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UTILIZING PLASTIC FOR PRETREATING RECYCLED CONSTRUCTION AGGREGATE TO ELIMINATE BINDER ABSORPTION IN ASPHALT MIXTURE

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The growing quantities of waste materials, lack of natural resources and shortage of landfill spaces represent the importance of finding innovative ways of reusing and recycling waste materials. Due to the large quantities of construction and demolition waste (CDW), recycling and utilization of Recycled Construction Aggregates (RCA) obtained from CDW in construction projects, including asphalt pavement construction, can be the most promising solution to this problem. Asphalt mixtures containing RCA have the problem of high bitumen absorption. Using plastic waste in RCA-contained asphalt mixtures reduces not only bitumen absorption but also the adverse environmental impacts associated with plastic waste disposal due to the non-biodegradability of plastic waste. In addition, the demand reduction for virgin aggregates is another advantage resulting in subsequent economic advantages. This paper characterizes the effects of different types of plastic on the bitumen absorption and properties of asphalt mixtures containing RCA through laboratory investigation. Different types of plastic including High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE) were investigated in this research. The test results indicate that the plastic waste can be a viable material for improving the problem of high bitumen absorption of asphalt mixtures containing RCA.

Keywords: Pavement, Waste, Bitumen, RCA, Non-biodegradability

1 INTRODUCTION

Waste materials are increasingly generated with the rapid growth in the economy and continuously increased consumption. The growing quantities of waste materials, lack of natural resources and shortage of landfill spaces represent the importance of finding innovative ways of reusing and recycling waste materials.

At the same time, as the world's population grows, the demand for public infrastructure and hence the construction materials increase. Today, the demand for aggregates is much greater than the amount of virgin aggregates that could possibly be supplied. Referring to the Australian Quarrying Industry, the average annual consumption of aggregates across Australia is about seven tonnes per person and will grow in the future with the population growth and infrastructure development. The biggest waste generator in Australia is the construction and demolition sector who is responsible for of generation of about 40% of all Australian waste material (CCAA

2008a). If this entire amount were treated as waste, at least 30 major landfill facilities were needed to operate all year round (Australia's Sustainable Aggregate Industry 2013). Thankfully however, of the 160 million tonnes of annual aggregate demand, less than 10% is being covered by sustainable aggregate products that contain recycled materials.

In Australia, RCA obtained from construction and demolition wastes has been used in construction projects as coarse and fine aggregates especially in recent years. Choosing RCA can be considered as a smart option because it reduces the need to excavate more virgin aggregates while extracting value from the waste materials, which generally dispose. Accordingly, in utilizing the waste materials in construction, RCA can be considered as one potential material due to large amount of construction and demolition wastes. To this point, over the last two decades, several studies (e.g. Guimarães and Ribeiro 2005, Paranavithana and Mohajerani 2006, Wong *et al.* 2007, Silva 2009, Mills-Beale and You 2010, Marinho 2011, Chen *et al.* 2011, Pérez *et al.* 2012, Zhu *et al.* 2012, Zulkati *et al.* 2013) have been performed on the various applications of RCA. Utilization of RCA in asphalt mixtures is a sustainable technology due to important role and high portion of aggregates in asphalt mixtures. In addition, for some parameters such as Flakiness Index and Particle Shape, which are two dominant characteristics having significant impact on asphalt mixture strength and stability; RCA displays smaller values in comparison with virgin aggregates such as basalt (Tahmoorian *et al.* 2017). This can be one of the strong points of RCA as flakiness index and particle shape are the two important properties for proper compaction, deformation resistance, and workability of asphalt mixture (Masad *et al.* 2007). However, the major drawback of RCA is its high water absorption compared to conventional aggregates, which subsequently results in high bitumen absorption of asphalt mixtures containing RCA.

On the other hand, recognizing the importance of managing particular waste streams and building the capacity for the implementation of projects regarding the conversion of waste into value-added materials, many researchers (e.g. Justo and Veeravarana 2002, Punith and Veeraragavan 2004, Brozyna and Kowalski 2016, Chandh and Akhila 2016) are investigating more environmentally friendly options for repurposing of plastic wastes. One viable economic solution for preventing vast quantities of plastic wastes from being landfilled or incinerated is using them in asphalt pavements through reliable methods. Utilization of plastic wastes combine the advantages of producing better asphalt pavement as well as plastic waste management and reducing the cost for asphalt industries.

Considering the high bitumen absorption of RCA, by combining plastic, the RCA can be coated and hence the high bitumen absorption of asphalt mixtures containing RCA can be compensated. Using plastic waste in RCA contained asphalt mixtures reduces not only bitumen absorption but also environmental issues associated with plastic waste disposal and the demand for virgin aggregates which will subsequently result in cost savings and economic advantages, as plastic wastes are durable and non-biodegradable wastes that may persist for hundreds or even a thousand years.

