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Evaluation of the double coated recycled concrete aggregates for hot mix asphalt

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HIGHLIGHTS

- We developed new state of the art double coating technique (DCT).
- RCAs were coated with cement slag paste and Sika Tite-BE to improve its strength and durability.
- Mixtures with 0%, 20%, 40% and 60% of double coated recycled concrete aggregates (DCRCAs) were evaluated.
- The developed DCT produced TSR higher than 98%.
- DCRCA-mixtures achieved higher stiffness than those required for intermediate mix.

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ABSTRACT

The use of recycled concrete aggregates (RCAs) in pavement industry can mitigate natural aggregates shortage, promote sustainable practices and reduce construction cost. However, the engineering properties of RCAs are usually inferior to those of natural aggregates. In this investigation, a new state of the art coating technique, namely, double coating technique (DCT), is developed to improve strength and durability of the RCAs. The RCAs were firstly coated with a layer of cement slag paste (CSP) to reinforce its weak particles. Then, a second layer of Sika Tite-BE (here called ABE) was applied to reduce its water/bitumen absorption and enhance the durability. Marshall tests, indirect tensile test, indirect tensile ratio test and indirect tensile resilient modulus test were performed to evaluate intermediate AC14 mixtures made with 0%, 20%, 40% and 60% of double coated recycled concrete aggregates (DCRCAs). The results indicated that the DCT decreases the water absorption of the DCRCAs by 12.3% and 26.1% compared to uncoated RCAs and RCAs coated with CSP respectively. Also, the DCT effectively enhances moisture resistance and produces stiffness higher than 4000 MPa proposed for AC14 intermediate mix according to Australian practices.

1. Introduction

The construction boom in the developed countries coupled with the natural disasters generates vast quantities of recycled concrete waste [17]. Wars are also producing tremendous amounts of solid waste the concrete aggregates is the main part of them. Due to those natural disasters and human activities, the recycled concrete waste has been increased [24], and the RCA's waste has become the most abundant materials in the world [23]. In Australia, this material comprises about 80 percent of the entire quantities of construction and demolition waste [27]. The use of this solid waste in hot mix asphalt industry could be the best way for reducing the construction cost [7], eliminating pollution [31,13] and mitigating natural aggregates shortage [8,14]. However, results from the literature have suggested that the quality of the RCAs should be upgraded before being used in HMA production.

Keeping with that, two types of strengthening techniques were used; chemical strengthen technique (CST) and physical strengthen technique (PST) [16,14]. While the PST focus on removing the old cement mortar from the RCA surfaces, in the CST different materials have been used to produce the required effect by soaking, sprinkling or coating the RCA particles [16]. For instance, Katz [15] treated the recycled aggregates with silica fume solution and ultrasonic cleaning method. Both treatments led to an increase in the compressive strength at ages of 7 and 28 days. Grabiec, Klama, Zawal, and Krupa [12] modified the RCA by calcium carbonate biodeposition. By this treatment, they obtained a reduction in

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water absorption of recycled aggregates. Saravanakumer et al. [25] used presoaking surface treatment in three different acidic solutions: hydrochloric acid (HCl), nitric acid (HNO3) and sulfuric acid (H2SO4). The samples were soaked for 24 h at room temperature (27–30 °C). It was concluded that these treatments could significantly improve the compressive strength of RCA. Another surface treatment was carried out using microbial carbonate precipitation (MCP) [28]. The researchers concluded that their technique reduces the water absorption and increases the compressive strength of RCAs. However, all the above-mentioned techniques were used to improve strength and reduce absorption of RCA used in cement concrete products, and some treatments are not applicable to be used in asphalt concrete mixtures [14].

