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Recycle Crushed Brick as Road Base Material

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Abstract: The demand for natural resources lead to environmental problems. In addition, construction activity always generated a lot of solid waste especially brick. This paper reviews recent research studies on the development of construction waste materials. Therefore, for this study, recycle crushed brick (CB) use as the partial replacement of natural aggregate in pavement structure. The objectives of this study are to study properties of CB and to identify the optimum percentage of CB as partial replacement of road base materials. The aggregate compaction, water absorption and density test and California bearing ratio (CBR) highlighted in this report. The data is collected from previous study. Different percentage replacement of CB is proven to give different values. It is found that 10.00 % CB replacement shows the best and acceptable amount to be used in real situation.

Keywords: Natural Aggregate, Recycle Crushed Brick

1. Introduction

The sharp population increase and also high standards of living have caused a considerable demand for developing infrastructure and therefore a growth of construction activities. This demand leads to a considerable rise in the extraction and consumption of natural aggregate and caused meaningful environmental impacts. Moreover, the growing trend of generating waste material from construction, renovation, demolition, and natural disaster lead to lack of landfills. Over the last decades, solid waste is one of the most troublesome to handle. Especially the solid waste generated from construction industry or what is commonly called as the Construction and Demolition Waste (CDW). Malaysia produces 17820 tons of construction waste in 2005 [1]. 46.00 % of construction waste is concrete waste [2].

Road construction has known as a high potential area for applying Recycled Crushed Brick (CB) with environmental and economic benefits [3]. The total extent of Malaysia roads network is approximately 179,517.59 kilometers of paved road and 57,504.76 kilometers of unpaved roads where about 8.40 % of the network is Federal Road and the other 96.40 % are State Road [3]. These days, construction industry gives greater attention on sustainability. Sustainability aspect in road construction

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concentrates more in giving the best way to decrease virgin materials, energy and waste in industry, without reduce the quality of the asphalt itself. Besides, cost of virgin or fresh construction materials continue increase because of quick development and depletion of natural recourses. Request in bitumen and aggregate for road development is reflected too. Malaysia government spends about RM 20 billion for road construction and maintenance in 2015 [4].

Recycling materials can support sustainability aspect at the same time reduce the construction and material cost. It conserved energy and non-renewable natural resources, preserved environment, reduced the usage landfill, reduced road construction cost [5].

1.1 Research objectives

The research on this paper consists two objectives which is to study physical and mechanical properties of CB based on data from previous researchers. The data of aggregate water absorption, aggregate density, compaction and California bearing ratio was collected. Second is to identify the optimum percentage of CB as partial replacement of road base materials.

1.2 Scope of Study

This study focused on gather the information from previous studies related to the partial replacement of natural aggregate (NA) with recycle crushed brick (CB). A detailed research is carried out based on road base mechanical and physical properties consisting of aggregate density, aggregate water absorption, aggregate compaction and California bearing ratio (CBR).

2. Literature review

2.1 Flexible pavement

The flexible pavement is surfaced asphalt materials. This pavement will be bending or deflecting when traffic loads applied on it. The wheel loads will transmit to the lower layers. It consists 5 layers [6] which subgrade, subbase, base, binder course and surface course.

2.2 Road base course

Road base is a well graded material, consisting of various sized particles containing coarse and fine aggregate. Then, it will be mixed and placed correctly into a layer that resists distortion due to weather cycles. It also able to prevent deformation due to vehicular mass and movement. According to JKR standard specification for road work [7], road base materials shall:

- the plasticity index shall be not more than 6
- the aggregate crushing value shall be not more than 30
- the flakiness index shall be not more than 30
- not less than 80.00 % of particles retained on the BS 4.75 mm sieve shall have at least one fractured face
- the material shall have a CBR value of not less than 80.00 % when compacted to 95.00 % of the maximum dry density

