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Performance of asphaltic concrete modified with recycled crushed bricks

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Abstract. The pavement industry relies greatly on this conventional material in constructing the road. However, the shortage of the mined material has led to the need of finding alternative with local materials to partially substitute the asphalt components. The conventional pavement industry also contributed to thermal and greenhouse emission resulting from the mining activities. In addition, throughout the year, the amount of construction and demolition (C&D) waste generated from civil construction activities particularly in Malaysia is increasing in alarming rate. Recycling the C&D waste specifically in bricks is viewed as reasonable potential as aggregate modifier in the impulse for greener and sustainable asphalt pavement production. In this paper, recycled crushed bricks (RCB) is introduced to bituminous wearing course as partial replacement for coarse aggregates. The coarse aggregate is partially replaced with RCB in proportions of 0%, 10%, 20%, 30% and 40% by weight. This study summarizes the results of laboratory evaluation of Los Angeles Abrasion Value, Aggregate Crushing Value and Marshall Test. Results show that asphaltic concrete modified with 10% RCB has the lowest abrasion and crushing values which were 20.2% and 30% respectively. Similarly, the mix has the highest Marshall Stability and lowest flow which 15.61 kN and 3.37 mm respectively. Thus, partial replacement of coarse aggregates with 10% RCB in bituminous mix is suitable to be used in wearing course and can be used as alternative material in bituminous mix to reduce the dependency on natural aggregates and utilize the C&D waste efficiently.

1. Introduction

Construction and demolition (C&D) material as waste or excess materials correlated with building and structure construction and demolition such as cement, stone, metal, wood, plastics, bricks and other construction material and products [1]. In Peninsular Malaysia, the quantity of solid waste produced throughout the time escalate from an estimated 23,000 tons in 2010 to 25,000 tons in 2012, averaging about 1000 tons per year [2]. The construction sector industry itself contributed 41% of waste generated from the total waste listed due to rapid development [3]. C&D materials are acquired from redeveloping of building infrastructure, construction and scrap building of demolition. C&D waste is produced from the various decisions making chain resulting to inefficient material handling and planning, design errors, improper procurement, which led to unexpected residues of raw materials [4]. Bricks have become one of the major wastes in construction and demolition(C&D) activities. These

C&D materials if do not manage in a proper manner will results to lots of environmental issues aftermath. The urgent need to dispose waste building materials has led to growing costs and environmental impacts pertaining to the disposal of these material [5, 6]. In addition, the application of C&D waste materials as asphalt modifier is considered as high potential alternatives since the asphalt pavement industry dominate an extensive amount of natural mineral resources which direct promotes to thermal and greenhouse emissions.

The construction of road mainly made up of conventional materials of asphalt, cement, aggregates, and filler. Aggregates is a natural resource from mining industries and these resources are reducing from day to day. The increasing need for recycling is because of environmental concern regards to scarcity of natural resources [6]. The machinery during quarry operation of natural aggregates produce huge amounts of fumes which led to increasing in carbon footprint [7]. In flexible pavement, at least 12, 500 tons of aggregates are being used for one kilometer and the composition of aggregates in the asphalt mixture is up to 90 to 95 percent by weight [8]. This value shows the huge consumption of mineral aggregates in the road construction. The increasing cost of these materials due to its shortage has triggered the development of road pavement facilities by modifying the components of the pavement.

For the natural aggregate's modification, RCB, recycle concrete aggregate and excavated rock are among the options available for substitution of natural aggregate for the application of sub-base pavement and other road construction applications [9]. Lifecycle of bricks or blocks starts from the transportation to the site of construction process until its purpose of use then either to be recycle or demolish which portrays the bricks can be recycle multiple times [10]. According to the research done by Sarkar et al. [11], bituminous concrete with 20:80 brick-stone aggregate mix shows considerable improvement in various mechanical properties of mix compared to other brick-stone aggregate mix ratios, namely, 40:60, 60:40, and 80:20. Hence, RCB as the C&D waste is applicable for the natural aggregate's alternative for the asphalt pavement. RCB's potential as natural aggregates' substitution can help managing the scarcity of natural resources.