However, developing a suitable mix design containing RCA and plastic is essential before deploying this technology as an alternative option for asphalt production. The purpose of the present work is to study the benefit of plastic addition on the bitumen absorption of asphalt mixtures containing RCA in order to optimize the RCA contained asphalt mix design. In that sense, as discussed in the following sections, several tests were conducted on individual aggregates in order to obtain comprehensive information and data of their properties and to compare these properties with the requirements specified in the standards as well as with the properties of the virgin aggregate. Based on the test results on the individual aggregates, necessary tests were conducted on different combinations of these aggregates in asphalt mixtures to investigate their performance in asphalt mixture and to characterize the effects of plastic on the bitumen absorption and volumetric properties of asphalt mixtures containing different percentages of RCA.

2 EXPERIMENTAL WORK

2.1 Materials

In the present study, RCA and basalt have been used as aggregates and the original bitumen studied in this research corresponds to C320, which is the most common binder for wearing courses subjected to heavy loading and/or in hot climates. The crushed virgin basalt aggregate was obtained from a local supplier in Sydney. In addition, RCA passing through 20 mm and retained on 4.75 mm I.S sieve is used throughout the experiments which was collected from a local recycling centre called Revesby Recycling Centre (Revesby, NSW, Australia), a licensed waste facility and transfer station which accepts all construction and demolition wastes from both the residential and commercial waste streams. Two different types of plastic wastes from milk bottles and plastic bags were used for coating RCA in this research.

2.2 Laboratory Tests on Coarse Aggregates

Since the information on aggregate fundamental properties is paramount in designing a durable and sustainable asphalt mixture, the properties of different coarse aggregates used in this research (i.e. RCA and basalt) are investigated through conducting different tests to assess their suitability as coarse aggregate in asphalt. The results of these tests on three samples for each aggregate type are summarized in Table 1.

Table 1. Summary of the test results for the evaluation of coarse aggregate properties.

Test	Test Method	Aggregate		Typical Limit Based on Australian Standards
		RCA	Basalt	
Flakiness Index Test	AS 1141.15	6.9	19.0	25% (max)
Particle Shape Test	AS 1141.14	6.2	18.3	35% (max)
Water Absorption	AS 1141.6.1	**6.30**	1.64	2% (max)
Particle Density	AS 1141.6.1	2.370	2.640	-
Particle Density on Dry Basis	AS 1141.6.1	2.212	2.530	-
Particle Density on SSD Basis	AS 1141.6.1	2.351	2.571	-
Aggregate Crushing Value	AS 1141.21	29.21	8.91	35% (max)
Weak Particles	AS 1141.32	0.23	0.23	1% (max)
Wet/Dry Strength Test	AS 1141.22	26.6	8.5	35% (max)
Wet Strength	AS 1141.22	**119.7**	359.2	150 kN (min)
Dry Strength	AS 1141.22	163.1	392.9	-

As can be observed in this table, the results of preliminary tests on coarse aggregates indicate that all properties of RCA, except for water absorption and wet strength, are within the limits specified by the relevant Australian Standards and hence deemed appropriate for use as aggregate in the asphalt mixture. Importantly, RCA displays smaller value for some parameters such as Flakiness Index and Particle Shape in comparison with basalt. As flakiness index and particle shape significantly affect the final performance of asphalt mixtures in terms of compaction, rutting resistance, and workability, better values for these properties can be one of the strong points of RCA. In addition, as can be seen in Table 1, the water absorption of RCA is higher than the corresponding value of basalt and the Australian Standard’s limit due to its high porosity and the great amounts of impurities in RCA. The high water absorption of RCA may result in high bitumen absorption in asphalt mixtures and hence plays an important role in asphalt mixture design. Accordingly, the necessity of finding and studying potential materials to compensate for this problem of RCA has led to the idea of utilization of plastic waste in combination with RCA in asphalt mixture design, which is the main goal of this paper.

2.3 Laboratory Tests on Asphalt Mixtures Containing RCA and Plastic Waste

In this study, the specimen of diameter 100 ± 2 mm and height of 65 ± 5 mm were prepared in accordance with AS2891.2.1 (2014) and AS2891.2.2 (2014). For this experimental work, a group of specimens were made without recycled materials (0%) as reference to specimens made with 25% RCA. In addition, in order to investigate the effect of plastic waste on the bitumen absorption of asphalt mixtures containing RCA, two groups of specimens were also prepared with the addition of 1% of LDPE (plastic bags) and HDPE (milk bottles).

Figure 1. Plastic wastes used in this study.