2.3 Recycle crushed brick

Recycled concrete brick (CB) is simply old brick that has been crushed into aggregate. Brick consists of a mixture of 50.00-75.00 % sand and 25.00 -50.00 % clay is blended with water until it is moldable [8]. Construction and demolition (CDW) waste increase years by years. Almost 50.00 % by all CDW materials are concrete, brick and asphalt [19]. It shows that brick is one of the major wastes. Recycled crushed brick are however viable alternative materials for natural construction materials in engineering applications such as pavement base layer [18]. Recycled crushed brick performs satisfactorily only at low moisture levels and suggested blending recycled brick with other recycled materials to enhance its performance in pavement sub-base applications [20]. The mechanical characteristics of an unbound base course made with recycled concrete and masonry rubble were mainly governed by the degree of compaction [17]. The water absorption, density, maximum dry density and optimum moisture content of CB is 13.76 %, 2.41 Mg/m^3, 2.04 Mg/m^3 and 12.75 % [9].

3. Methodology

3.1 Flow chart of methodology

This sub-topic is to illustrate the flow of producing this research paper from start until end in Figure 1. This paper is focusing on data from two previous researchers.

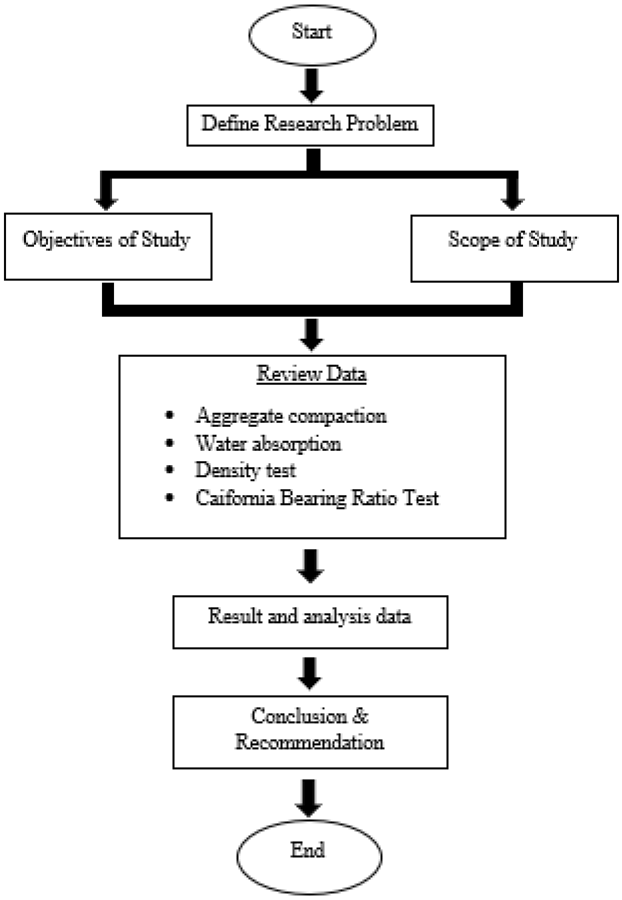


Figure 1: Work frame of methodology

This review mainly obtained from the related journals or articles sources from Mendeley, Google Scholar, Science Direct, ResearchGate and others. Total journals use for this review is almost 30 papers. Initially, Google scholar started a broad search for a list of main-source and peer-reviewed research papers. The Universiti Tun Hussein Onn Library, known as the UTHM Library, was another database used for the location of sources. UTHM Library commonly used to find conventional sources, including books and some articles of science. Science Direct is more friendly interface and covered wide research fields such as of science, technology, medicine, social sciences and humanities.

3.2 Testing Involved

The findings of density test, aggregate water absorption test, aggregate compaction test and California bearing ratio test from some previous researchers are reviewed. Then, the result for each test from researchers' observation is compared to find the optimum replacement based on JKR standard specifications. The details of each test used by the previous researchers are show in this sub topic.

