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EFFECT OF OPEN-GRADED COARSE AGGREGATE ON CONCRETE PAVING BLOCKS PROPERTIES FOR PAVEMENT

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ABSTRACT

The potential of using coarse aggregate for open graded in the production of concrete paving blocks (CPB) were presented in this study. Three different sizes of coarse aggregate were used through the investigation: (a) passes 8 mm retains 5 mm, (b) passes 10 mm retains 8 mm and (c) passes 10 mm retains 5 mm as control. Furthermore, a series of tests were carried out to determine the properties of the blocks, namely density, porosity, weight loss, compressive strength and skid resistance test. It was found that the size of coarse aggregate effects on many aspects, especially in the strength of the blocks. However, at the same time it also provides sufficient strength or the minimum required strength (30 MPa) for a rectangular block to be used as part of paving surface. In addition, the blocks show that it is suitable for use in vehicle area when the value of the British Pendulum Number of skid resistance test more than 45 referred to BS 6717; 2001.

Keywords: concrete, block pavement, compressive strength and skid resistance.

INTRODUCTION

The use of concrete block pavement has markedly in recent years. It has been spreading in developing countries including Malaysia [1]. Concrete block pavement are not only used for pedestrian walkway, but also for a variety of commercial, municipal and industrial application [2]. Superior engineering properties, easy maintenance and repair, reuse of the original block, availability in various shapes and color, aesthetic appeal and intermediate availability are the primary reason for choosing the concrete block pavement over the other paving surface [3].

Presence of aggregate in concrete mixes to manufacturer CBP is most important. This is because aggregates comprise as much as 60 % to 80 % of a typical concrete mix, so it must be properly selected to be durable, blended for optimum efficiency, and properly controlled to produce consistent concrete strength, workability and durability. Changes in gradation, maximum size, unit weight, and moisture content can all alter the character and performance of the concrete mix. Besides, the economy is another reason for thoughtful aggregate selection. It is well known as a cheap and strong material. It can often save money by selecting the maximum allowable aggregate size. Using larger coarse aggregate typically lowers the cost of a concrete mix by reducing cement requirements, the most costly ingredient. However, excessively coarse material will produce harsh mixes that are more difficult to place, consolidate and finish.

The objective of this study is to determine the physical properties of CPB by using different sizes of coarse aggregate. The study used the three open-graded aggregate sizes and low w/c ratio to produce CPB. The strength, density, porosity and skid resistance of CPB were evaluated in this study.

MATERIALS

Cement

Ordinary Portland Cement (OPC) was used as the major binder material in the production of PCPB. The chemical compositions of the OPC are in Table-1.

Table-1. Chemical compositions of the OPC [4].

Chemical Compositions	Percentage (%)
Calcium Oxide (CaO)	70.0
Silicon Dioxide (SiO_2)	17.0
Aluminum Oxide (Al_2O_3)	3.90
Sulfur Trioxide (SO_3)	3.60
Iron Oxide (Fe_2O_3)	3.20
Magnesium Oxide (MgO)	1.50
Potassium Oxide (K_2O)	0.53
Loss of Ignition (LOI)	0.25
Sodium Oxide (Na_2O)	0.02

Aggregate

In this investigation, coarse aggregate with a 10 mm maximum nominal size was used, pursuant to ASTM C33 [5]. Three groups of coarse aggregate size were formed in this study: (a) passes 8 mm retains 5 mm, (b) passes 10 mm retains 8 mm and (c) passes 10 mm retains 5 mm as control to investigate the effects on properties of CPB. Density test was conducted to determine the properties of the coarse aggregates used followed ASTM C127 – 12 [6]. The results on properties of coarse aggregates were summarized in Table-2 below. From the results, it can state that the coarse aggregate in this study is in a range of general granite.

Table-2. Physical properties of different sizes of coarse aggregate.

Coarse Aggregate Size (mm)	Saturated Surface Dry Density (g/cm³)	Absorption (%)
5 – 10	2.52	0.53
5 – 8	2.59	0.61
8 – 10	2.58	0.52

Mix proportion

In this study, CPB was manufactured in Highway Laboratory in Universiti Teknologi Malaysia, UTM with dimension of 200 mm in length, 100 mm in width and 80 mm in thickness, respectively, with the length to width ratio as 2 for this study [7]. Mix proportions of PCPB in this study; cement: fine aggregate: coarse aggregate is 1: 1.02: 1.53 and 0.35 of water cement (w/c) ratio were used. For compaction process, the mixed were vibrated using vibrating table for 6 seconds. The blocks were air cured for 7 days and 28 days at room temperature. Then the blocks were tested at the age of 7 days and 28 days to ensure that the concrete mix satisfied the specification.