It is generally recognized that the volumetric composition of mixtures greatly influences their performance. Volumetric properties evaluation of asphalt mixtures is the basis of asphalt mix design and largely determines the performance of asphalt mixture. The asphalt mixture volumetric properties including void content, voids in mineral aggregate (VMA) and voids filled with asphalt (VFA) have been identified as important parameters for the durability and performance of asphalt pavements. The volumetric properties of the basalt-RCA asphalt mixtures with and without plastic were determined and compared accordingly with the standards specifications. To determine the optimum bitumen content for the mixture, the procedure indicated by Australian standards, AGPT04B-14, was followed in this research. Specimens at different bitumen content (4.5, 5, 5.5, 6, and 6.5%) were tested for maximum density, bulk density, and subsequently air voids and VMA calculations. The results of these tests and calculations were used to select the optimum bitumen content. According to the results obtained, Figure 2 illustrates the effect of plastic addition on bitumen content and air voids of samples containing RCA.

As can be clearly observed in these figures, air voids of mixtures containing plastic are lower than the mixtures containing RCA without plastic because of reduction in RCA particles porosity as a result of their coating with plastic.

Importantly, the results of volumetric analysis and air voids calculations based on the bulk density test and maximum density test reveal that the optimum bitumen content of asphalt mixtures varies with the type of plastic waste used, so that mixtures containing LDPE require less bitumen, as presented in Figure 2.

In general, the test results reveal that plastic waste is a viable material for improving the problem of high bitumen absorption of asphalt mixtures containing RCA.

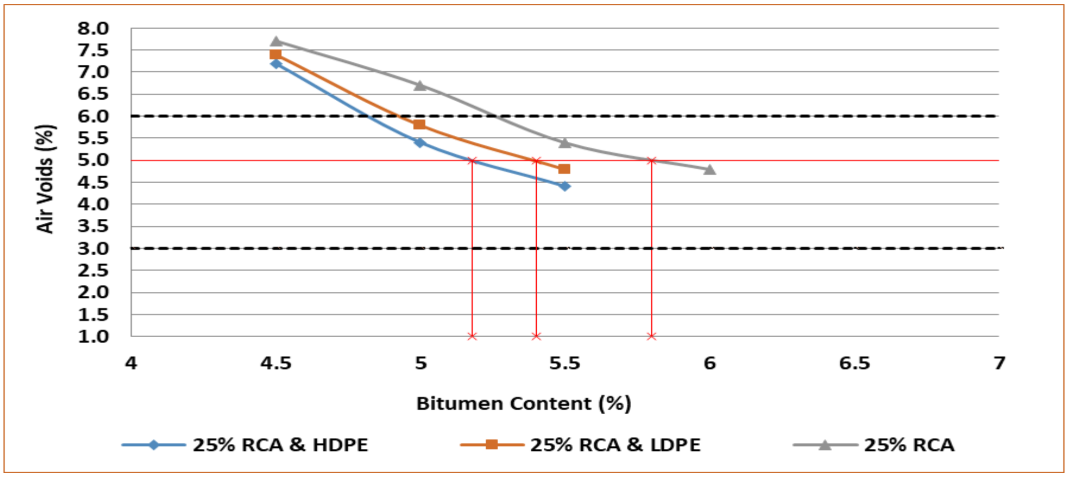

Figure 2. Comparison of optimum bitumen content in different samples.

3 CONCLUSIONS

Considering the rising amount of waste generation in the worldwide, the research project was aimed at evaluating the potential of using plastic waste for compensation of high bitumen absorption of asphalt mixtures containing RCA. The test results on aggregates and asphalt mixtures containing RCA with/without plastic indicate that:

1) The utilization of RCA in asphalt mixtures influences the performance of asphalt mixture and leads to both advantages and disadvantages.
2) RCA has a lower value of flaky and misshapen particles in comparison with basalt. This implies that asphalt mixtures containing a certain amount of RCA can have better workability, deformation resistance, and compaction.
3) RCA exhibits comparatively more absorption and wet/dry strength variation than conventional aggregate, while the results of other tests show that RCA still meets the requirements for aggregate in asphalt mixtures. Cracks and adhering mortar can be significant reasons for the high water absorption of RCA, which needs to be compensated for during mix design.
4) The results of tests on different asphalt mixtures containing different percentages of RCA revealed that a RCA increase will increase optimum bitumen content of the mixtures. Therefore, the selection of the optimum combination of RCA and other aggregates is required to satisfy the relevant requirements.
5) Utilization of plastic waste in combination with RCA was observed to improve the bitumen absorption of these asphalt mixtures.
6) The results of tests on different asphalt mixtures containing RCA and plastic waste indicate that the bitumen absorption depends on the type of plastic waste. In other words, asphalt mixtures containing LDPE have lower optimum bitumen content in comparison with asphalt mixtures containing HDPE and without plastic.

7) The results of volumetric properties of all asphalt mixtures at their optimum bitumen content indicates that asphalt mixtures made by combining 25% RCA and 1% LDPE is the most similar mixture to control samples in terms of optimum bitumen content and volumetric properties requirements.

The natural extension of this work could involve using plastic at different percentages to determine the optimum design content.

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