2. Materials and Methods

2.1. Materials

Asphalt mixture is made up of aggregates, bitumen and filler. The sample of natural aggregates were taken at Kajang Rock Quarry Sdn Bhd while the bricks (Figure 1) were taken from demolition building in Lenggong, Perak. Then, the bricks were crushed into the desired size by using chisel and hammer. Later, the size gradation of the RCB was determined by conducting sieve analysis. Since Malaysia's climate is hot, harder grade of 60/70 grade bitumen is used and the softening point of the bitumen is 50°C.

Figure 1. Bricks are crushed using chisel and hammer

2.2. Methods

There were five samples consisted of a controlled sample and modified samples of 10%, 20%, 30% and 40%. The experiments will be done in two phases. The first phase is to determine the durability of the RCB – aggregates combination by performing Aggregate Crushing Value (ACV) and Los Angeles Abrasion Value (LAAV). ACV test is being carried out with the aggregate is being applied to 400 kN compression load in a cylindrical [12]. Meanwhile, LA Abrasion Test is performed by putting coarse aggregate and steel sphere in rotating drum. The main point of both tests is to stimulate abrasion and toughness of aggregate during manufacturing, placing, construction and service life especially under the pressure of wheel load in traffic congestion. The second phase is to evaluate stability and flow performances of both controlled and modified asphaltic concrete by using Marshall Test. Stability measures the maximum load the sample can withstand at a loading rate of 50.8 mm/min. As the road pavement subjected to heavy traffic load, a pavement with good stability is required to ensure a long-lasting pavement with less maintenance. Flow performance indicates the deformation occurs during the Marshall test. It shows that the movement of aggregates under the applied load where the deformation occurred. Sample preparation of Marshall test started with grading the aggregates and RCB according to AC14 grading limit as in Table 1 [13]. Then, they are mixed together with 5% bitumen content of grade 60/70 at temperature 160°C until uniformly coated. The mixture was compacted with 75 blows both at the top and bottom to obtain cylindrical samples for the Marshall tests. The samples were extruded after being cold at room temperature for 24 hours. The samples were soaked in water bath of 60°C for 30 minutes before performed with Marshall Test.

Table 1. AC 14 Grading Limit.

Sieve in mm	Percentage Passing by Weight	% Passing	% Retained	Mass(g)
14 mm	90-100	95	5	60
10 mm	76-86	81	14	168
5 mm	50-62	56	25	300
2.36 mm	40-54	47	9	108
1.18 mm	18-34	26	21	252
300 µm	12-24	18	8	96
150 µm	6-14	10	8	96
75 µm	4-8	6	4	48
Pan		0	6	72
Total				1200

3. Results and Discussion

3.1. Aggregate Properties Test

From Table 2, crushing values of all samples were satisfactory and within 30% of crushing limit for wearing course. The crushing values of ACV test for 10% RCB, 20% RCB, 30% RCB and 40% RCB were 20.2%, 20.6%, 24.3% and 28.3% respectively. Similarly, abrasion values from LAAV test of all samples were acceptable since all the values within the abrasion limit of 40%. The abrasion values for 10% RCB, 20% RCB, 30% RCB and 40% RCB were 30.0%, 32.0%, 33.7% and 34.7% respectively.
The percentage of both crushing and abrasion values increased as the percentage of RCB increased due to more breakage of bricks during the tests. To sum up, asphaltic concrete of 10% RCB had the minimum value of crushing and abrasion value for the modified sample since the amount of RCB in this sample was lesser compared to the other modified samples. The lower the crushing and abrasion value, the durable the aggregates are. The service life of the pavement can be longer due to the lower crushed aggregate and less maintenance is needed. Although, the controlled sample has the lowest crushing and abrasion value compared to the other modified samples, all the results displayed by the modified samples were acceptable and within the required values of both tests.