3.2.1 Water absorption and density

Generally, density is described as a compactness of a substance. It can be acquired from the proportion of the substance mass to its volume. When the density of a substance is being ratio with the reference substance like water, then it called the relative density or the specific gravity [10]. The aggregate with maximum size is 20 mm. Water absorption values are used to identify the change in mass of aggregate due to water absorb by pore spaces between the small particles in the aggregate compared to dry condition. When the aggregate deemed in the water, it has been in contact with water long enough to satisfy most of the absorption potential. This test is referred to ASTM C127-01 [16].

3.2.2 Compaction

Proctor in 1933 developed a laboratory compaction test procedure to determine the optimum dry density and optimum moisture content of compaction of soils, which can be used for specification of field compaction. This test is referred to as the Standard Proctor Compaction Test ASTM D1557 [15]. The equipment will be used is 152.4 mm diameter and 178 mm height mold and standard proctor hammer with 50 mm diameter face weighing 4.5 kg of free fall of 300 mm. The sample is divided into 5 layers in the mold with 56 blows for each layer using the proctor hammer. Then, the water content added gradually every time a sample is done and weighted. Finally, the result is recorded and expressed into graphic of ODD-OMC relationship. Based on this graphic, the best ODD and OMC can be obtained.

3.2.3 California bearing ratio

This test used to evaluate the mechanical strength of subgrade and road base materials. The CBR test is measures the shearing resistance of a crushed aggregate under controlled moisture and density conditions. The test yields bearing ratio number that is applicable for the state of crushed aggregate as tested. The specimen is compacted into a mold based on the compaction values obtained from ODD-OMC test. The CBR test method followed the Australian standard AS 1289.6.1.1 [13]. The test samples were soaked in water for 4 days to simulate the worst-case scenario. In the modified CBR tests, samples were placed in a cylindrical mold with internal diameter of 152.4 mm and compacted in five layers totaling an effective height of 118 mm by using a spacer disc inserted into the mold before compaction.

4. Results and Analysis

The findings from two researchers [11][12] are combined and discussed. Then the results analyses to identify either meet the JKR requirement or not. Both researchers use same ratio CB replacement which at 10.00 %, 15.00 %, 20.00 %, 25.00 %, and 30.00 %.

4.1 Aggregate water absorption and density

Aggregate water absorption affected by amount and size of voids of the aggregate [10]. Based on Figure 2, the water absorption decreases from 10.00 %CB until 20.00 %CB and then increase at 25.00 %CB and 30.00 %CB [11]. He mixes CB-NA blends results indicate that the existence of high-quality aggregates in that mix blends. But, the existence of fine particle in the mixture of CB and cement mortar from concrete are reducing density values and increase water absorption. The lowest value is 3.08 % at 80.00 %NA+20.00 %CB [11]. It is contrast with researcher [12]. He shows the water absorption decrease until 15%CB and then continues increase until 30.00 %CB. The lowest value is 2.83 % at 85.00 %NA+15.00 %CB. 100.00 %NA has 3.32 % water absorption [11][12].