In the past decade, different treatments have been applied to improve the performance of RCAs/HMA fabricated with RCAs. For instance, Wong, Sun, and Lai [29] heated the fine aggregate (<3.15 mm) at a temperature ranged from 27 °C to 950 °C to produce lime from calcium carbonate. The results from this study revealed that the stiffness and creep resistance of asphalt mixtures made with heat-treated aggregate were higher than those made with control aggregates. Lee et al. [16] coated the coarse RCA with cement slag paste (CSP) to improve its resistance to crushing and enhance the mixtures performance. The results showed that HMA made with coated RCA satisfied Taiwanese specification requirements. A different treatment proposed by Zhu, Wu, Zhong, and Wang [30] to improve the adhesion between RCA particles and asphalt binder and reduce permeability. The coarse RCA particles were pretreated with a liquid silicone resin. The results showed that this technique could enhance the resistance of asphalt mixture to moisture and low-temperature flexibility, and result in better rutting performance at elevated temperatures. The authors concluded that the coated RCA with liquid silicone resin could be utilized as aggregate in asphalt mixtures. A. R. Pasandín and Pérez [21] cured the asphalt mixture in an oven for four hours at 170 °C to improve its moisture resistance. The results obtained for Marshall parameters and moisture resistance were complied with Spanish specification requirements. Furthermore, to improve the resistance to moisture, A. R. Pasandín and Pérez [22] coated the RCA with 5% asphalt emulsion. It was found that this treatment enhances the behavior of the mixtures made with coated RCAs and improves their stripping resistance. Keeping in with RCA-coated with bitumen emulsion, studies on cold asphalt mixture (CAM) made with RCA after being mixed with bitumen emulsion and water are experienced growing trend recently [9,10,19,11]. However, CAM seemingly fails in providing the required strength and stiffness to withstand loads subjected to urban roads. Therefore, it is more suitable for construction of rural roads to carry low/medium traffic conditions [9]. A different technique was developed by Hou et al. [14]. The RCA was activated with organic silicon resin. The results showed that asphalt mixtures containing less than 60% activated RCAs were satisfied with all specification requirements in China. However, hitherto, none of these techniques have been applied to pavement industry practices. Therefore, a need to develop a new technique, which can bring the RCAs properties/asphalt mixture properties to an acceptable limit of performance, is still required. The importance of such technique is to ease the flow of the RCAs within the community and mitigate its economic/ecological impacts.

2. Developing the double coating technique (DCT)

The aim of developing the DCT is to improve RCAs properties/ RCA-asphalt mixtures properties. The concept is based on combining two main previous treatments. This has been done by taking into consideration the performance of the RCAs/asphalt mixtures when previous treatments had been applied. For example, coating the RCAs with CSP as proposed by Lee et al. [16] and then, apply another coating layer (bitumen emulsion layer) as proposed by A. R. Pasandín and Pérez [22] could be suggested. It is expected that coating the RCAs with two layers can produce asphalt mixtures with better performance. On the one hand, the CSP layer reinforces the weak RCAs particles by sealing the pores/cracks presented on the RCAs' surfaces. On the other hand, when a second coating layer (in this study Sika Tite-BE (ABE) is used to form the second coating layer) is applied, it is expected to mitigate the absorptive nature of RCAs coated with CSP [16]. Thus, due to filling the existed pores on its surfaces. The DCT is therefore expected to reduce the bitumen/ water absorption of DCRCA, and improve the affinity between the DCRCAs and bitumen. Fig. 1, describes the concept of the DCT developed in the present study. At the first stage of the experimental program, the characterization of the DCRCA was carried out to select the optimum CSP coating thickness and the percentage of ABE used. To evaluate The DCRCAs for pavement industry, AC14 asphalt mixtures with 0%, 20%, 40% and 60% of DCRCAs were produced. To provide the same aggregates surface area when a lighter aggregate (DCRCA) being used in HMA production, the substitutions of granite aggregates by DCRCAs were based on a volumetric

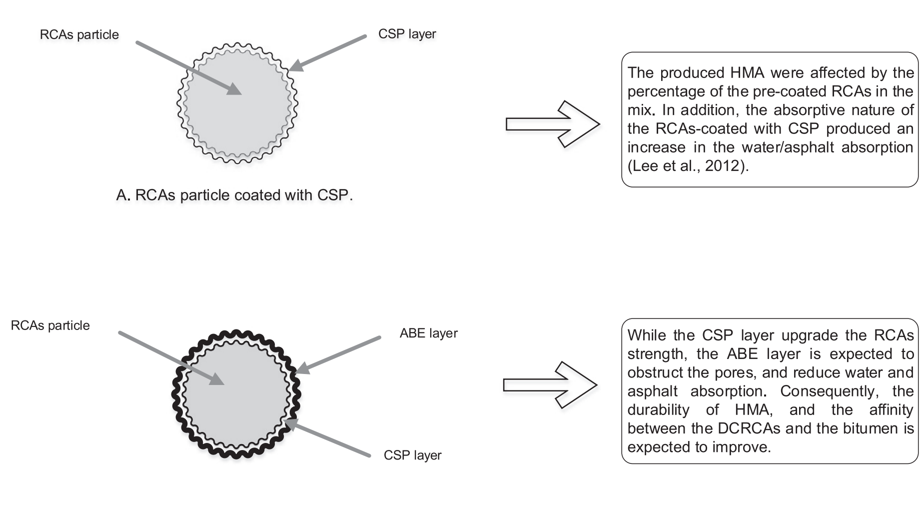

Fig. 1. The concept of the double coating technique (DCT).