TESTING

Compressive strength

Compressive strength of CPB was performed according to BS EN 1338:2003 [8]. The blocks were compressed by using a compression machine with maximum capacity of 3000 kN and a loading rate of 3.0 kN/s at 7 days and 28 days. The reported compressive strength was the average of three block measurements.

Density

This test method covered the determinations of density, air void and porosity in hardened concrete followed ASTM C642 – 13 [9]. The blocks were weighed before immersed in water not less than 24 hours. Then removed the blocks from the water, allow it to surface-dry by removing the surface moisture with a towel to determine the mass. Then the blocks were dried in a ventilated oven at 105 ± 5oC for not less than 24 hours and determined the mass.

Skid resistance

Skid resistance is the most important characteristic for road pavement. Test method using a pendulum type tester with a standard rubber slider was used in this study followed steps as specified in BS 13036 – 4: 2011 [10]. Each block shall permit a test area of 136 mm x 86 mm which is representing the whole specimen. Five swings of the pendulum for each surface of the blocks and the average of three measurements were represented in this study.

RESULTS AND DISCUSSIONS

Compressive strength

Figure-1 show that the compressive strength of CPB increases from 7 days to 28 days. However, the result shows a systematic reduction in compressive strength with the increase of coarse aggregate size. It shows that the compressive strength of CPB decreased from 56 MPa to 54 MPa at 28 days. The reason for the strength reduction could be attributed by increasing amount of voids inside the blocks.

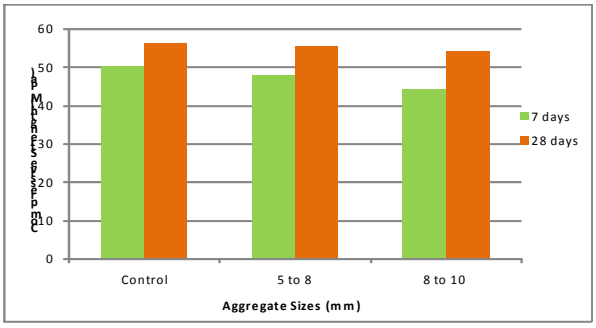

Figure-1. Strength of CPB with different coarse aggregate sizes.

Density

The effect of coarse aggregate sizes on density was evaluated according to ASTM C642 – 13 [9]. The density of CPB was approximately 2.05 g/cm3 to 2.34 g/cm3 at 7 days and 2.32 g/cm3 to 2.38 g/cm3 at 28 days. It shows that the density of CPB increases from 7 days to 28 days. However, the density of CPB decreases with increase size of coarse aggregate. This is due to increasing void content inside the blocks.

Weight loss

The result presented in Figure-2 indicates a systematic increase in the weight loss with increase in coarse aggregate sizes at 7 days and 28 days. However, approximately between 20 % to 25 % reduction in the weight loss of the blocks after 28 days cured. At this age, the density of the blocks is higher which gives results in low weight loss and also produce better quality of the CPB.

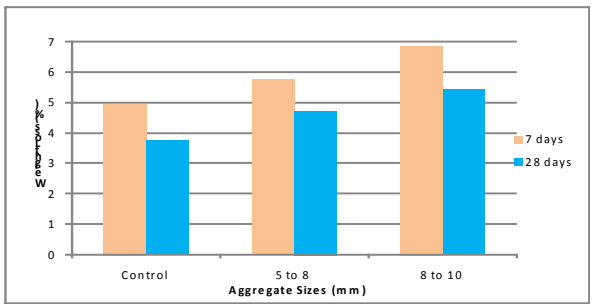

Figure-2. Weight loss of CPB with different coarse aggregate sizes.

Skid resistance

Figure-3 shows that there are increasing in the skid resistance from 43 to 48 with increasing of coarse aggregate sizes. It contributed by the roughness of surface texture. As stated in BS 6717; 2001, the value of the British Pendulum Number (BPN) for paving blocks more than 35 indicates a satisfactory surface for use in pedestrian areas while paving blocks with a BPN rating of 45 and above indicates a general acceptable skid resistance for use in vehicular areas [11].