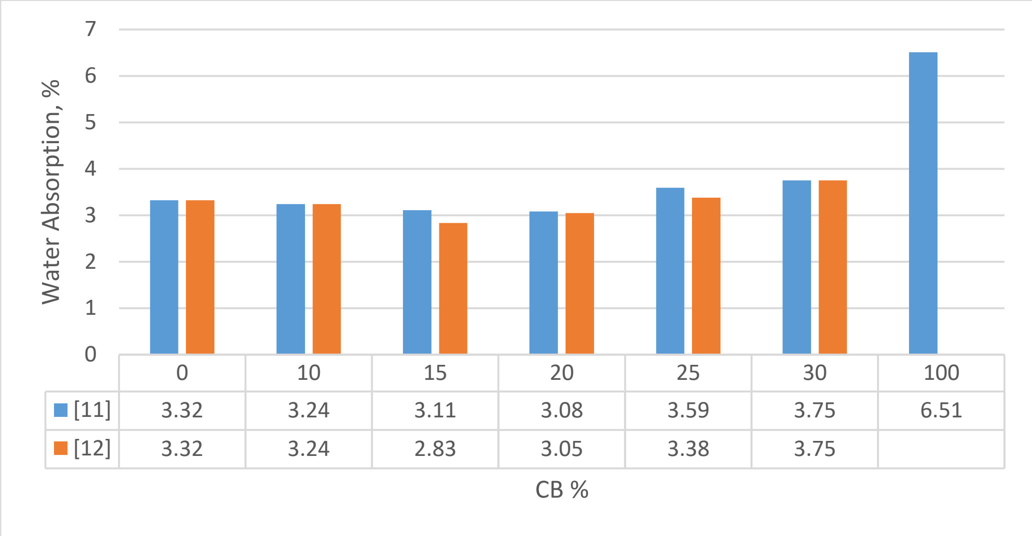


Figure 2: Aggregate water absorption

Based on figure 3, the density value of NA is 2.86 Mg/m^3 [11]. The second higher is 2.80 Mg/m^3 at 90.00 %NA+10.00 %CB. The high aggregate density shows the compactness and less void of a substance [11]. Data from researcher [12] show the highest density is 2.78Mg/m^3 at 100.00 %NA, 15.00 %CB and 20.00 %CB.

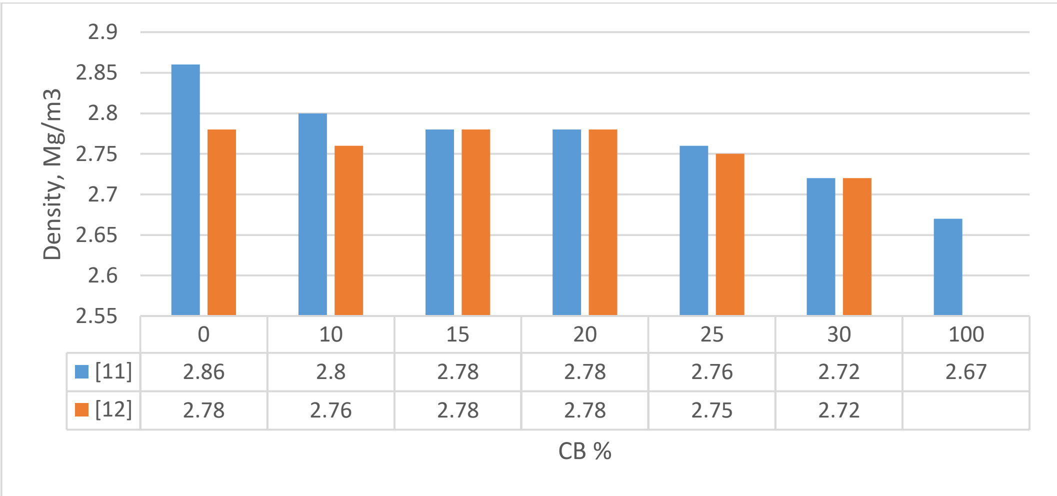
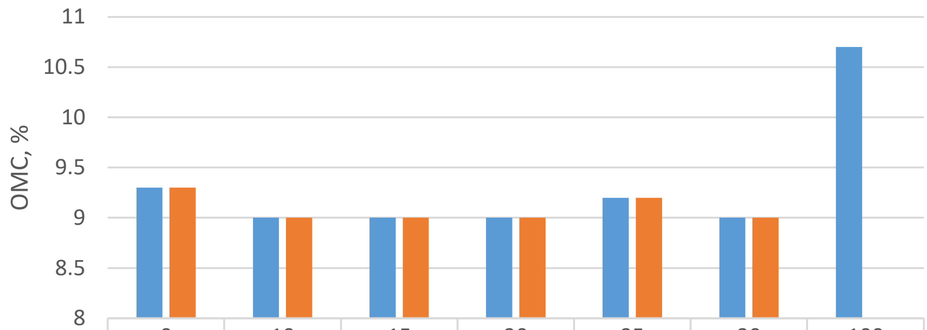


