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Sound absorption and morphology characteristic of porous concrete paving blocks

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Sound absorption and morphology characteristic of porous concrete paving blocks

N H Abd Halim[1], H Md Nor[1], P J Ramadhansyah[1], A Mohamed[1], N Abdul Hassan[1], M H Wan Ibrahim[2], N I Ramli[3] and F Mohamed Nazri[4]

[1] Faculty of Civil Engineering, Department of Geotechnics and Transportation, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia
[2] Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor Bahru, Malaysia
[3] Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia
[4] School of Civil Engineering, Universiti Sains Malaysia, Engineering Campus, 14300 Nibong Tebal, Penang, Malaysıa
Corresponding author: ramadhansyah@utm.my

Abstract. In this study, sound absorption and morphology characteristic of Porous Concrete Paving Blocks (PCPB) at different sizes of coarse aggregate were presented. Three different sizes of coarse aggregate were used; passing 10 mm retained 5 mm (as Control), passing 8 mm retained 5 mm (8 – 5) and passing 10 mm retained 8 mm (10 – 8). The sound absorption test was conducted through the impedance tube at different frequency. It was found that the size of coarse aggregate affects the level of absorption of the specimens. It also shows that PCPB 10 – 8 resulted in high sound absorption compared to the other blocks. On the other hand, microstructure morphology of PCPB shows a clearer version of existing micro-cracks and voids inside the specimens which affecting the results of sound absorption.

1. Introduction

An increase in volume of road traffic has resulted in an increase in road-generated disturbance to nearby residents as well as contributing to environmental noise pollution [1,2]. If the traffic noise sources are considered in more detail it turns out that vehicle noise is related by the engine, the exhaust opening, vehicle speed and the tyres [3]. Among all, tyres noise is certainly a very important problem in noise control. Tyres noise is generated by tyres vibration and the movement of air particles in the tread tyre pattern [4]. Porous surface has been introduced to reduce the tyre noise. A dense road surface reflects the sound energy, while a porous road surface absorbs the sound energy [5-7]. Ferguson also states that a porous surface absorb sound energy and allow some of the air around the tires to be pressed into the voids, wipe out air pressure before any noise is generated. Nowadays, porous surface has been applied in concrete block shape used for pavement; known as Porous Concrete Paving Blocks (PCPB) or Permeable Blocks. The use of open-graded aggregate with little or no fine aggregates can achieve a continuous void network inside the block; which allowed water to infiltrate directly through the pavement and also help in reducing the noise generate from interconnected between tyres and road surface [8]. Yu et al. [9] reported that noise level generated from PCPB is found to be very similar to those of the ordinary asphalt pavement.

2. Materials and Methods

2.1. Ordinary Portland Cement and Coarse Aggregate
The three sizes of crushed granite as coarse aggregate were used; passing 10 mm retained 5 mm (Control), passing 8 mm retained 5 mm (8 - 5) and passing 10 mm retained 8 mm (10 – 8) and mixed with Ordinary Portland cement (OPC) as a major binder. No fine aggregate used, to allow voids inside the block. The water-cement ratio of 0.35 was used and for compaction process; the mixed were vibrated using vibrating table for less than 3 seconds. The blocks were air cured for 7 days and 28 days at room temperature.

2.2. Sound Absorption Test
The absorption coefficient is commonly reported as a measure of a material ability to absorb sound [10]. In this study, the acoustic absorption coefficient was measured using an impedance tube as per ASTM E 1050 [11]. The specimens with diameter 100 mm and thickness of 80 mm was placed in a thin cylindrical and placed against a rigid backing at one end of the impedance tube (as in Figure 1a and Figure 1b). Microphones placed along the length of the tube were used to detect the sound pressure level (P), which were translated into the reflection (R) and absorption coefficient (α)1.

Figure 1. (a) Sound absorption test instrument, left and (b) Position of a specimen, right.

2.3. Field Emission Scanning Electron Microscopy
Field emission scanning electron microscopy (FESEM) studies were carried out on platinum-coated fractured surface PCPB samples using Hitachi Scanning Electron Microscope SU8020. In general, FESEM is microscopies techniques are used to magnify images of surface morphology for example the shape and size of the topographic features of the specimen surface.

3. Results and Discussion

3.1. Sound Absorption of PCPB
In order to analyse the sound absorption characteristics of PCPB, the specimens were measured for each frequency using the impedance tube. The measurement result is shown in figure 2. It can be seen that the results of Jusli *et al.* [12] the PCPB of control specimens, the absorption coefficient became highest in the frequency range of 500 – 550 Hz; Nur Hidayah *et al.* [13] for the PCPB 8 – 5, it becomes highest in the frequency range of 550 – 600 Hz; and Jusli *et al.* [14] for the PCPB 10 – 8, become highest in the frequency range of 600 – 650 Hz. This signifies that the frequency of the highest absorption coefficient was obtained as the coarse aggregate size increased. This is because absorption became higher as the porosity and voids inside the blocks increased. This result has been supported by previous findings by Park et al. [15] where the absorption becomes higher as the surface area of voids increased and resulting in the highest sound absorption coefficient.

