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Permeability and Strength of Porous Concrete Paving Blocks at Different Sizes Coarse Aggregate

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Abstract. Porous concrete paving block (PCPB) is a block with continuous voids which are intentionally incorporated into concrete. The permeability and strength of PCPB with different sizes of coarse aggregate was presented in this study. Three different sizes of coarse aggregate were used namely passing 10 mm retained 5 mm (as control), passing 8 mm retained 5 mm (CA 5 – 8) and passing 10 mm retained 8 mm (CA 8 – 10). Furthermore, a series of test were conducted in this study such as compressive strength, porosity and permeability. It was found that the size of coarse aggregate affects the strength and porosity of the specimens. The result also shown that PCPB with CA 8 – 10 caused in low strength, but high in porosity and permeability compared to the other blocks. Beside that PCPB using CA 8 – 10 is able to remove surface runoff efficiently.

1. Introduction

Rapid economic growth in the last two decades has turned many sub-urban areas into busy cities, which created unpredictable urbanization effects. Coupled with the global climate change and also the large ratio of road compares paved to water-permeable (porous) surface road, these in turn lead to increased volume of surface runoff and flash flood. High volume of surface runoff, low skid resistance, minimum appearances, glace and splash water is the factors contributing to the increased number of accidents during rainy weather. Recently, road pavements with a water-permeable (porous) surface have been increasingly used. Porous surface for pavements are adopted for various reasons, such as to increase the driving safety during rainy weather, to reduce the traffic noise, to recharge ground-water and to alleviate the heat island phenomena in urban city centres. It is designed to reduce surface runoff by allowing infiltration [1]. Unlike traditional installation of concrete, porous concrete usually contains a void content 15 % to 25 %, which allows water to infiltrate directly through the pavement surface to the subsurface [2].

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Porous block for Concrete Blocks Pavement nowadays enthused by many developed countries. It is known as porous concrete paving blocks, permeable or pervious interlocking concrete paving blocks. Hassani et al. [3] reported that permeable concrete block pavement is suitable for trafficking and also acts as the drainage system Other than that, porous surface in parking lots are believed to help infiltration and the cleansing of storm water [4]. Three quarters of the volume of PCPB is occupied by aggregates and its physical characteristics differ greatly from conventional concrete block [5]. The use of open-graded aggregate with little or no fine aggregates can achieve a continuous void network inside the block [6]. In addition, previous studies found that between 60 to 65 percent reduction in compressive strength of conventional concrete blocks, but increased in porosity when the fine aggregate was eliminated 100 percent of the mixed [7]. It also reported that, the compressive strengths in the range of 4 MPa to 25 MPa for 28 days (600 psi to 3,600 psi) [8,9]. In this experimental study, the effects of coarse aggregate sizes on the performance of the PCPB were extensively examined. The changes in voids content, porosity and permeability of PCPB subjected to the sizes of coarse aggregate were studied.

2. Materials and methods

2.1. Ordinary Portland cement (OPC)

The porous concrete mixtures were prepared by using Ordinary Portland cement (OPC) as a major binder. According to Hainin et al. [10], the chemical composition of the OPC was within the standard range of 70% CaO, 17.8% SiO_2, 3.9% Al_2O_3, 3.2% Fe_2O_3, 1.5% MgO, and 3.6% SO_3. The OPC similarly indicated a compound composition of 54.5% C_3S, 18.2% C_2S, 9.4% C_3A, and 10.5% C4AF.

2.2. Coarse aggregate

In this investigation, crushed granite as coarse aggregate at three different sizes was used i.e. passing 10 mm retained 5 mm (Control), passing 8 mm retained 5 mm (CA 5 – 8) and passing 10 mm retained 8 mm (CA 8 – 10). However, fine aggregate was eliminated in this investigation. Table 1 summarize the physical properties of the aggregate.

Table 1. Properties of coarse aggregate at different sizes

Size of aggregate (mm)	Type of aggregate	Specific gravity	Water Absorption (%)	Flakiness Index (%)	Elongation Index (%)
Control	Crushed granite	2.57	1.18	19.1	12.1
CA 5 – 8		2.59	1.41	27.1	3.8
CA 8 – 10		2.58	1.50	4.3	26.4

2.3. Permeability test

Permeability test was carried to determine the relative permeability of PCPB. Falling head permeability test was used by using a flexible wall permeameter (Figure 1) and the permeability was measured in term of its discharge time in seconds, which indicate the time taken for a specified volume of water permeate through the sample. The coefficient of water permeability, k, was a product of Darcy's Law equation as state in ASTM PS129 [11]. The test was conducted on a total 18 samples, with dimension of 100 mm diameter and thickness of 80 mm. The permeability was measured in term of time taken for the water level to fall between two designated points from 60 to 20 on the permeameter tube. The experiment was repeated three times for each sample and the average value was calculated.

Figure 1. Permeameter apparatus for permeability test

2.4. Compressive strength test
Compressive strength of PCPB was performed according to BS EN 1338:2003 [12]. 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.

2.5. Porosity test
The porosity test was carried out in accordance with ASTM C642 [13]. The vacuum saturation method was used to determine the porosity of the PCPB. According to ASTM standard, the porosity was calculated based on equation (1).

$$P = [(W_{ssd} - W_d) / (W_{ssd} - W_{ssw})] / 100 \quad (1)$$

where P is the vacuum saturated porosity (%),Wssd is sample weight in saturated surface dry condition in air (g), Wssw the weight of saturated sample in water (g) and Wd the dry weight of the specimen after 24 h in an oven at 100±5 °C (g).