Figure 3: Aggregate density

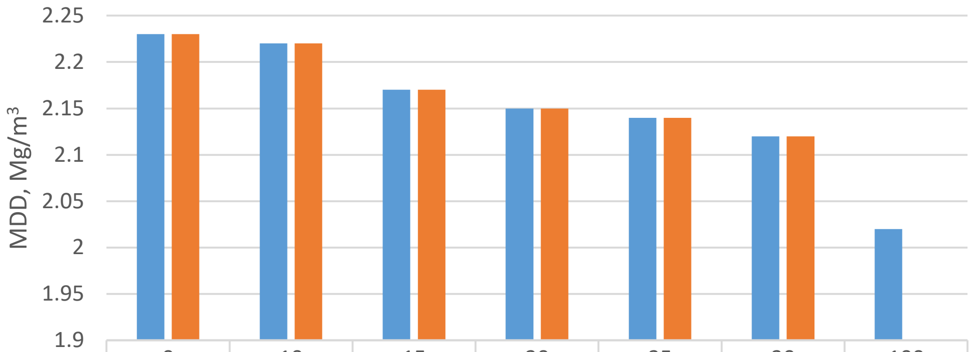
4.2 Compaction

Figure 4 and 5 show the result of optimum moisture content (OMC) and maximum dry density (MDD) [11][12]. The OMC value for NA (9.30 %) higher than value at 10.00 %CB, 15.00 %CB, 20.00 %CB and 30.00 %CB which at 9.0.00 % [11][12]. The optimum moisture content is important to achieve suitable compaction in order to reduce the susceptibility of aggregate [12]. In other hand, the MDD values for NA (2.23Mg/m^3) higher than others ratio [11][12]. Both researchers show that amount of CB will reducing aggregate density due to existence of fine particle in the mixtures. However, only 0.01Mg/m^3 reduce when they use 10.00 %CB. Below 30.00 %CB replacement is acceptable due to JKR does not put any requirement for OMC and MDD.



	0	10	15	20	25	30	100
[11]	9.3	9	9	9	9.2	9	10.7
[12]	9.3	9	9	9	9.2	9	

Figure 4: Optimum moisture content



	0	10	15	20	25	30	100
[11]	2.23	2.22	2.17	2.15	2.14	2.12	2.02
[12]	2.23	2.22	2.17	2.15	2.14	2.12	

Figure 5: Maximum dry density

4.3 California bearing ratio

The objective of this test it to evaluate the bearing capacity of road base materials. Both researchers are following AS 1289.6.1.1 [13]. The samples soaked for 4 days. Based on Australia standard [14], the CBR value must be more than 80.00 %. It is similar with JKR standard requirement for road work [7]. Both researchers show the different result for each ratio. As seen on Figure 6, NA show the highest value (204.00 %) while the second higher (176.00 %) at 10.00 %CB [11]. It is different with researcher [12]. The CBR value of 10.00 %CB (176.00 %) higher than NA (174.00 %). This could be due to segregation of aggregates during compaction or minor fluctuations in the experimental works [12]. There is 14.60 % reduction [11] and 1.14 % [12] improvement when they replace 10.00 %CB. As conclusion, below 30.00 % crushed brick replacement is acceptable because it satisfies the road authority specifications. The data collected from crushed brick mix does give little or no effect on overall performance of CBR value [12].