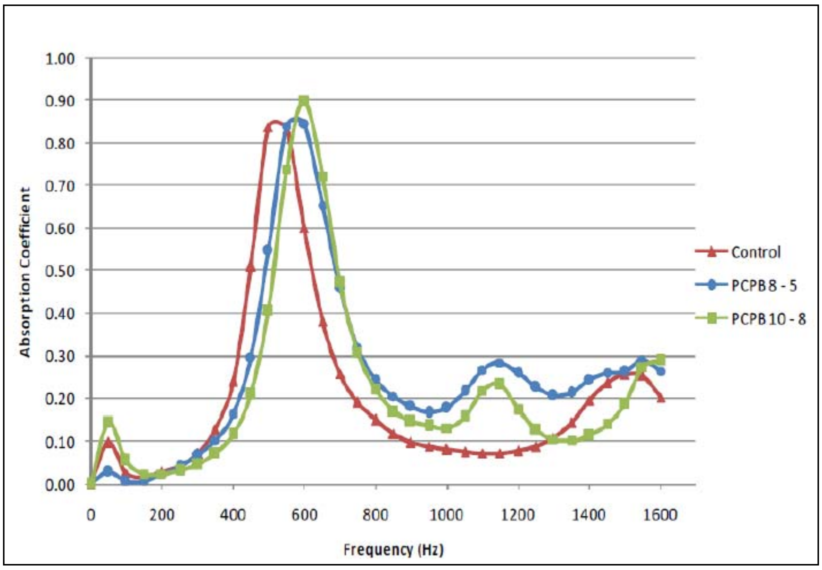

Figure 2. Sound absorption of PCPB specimens.

3.2. Sound Absorption of CPB

By comparing the results of PCPB with the CPB in sound absorption, it proved that by eliminating the fine aggregate in the mix will contribute to high sound absorption. In general, the results of CPB specimen (Figure 3) with all sizes of coarse aggregate in sound coefficient is less than 0.1 compared to PCPB specimens which is more than 0.8. This shows that, PCPB specimens suggested was applied at road with high noise generated.

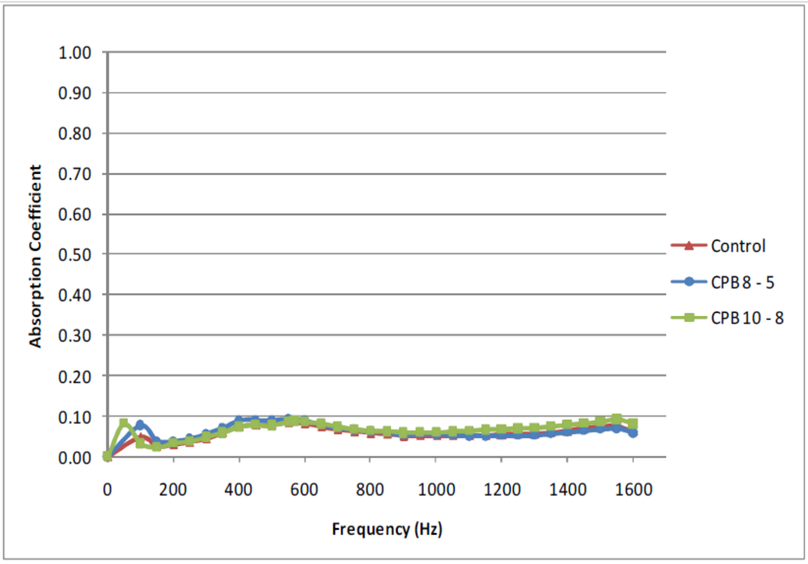

Figure 3. Sound absorption of CPB specimens.

3.3. Morphology Image

FESEM investigations on hardened PCPB show distinct changes in the morphology after 7 days curing process at room temperature. The samples drawn from the fractured surface of the PCPB specimens were examined. A number of FESEM micrographs illustrating various characteristic of PCPB as in Figure 4. FESEM micrographs of hardened PCPB at room temperature, respectively, reveal well developed hydrated phases such as Portlandite, $Ca(OH)_2$ crystals (marked "CH") intermixed with C-S-H (marked "CSH"), voids (marked "V") and deformation of ettringite, $\{Ca_6[Al(OH)_6]2 \cdot 24H_2O\}[(SO_4)3 \cdot 1.5H_2O]$ (marked "E"). In addition, due to no fine aggregate in the PCPB, it leads to the predominance of micro-cracks and voids as shown in Figure 4.

