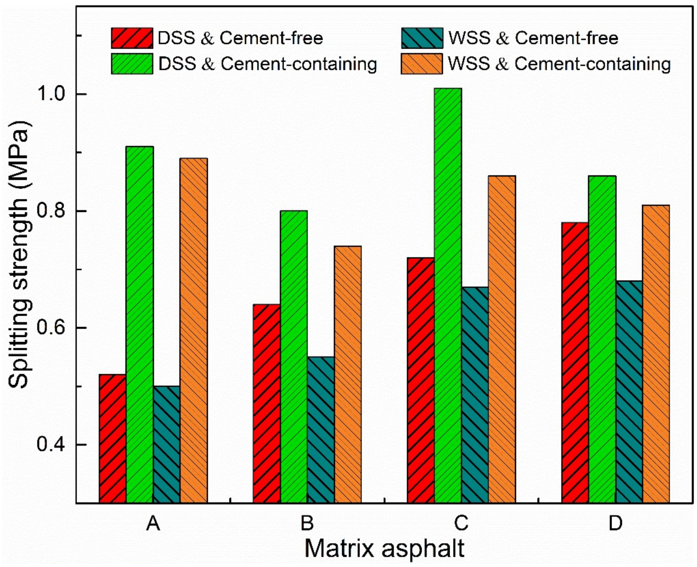

Figure 5. Effect of cement on splitting strength

For all four types of emulsified asphalt, DSS and WSS of CRMEA under 15°C are all increased after the cement is added. This is because a space network structure is formed by interweaving of cluster hydration products and asphalt film formed by demulsification of the emulsified asphalt, and this space network structure can increase high-temperature stability and tensile strength of the mixture. But the involvement of hydration products decreases the thickness of effective asphalt film and the adhesion area between the asphalt film and RAP, it may cause the attenuation of water damage resistance and fatigue property of the mixture, so the amount of cement added should be controlled within a certain range [16, 17].

3.4. Bonding Performance

The flying loss is used to evaluate the bonding performance of aggregates and binders in the mixture, and it can be measured by an improved Cantabro test based on the T0733 method in Standard Test Methods of Bitumen and Bituminous Mixture for Highway Engineering [13]. In the Cantabro test specimens were cooled to room temperature at the end of curing and then were applied to the Los Angeles abrasion experiment directly, without immersion in water. Specimens were grinded by 150 turns in 5 min, 30 r/min. The results are shown in Figure 6.

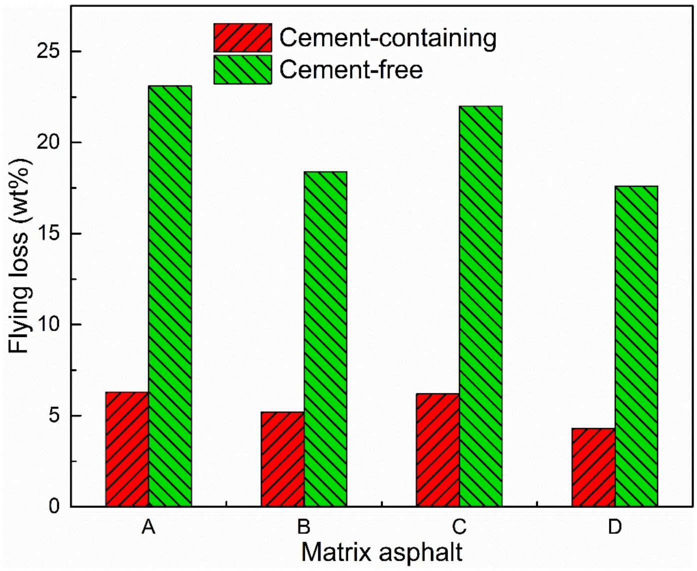

Figure 6. Effect of cement on bonding performance

It can be seen that With respect to all four types of emulsified asphalt, flying loss of specimens with 1.5% cement is significantly higher than that without cement. Although the hydration products decrease the thickness of the effective asphalt film and the adhesion area between the asphalt film and RAP, the experimental results showed that the hydration products' positive effects on interfacial adhesion properties is significantly higher than those negative impact. Therefore, the mixture is more difficult peeled off after the cement is added and the bonding property between the RAP and binders is enhanced, resulting in a decrease in flying loss.

4. Conclusion

The following conclusions can be drawn according to the research content mentioned above:

1) Hydration products of cement and the asphalt film formed by demulsification of emulsified asphalt interweave into a complicated network structure which is wrapped around RAP, decreasing the porosity of CRMEA.