3. Results and discussion
3.1. Compressive strength and porosity
Figure 2 illustrates the relationship between porosity and compressive strength of PCPB. It is clearly shown that the porosity reduces when the compressive strength increases, also concrete porosities reduce with increasing age of PCPB and a similar result was reported by Jaya et al. [14]. At 7 days, the porosity reduces from 15.41 % to 15.01 % for an increase in strength from 16.3 MPa to 19.03 MPa. Furthermore, when tested at 28 days, porosities decreased 15.27 % to 14.69 % with the increase in strength from 23.75 MPa to 27 MPa. A statistical linear regression analysis was carried out on the data and the correlation between compressive strength and porosity is shown in Table 2. The table shows

that the ‘m’ value at 7 days was lower than at 28 days. It can be concluded that the porosity at 7 days greater than porosity at 28 days, it is due to the PCPB become denser while the voids inside the block reducing with the increasing age [15].

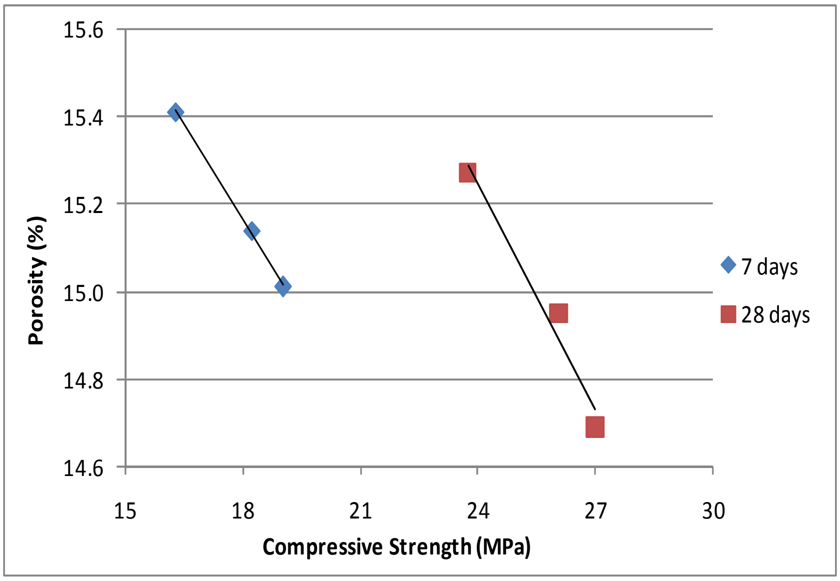

Figure 2. Compressive strength and porosity of PCPB at different curing duration

Table 2. Compressive strength and porosity correlation

Age : days	Slope, *m*	Intercept, *c*	R^2
7	0.145	17.78	0.99
28	0.170	19.33	0.97

3.2. Permeability

The result of different coarse aggregate size against the coefficient of permeability was presented in Figure 3. The results show that the coefficient of permeability ranges between 0.35 cm/s to 0.48 cm/s at 7 days and 0.32 cm/s to 0.41 cm/s at 28 days. The graphs also show the high rate of permeability particularly in early curing duration, but decreasing at a slower rate for further curing duration. There are between 8% to 17% of reduction in permeability when the curing duration increase from 7 days to 28 days. The reduction of the coefficient of permeability is due to the increasing density [16] and decreasing the porosity of the sample with the increasing curing duration. However, for PCPB with CA 8 – 10 show that at both curing duration it gives a result in high permeability compare to the other sample as in Figure 3.

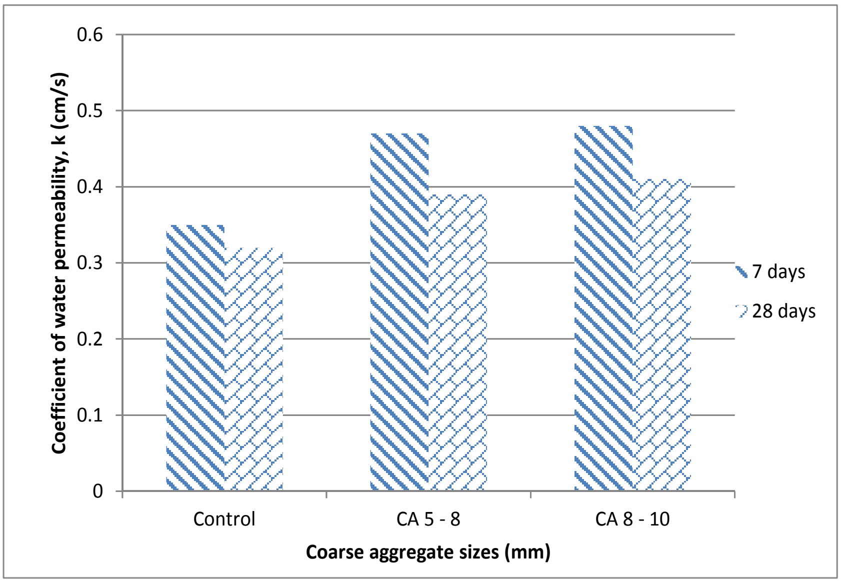

Figure 3. Coefficient of permeability at different size of coarse aggregate

4. Conclusions

a) All PCPB with different size of coarse aggregate cause a great reduction in the water volume during permeability test. However, differences in this reduction between the samples are depending on the coarse aggregate size and porosity. PCPB with CA 8 – 10 give better results in permeability and more suitable be applied at areas with high surface runoff.

b) The permeability results indicate that there are large differences in permeability for all samples when the curing duration increases. Furthermore, the permeability of sample with 28 days curing was lower than the sample with 7 days curing; indicating that age is a factor affecting permeability.

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