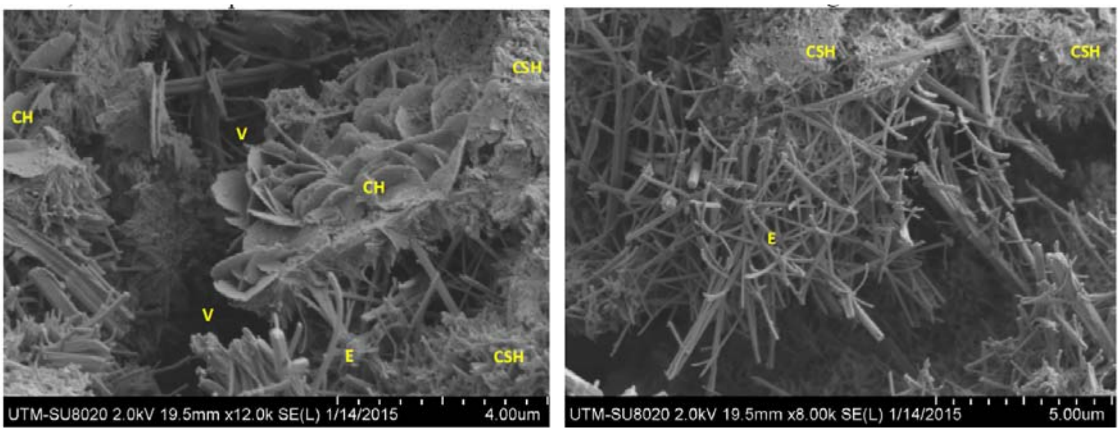

Figure 4. Morphology in the porous concrete paving blocks specimen.

4. Conclusions

a) By eliminating the fine aggregate in mixed, results in an increasing absorption coefficient. In this study, it shows that approximately 80 % to 90 % improves in sound absorption with PCPB and it's also suggested as noise reducing concrete block for pavement.
b) An increase in coarse aggregate size results in high sound absorption, it is due to the increased of the pore size and porosity. In this study, PCPB with CA 10 – 8 give in the result of high absorption coefficient at the highest frequency compared to other specimens.

5. References

[1] Nur Hidayah A H, Nor H M, Ramadhansyah P J 2016 Effect of open-graded coarse aggregate on concrete paving blocks properties for pavement, *ARPN J. Eng. Appl. Sci*. **11** 11836-11839
[2] Graf R A G, Kuo C Y, Dowling A P, Graham W R 2002 On the horn effect of a tyre/road interface, part I: experiment and computation, *J. Sound Vibration* **256** 417-431
[3] Heckl M 1986 Tyre noise generation, *Wear* **113** 157-170
[4] Gołebiewski R, Makarewicz R, Nowak M, Preis A 2003 Traffic Noise reduction due to the porous road surface, *Appl. Acoustics* **64** 481-494
[5] Jusli E, Nor H M, Putra Jaya R, Haron Z 2014 Double layer concrete paving blocks using waste tyre rubber as aggregate replacement, *Appl. Mech. Mater*. 554 128-132
[6] Yamaguchi M, Nakagawa H, Mizuno T 1999 Sound absorption mechanism of porous a sphalt pavement, *J. Acoustical Society Japan* **20** 29-43
[7] Bérengier M C, Stinson M R, Daigle G A, Hamet J F 1997 Porous road pavements: Acoustical characterization and propagation effects, *J. Acoustical Society America* **101** 155-162.
[8] Nur Hidayah A H, Nor H M, Ramadhansyah P J 2014 Porous concrete paving blocks using coarse aggregate, *Appl. Mech. Mater*. **554** 111-115
[9] Yu C, Ke-Jin W, Di L 2012 Mechanical properties of pervious cement concrete, *J. Cent. South. Univ*. **19** 3329–3334

[10] Marolf A, Neithalath N, Sell E, Wegner K, Weiss J, Olek J 2004 Influence of aggregate size and gradation on acoustic absorption of enhanced porosity concrete, *ACI Mater. J.* **101** 82-91
[11] ASTM E1050 2012 *Standard test method for impedance and absorption of acoustical materials using a tube, two microphones and a digital frequency analysis system* (United States: American Standard) pp 1-12
[12] Jusli E, Nor H M, Putra Jaya R, Haron Z 2014 Mechanical properties of double layer rubberized concrete paving blocks, *Adv. Mater. Res.* **911** 463-467
[13] Nur Hidayah A H, Nor H M, Azman M 2014 Effect of jointing sand sizes and width on horizontal displacement of concrete block pavement, *J. Teknologi* **71** 83-86
[14] Jusli E, Nor H M, Jaya R P, Haron Z, Azman M 2014 Effect of using waste tyre rubber on the properties of double layer rubberized concrete paving blocks, *J. Teknologi* **71** 1-5
[15] Park S B, Seo D S, Lee J 2005 Studies on the sound absorption characteristics of porous concrete based on the content of recycled aggregate and target void ratio, *Cement Concrete Res.* **35** 1846-1854

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