2) The Marshall stability of CRMEA under 40°C and 60°C are increased after the cement is added. The Marshall stability of CRMEA under 60°C increases more pronounced compared with that under 40°C. This reflects that the cement is conducive to increase stability of the CRMEA as an additive.

3) The DSS and WSS of CRMEA under 15°C are both increased after the cement is added. This is because a space network structure is formed by interweaving of cluster hydration products and asphalt film formed by demulsification of the emulsified asphalt and this space network structure can increase high-temperature stability and tensile strength of the mixture.

4) The bonding property between the RAP and binders is enhanced after the cement is added. This reveals that the hydration products' positive effects on interfacial adhesion properties is significantly higher than those negative impact.

Acknowledgements
This work is part of an Applied Basic Research Project of the Ministry of Transport (Project No.2013319781140), the authors sincerely acknowledge their financial support.

References

[1] Zhang, K.; Shen, S.; Lim, J.; Muhunthan, B., Development of Dynamic Modulus-Based Mixture Blending Chart for Asphalt Mixtures with Reclaimed Asphalt Pavement. Journal of Materials in Civil Engineering 2019, 31, (2).

[2] Yan, J.; Zhu, H.; Zhang, Z.; Gao, L.; Charmot, S., The theoretical analysis of the RAP aged asphalt influence on the performance of asphalt emulsion cold recycled mixes. Constr Build Mater 2014, 71, 444-450.

[3] Bowers, B. F.; Huang, B.; Shu, X.; Miller, B. C. J. C.; materials, b., Investigation of reclaimed asphalt pavement blending efficiency through GPC and FTIR. 2014, 50, 517-523.

[4] Gómez-Meijide, B.; Pérez, I., A proposed methodology for the global study of the mechanical properties of cold asphalt mixtures. Materials & Design 2014, 57, 520-527.

[5] Alizadeh, A.; Modarres, A., Mechanical and Microstructural Study of RAP-Clay Composites Containing Bitumen Emulsion and Lime. Journal of Materials in Civil Engineering 2019, 31, (2).

[6] Du, S., Mechanical properties and reaction characteristics of asphalt emulsion mixture with activated ground granulated blast-furnace slag. Constr Build Mater 2018, 187, 439-447.

[7] [7] Omrani, M. A.; Modarres, A., Emulsified cold recycled mixtures using cement kiln dust and coal waste ash-mechanical-environmental impacts. Journal of Cleaner Production 2018, 199, 101-111.

[8] Guo, Y.; Liu, Z.; Liu, Q., Fatigue Property Analysis of Modified Asphalt Emulsion-Cement Cold Recycling Mixtures. In Renewable and Sustainable Energy Ii, Pts 1-4, Ren, N.; Che, L. K.; Jin, B.; Dong, R.; Su, H., Eds. 2012; Vol. 512-515, pp 2965-+.

[9] Liu, Y.; Wang, Y., Study on Mechanical Properties of Cement Cold Recycling Mixtures in Seasonally Frozen Soil Region. 2016; p 972-981.

[10] Wang, T.; Wang, W.; Liu, T., Researches on Cement Cold-recycled Base. In Progress in Industrial and Civil Engineering Ii, Pts 1-4, Yang, W.; Liang, J., Eds. 2013; Vol. 405-408, pp 2586-+.

[11] Research institue of highway ministry of transport, m. o. t., Technical Specifications for Highway Asphalt Pavement Recycling. China Communications Press: Beijing,China, 2008.

[12] Research institue of highway ministry of transport, m. o. t., Test Methods of Soils for Highway Engineering. China Communications Press: Beijing,China, 2007.

[13] Research institue of highway ministry of transport, m. o. t., Standard Test Methods of Bitumen and Bituminous Mixture for Highway Engineering. China Communications Press: Beijing,China, 2011.

[14] Du, S.; Liu, C., Research on the mechanical properties of Cement recycled reclaimed asphalt pavement mixture. In Chemical Engineering and Material Properties Ii, Li, B., Ed. 2012; Vol. 549, pp 715-+.

[15] Cao, W.; Wang, C., Fatigue performance characterization and prediction of asphalt binders using the linear amplitude sweep based viscoelastic continuum damage approach. International Journal of Fatigue 2019, 119, 112-125.
[16] Lytton, R. L.; Zhang, Y.; Gu, F.; Luo, X., Characteristics of damaged asphalt mixtures in tension and compression. International Journal of Pavement Engineering 2018, 19, (3), 292-306.
[17] Ma, T.; Wang, H.; Zhao, Y.; Huang, X.; Pi, Y., Strength Mechanism and Influence Factors for Cold Recycled Asphalt Mixture. Adv Mater Sci Eng 2015.