Table 2. Properties of Aggregates

Test performed	Controlled Sample	Modified samples			
		10% RCB	20% RCB	30% RCB	40% RCB
Aggregate Crushing value	17.4	20.2	20.6	24.3	28.3
Los Angeles Abrasion value	29.6	30.0	32.0	33.7	34.7

3.2 Marshall Stability and Flow

From Table 3, the stability performance for all asphalt mixture samples satisfied the design criteria of Marshall Stability which should exceed 8 kN for wearing course. The stability values for 10% RCB, 20% RCB, 30% RCB and 40% RCB were 15.61 kN, 13.19 kN, 10.88 kN and 9.33 kN respectively. As for modified asphalt mixture samples, the stability performance of the mix decreased as the percentage of RCB increases. Controlled sample showed the highest stability value among all the samples which was 20.86 kN and this value was acceptable since controlled sample used 100% natural aggregates. Meanwhile, modified sample of 10% RCB showed the maximum Marshall Stability value for modified samples category which was 15.85 kN. Modified sample of 40% RCB has the lowest value of stability. It is due to RCB - aggregates cannot coat completely and the sample breaks down easily during the Marshall test. As the surface of RCB was porous and required more bitumen to coat the surface [15]. The bitumen content used for both controlled and modified samples was 5% only which is 63.16 g. sufficient bitumen content in mix was significant since bitumen fulfill the cracks and pores in between the RCB - aggregates surfaces thus increase the adhesion by having bond of mechanical interlock between them. From these results, it can be discussed that to strengthen the stability of higher percentage of RCB was by having higher bitumen content so proper coating can be provided. Hence, modified asphaltic concrete of 10% RCB was considered as the most preferred modified asphalt mixture for bitumen content of 5%.

As for Marshall Flow, the values of modified samples are within the range of 2 to 4 mm except Modified sample of 30% RBC. Supposedly, the flow value needs to lie in between 2 to 4 mm for wearing course design criteria. If the flow of the mix is in the upper limit, the mix is too plastic and if the mix is in the lower limit it is too brittle. An optimum flow value has a lower flow value which within the flow criteria value. In this study, the flow value for Modified sample of 10% RCB has the optimum flow value for all asphalt mixture samples which is 3.369 mm. However, controlled sample has the highest flow value even though there is no modification occurs which is 5.512 mm. The flow value is above the upper limit and too plastic for an asphalt mixture. Plastic deformation is undesirables since will results to permanent distortion of pavement. This result may be developed from the poor compaction of unequal compaction speed and heat loss during the compaction process. The sample is not dense enough and when subjected under load during Marshall Test, the displacement of aggregates occurred and failed. Proper compaction with suitable temperature is needed in wearing course layer to be able to have a dense sample. In addition, the filler that has been used throughout this study is stone dust. Briefly, filler is significant in filling the spaces between aggregates and asphaltic binder forming asphaltic mastic that have properties of viscoelastic material that can holding the asphalt mixes together resulting its performance against various distresses. More fine filler is needed to lower the flow value, and can stiffen the mixture better. Thus, any filler which have lower specific gravity than stone dust which is 2.63 such hydrated lime ad fly ash is recommended for lower flow performance.

Table 3. Marshall Test Results

Parameter	Controlled Sample	Modified samples			
		10% RCB	20% RCB	30% RCB	40% RCB
Stability, kN	20.859	15.614	13.192	10.877	9.929
Flow, mm	5.512	3.369	4.430	3.957	3.736

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4. Conclusion

The modification of asphaltic concrete with RCB has impact on the strength properties, stability and flow performance of the mixtures. The impacts can be seen from the laboratory result of aggregate properties test and Marshall test. For aggregates properties test, Modified sample of 10% RCB as aggregates substitution shows the lowest percentage values among the modified asphalt mixture samples. The strength properties of both crushing and abrasion values which are 20.2% and 30% respectively is the lowest which indicates the durability and toughness of the RCB – aggregates itself under the stress. Moreover, all the modified samples incorporating with RCB also shows positive values which within the requirement of wearing course for both ACV and LAAV tests. Similarly, Modified sample of 10% RCB also has the highest Marshall stability value which 15.614 kN among the modified samples and lowest flow values which is 3.369 mm of both controlled and modified samples. These values indicate sample mixtures that have a strength and flexibility needed for wearing course of pavement. RCB has potential of substituting partial aggregate placement and provide an affordable source of pavement material thus minimizing the dependency on mineral aggregates while stimulating good way of recycle waste.

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