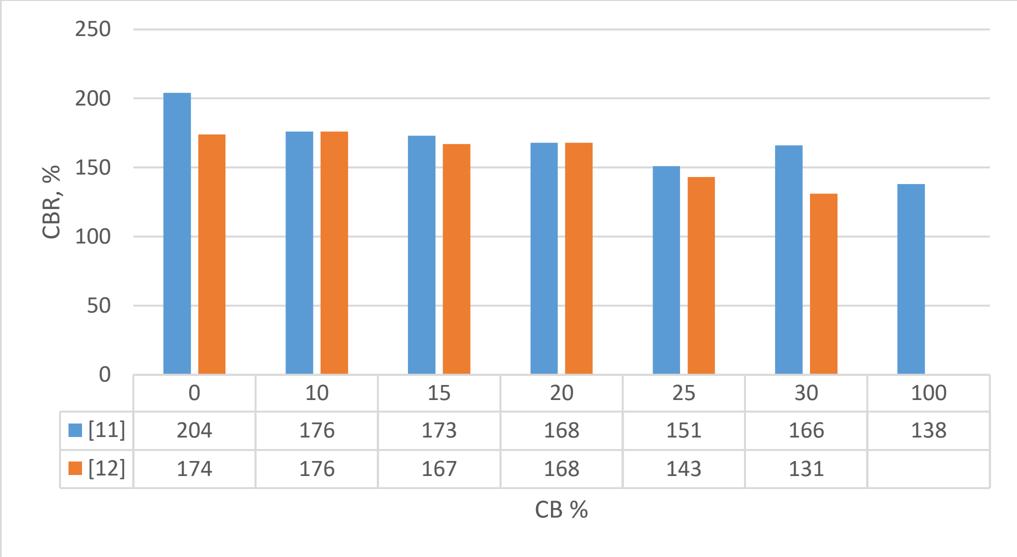


Figure 6: California bearing ratio

4.4 Optimum Ratio

Based on all the data reviewed and discussed. 10.00 % CB + 90.00 % NA is chosen as the optimum CB replacement based aggregate water absorption and density test, compaction test and CBR test. All the data of 10.00 % CB replacement is summarized in the Table 1 in order to compared with JKR standard requirement for road base materials and to analyze different values with NA. JKR standard does not have any requirement values for aggregate density and water absorption. Natural aggregate is the commercial road base materials in Malaysia. Therefore, CB mixes needs to be compared with the NA in order to commercialize this material as partial replacement. First, the different of density for this mix with 100.00 % NA is 0.06 Mg/m^3 reduction [11] and 0.02 Mg/m^3 [12]. Second, around 0.08 % water absorption increasing [11][12] from 100.00 % NA. Third, the data collected from crushed brick mix does give little or no effect on overall performance of CBR value [12].

Table 1: Result summary

Thesis	**Mix Percentages**	**Density, Mg/m^3**	**JKR Standard**	**Status**
(Arulrajah et al., 2010)	100% NA	2.86	None	Acceptable
	90% NA+10% CB	2.80		
(Aatheesan el al., 2008)	100% NA	2.78		
	90% NA+10% CB	2.76		
Thesis	**Mix Percentages**	**Water absorption, %**	**JKR Standard**	**Status**
(Arulrajah et al., 2010)	100% NA	3.32	None	Acceptable
	90% NA+10% CB	3.24		
(Aatheesan el al., 2008)	100% NA	3.32		
	90% NA+10% CB	3.24		
Thesis	**Mix Percentages**	**CBR, %**	**JKR Standard**	**Status**
	100% NA	204		Pass

(Arulrajah et al., 2010)	90% NA+10% CB	176	> 80%	Pass
(Aatheesan el al., 2008)	100% NA	174		Pass
	90% NA+10% CB	176		Pass

5. Conclusion

The purpose of this chapter is to conclude all the findings derived from the previous research based on objectives of this paper.

1) Mechanical properties (CBR values) and physical properties (water absorption and density values) of the recycled crushed brick from previous research are review in this paper. If the amount of CB in the mixes increase, it reducing CBR and density values. When the percentage of CB increase, the water absorption of the mixes increases.
2) Based review in this paper, 10.00 %CB+90.00 %NA is chosen as the optimum mixes due to acceptable value when compared with NA and JKR standard.

There are a few recommendations for the future studies in order to reduce construction and demolition waste:
1) Conducting research for other recycle materials such as recycled aggregate, glasses, and recycle asphalt pavement for pavement materials
2) Conduct testing for plasticity index, aggregate crushing value, flakiness index and sieve analysis for recycle crush brick.
3) Including more percentage mixes to determine the effect and find out the best materials proportion to be used as pavement materials.
4) Study the best ways to improve density and reduce water absorption of recycled materials

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