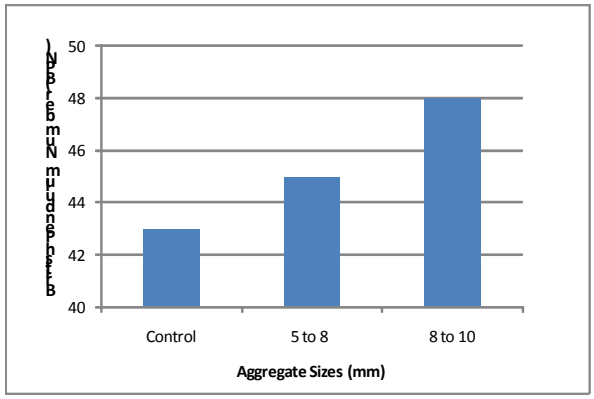

Figure-3. Skid resistance of CPB with different coarse aggregate sizes.

Relationship between density and compressive strength

From the results in Figure-4, it shows that the relationship between the blocks density is directly proportional to the compressive strength. The compressive strength is slightly higher when the density of the blocks is more than 2.31 g/cm3. From the figure, a linear relationship between density and strength give value in m = 0.005, c = 2.053 and R2 = 0.95 at 7 days and m = 0.005, c = 2.038 and R2 = 0.98 at 28 days.

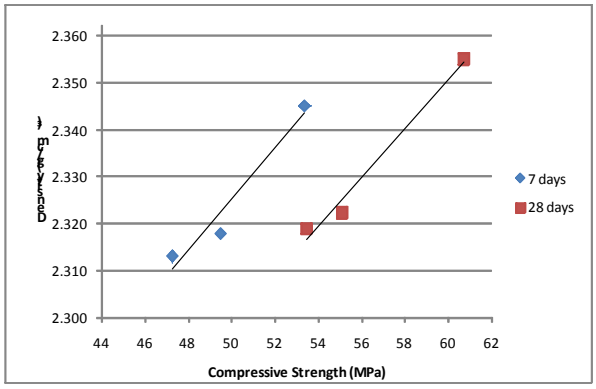

Figure-4. Relationship between density and compressive strength of CPB.

Relationship between porosity and compressive strength

Figure-5 represents the graphical illustration of the relationship between porosity and compressive strength of the blocks. It shows that the porosities reduced with an increase in age. However, the porosity of the blocks increases with increase of coarse aggregate sizes. The strength and porosity were found that the strength less than 50 MPa give higher in porosity. Therefore, if the quality of coarse aggregate and the paste can be controlled, the porosity of the blocks can be estimated. From the figure, a linear relationship between density and strength give value in m = -0.209, c = 20.83 and R^2 = 0.96 at 7 days and m = -0.227, c = 22.80 and R^2 = 0.99 at 28 days.

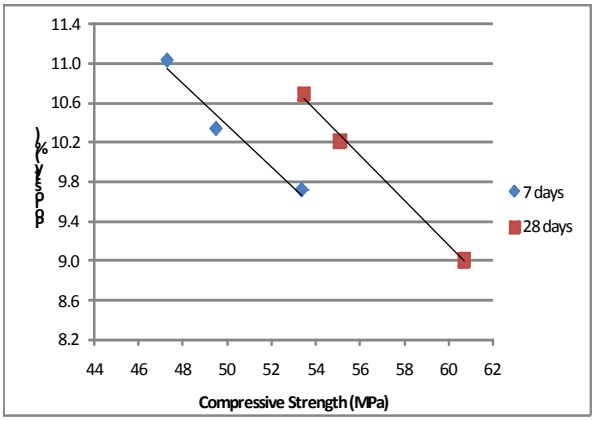

Figure-5. Relationship between porosity and compressive strength of CPB.

CONCLUSIONS

- Test result shows that the compressive strength of CPB with different sizes of coarse aggregate: (a) passes 8 mm retains 5 mm, (b) passes 10 mm retains 8 mm and (c) passes 10 mm retains 5 mm as control are quite similar at 28 days. In addition, all blocks give result in sufficient strength or the minimum required strength (30 MPa) for a rectangular block to be used as part of paving surface.
- CPB with coarse aggregate size passes 10 mm retains 8 mm seems to have better in skid resistance compared to the other blocks. It is suitable to be used for pavement and at slope area. It improves the driving safety and prevent from hydroplaning of vehicle tires.
- Open graded coarse aggregate affect the strength and porosity of the blocks. It increases the air voids and increase the porosity of the blocks. From the results it shows a strong relationship between the porosity and the strength of blocks. However, the strength of blocks will reduce with the increase of porosity of the blocks.

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