Jurnal
Teknologi

Full Paper

# STRENGTH OF POROUS CONCRETE PAVEMENT AT DIFFERENT CURING METHODS

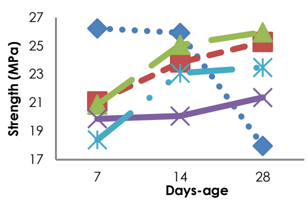
Mohd Ibrahim Mohd Yusak[a], Ramadhansyah Putra Jaya[a*], Mohd Rosli Hainin[a], Che Ros Ismail [a], Mohd Haziman Wan Ibrahim[b]

[a]Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor Bahru, Johor
[b]Department of Material and Structure Engineering, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor

**Article history**
Received
*30 April 2015*
Received in revised form
*5 August 2015*
Accepted
*1 September 2015*

*Corresponding author
ramadhansyah@utm.my

**Graphical abstract**




**Abstract**

Porous concrete pavement has been used in some countries as a solution to environmental problems. Contrary to conventional concrete pavement, there is still lack of knowledge in some areas of production and performance of porous concrete pavement. One of the issue concern is curing conditions. These greatly affect the performance of porous concrete pavement. This paper elaborates the experimental results examining the influence of curing method and makes a comparison between five different curing methods on the strength of porous concrete pavement specimens. The properties analyzed include compressive strength, tensile splitting strength and flexural strength. The experimental results indicate that the different curing methods give a different effect to concrete strength. Based on the results obtained in this experiment, curing method by using polyethylene bag promise a good result and better performance to porous concrete pavement specimen strength.

*Keywords*: Porous concrete pavement, curing method, strength



## 1.0 INTRODUCTION

Porous concrete pavement (also called as pervious concrete, permeable concrete and no-fines concrete pavement) [1] is a special type of concrete that contain high percentage of porosity in it's structure. This type of pavement is normally designed with pores that allow water to flow through its structure. The porous concrete pavement (PCP) has been used as one of the solution to mitigate storm water runoff by capturing and percolate water to drain into land surface [2, 3]. Basically, porous concrete pavement consists of coarse aggregates, cement and water. Some researchers include a small amount of fine aggregates in the mixture in order to expand the strength and durability development [3]. The addition of admixture (superplasticizer) is optional in order to enhance the workability.

Proper concrete curing is particularly important for developing high quality pavement. Proper curing of concrete defined providing a satisfactory moisture and temperature conditions for a period of time immediately to promote cement hydration and concrete microstructure development, so that the desired properties for its intended uses may developed [4, 5]. Curing has a substantial influence on the properties of hardened concrete. Proper curing of the concrete plays a very important role to increase durability, strength, water tightness, abrasion resistance, volume stability and resistance to freezing and thawing and deicers [5, 6]. In order to hit its target performance strength, careful concrete casting must be followed by an adequate curing regime/method, especially in the first days of concrete setting [7].

There are a variety of methods for concrete curing purposes such as pounding and immersion, fogging and sprinkling, wet coverings/burlap, impervious paper, plastic sheets, steam curing, liquid membrane forming compounds, microwave and infrared curing [4, 5]. Presently, there is no appropriate testing method and lack of references addresses proper curing of porous concrete in laboratory available to evaluate the effectiveness of curing method [4]. Even though no studies have been performed to determine if that is sufficient or even required, porous concrete has been covered with plastic for 7 days as curing method [8]. Burg [9] mentioned that the most effective method for curing concrete depends on the materials used, method of construction and the intended use of the hardened concrete. Therefore, the objective of this research is to study the influence of curing method and make a comparison between five different curing methods on the strength of porous concrete pavement specimens.

## 2.0 EXPERIMENTAL

The aggregate properties were characterised based on the standard tests specified in Table 1. The aggregate gradation shown in Figure 1 and aggregates physical properties are presented in Table 2.

The mix proportion of concrete is presented in Table 3. Once the porous concrete was mixed using drum mixer, the mix was cast in the moulds and compacted using vibrating table. After the samples were casted in the molds, it was kept for 24 hours in the concreting area inside the laboratory before demoulding and curing process respectively.

The comparison of various curing method on strength of porous concrete pavement specimens were the main objective of this study. The curing methods were created as per listed below. Method 1,2,4 and 5 were compared to method 3 in the discussion part.

Method 1 - Water curing [10]
Method 2 - Water curing - change water periodically [10]
Method 3 - Curing in polyethylene bag [11]
Method 4 - Laboratory condition air curing
Method 5 - 7 days-age in water tank and the rest laboratory condition air curing

Method 1 was performed in a water curing tank where the temperature (20 ± 2 °C) and relative humidity (100%) are kept constant. In this method, the water never changes until the end of curing time.

Method 2 was performed similar to Method 1 which is kept in water curing tank where the temperature and relative humidity were 20 ± 2 °C and 100% respectively. The difference with method 1 is this method being periodically changed water.

Method 3 has been conducted according to British standard for curing no-fines concrete [11]. Immediately after demoulding, the specimens were wetted by immersing it in water until air bubbles cease to rise. Then, the specimens were drained and immediately place in polyethylene bags. The specimens were kept in the polyethylene bag until the end of curing time.

For Method 4, after demoulding, the specimens were kept in laboratory condition until the end of curing time, whereas Method 5, after demoulding, the specimens were curing in water curing tank until 7 days-age and kept in laboratory condition until 28 days-age. The temperature and relative humidity of laboratory condition were recorded approximately 27°C and 65% respectively. The test methods for hardened porous concrete pavement specimens used in this study were listed in Table 4.

Compressive strength at 7, 14 and 28 days-age was determined respectively by three numbers of 100 mm cubic specimens were produced. For tensile splitting strength, 9 numbers of Ø 100 mm x 200 mm cylindrical specimens were produced. 3 numbers of cylindrical specimens were tested for each age of 7, 14 and 28 days-age respectively. The flexural strength test, 3 numbers of 100 mm x 100 mm x 500 mm beam is produced and tested at 28 days-age.

The numbers of specimens specified refer to only one type of curing method. The overall number of specimens produced for this study is those specified multiplied by 5 curing methods.

**Table 1** Standards test used to characterize aggregate

| Properties | Standard used |
|---|---|
| Sieve analysis | ASTM C33/C33M-13 |
| Particle density and water absorption | ASTM C127-12 |
| Aggregate impact value | BS 812-112:1990 |
| Flakiness Index | BS 812-105.1:1989 |
| Elongation Index | BS 812-105.2:1990 |

**Table 2** Physical properties of aggregate

| Property | Result |
|---|---|
| Oven dry density (kg/m$^3$) | 2580 |
| Saturated surface dry density (kg/m$^3$) | 2600 |
| Apparent density (kg/m$^3$) | 2630 |
| Water Absorption (%) | 0.75 |
| Aggregate impact value (%) | 17 |
| Flakiness index (%) | 13.8 |
| Elongation index (%) | 25.4 |

**Table 3** Mix proportion

| Material | Quantity |
|---|---|
| Ordinary Portland Cement (kg) | 450 |
| Coarse aggregate (kg) | 1115 |
| Water (kg) | 153 |
| Water cement ratio | 0.34 |

**Table 4** Standard test method used for hardened concrete specimen

| Property | Method |
|---|---|
| Compressive strength | BS EN 12390-3:2009 |
| Tensile splitting strength | BS EN 12390-6:2009 |
| Flexural strength | BS EN 12390-5:2009 |

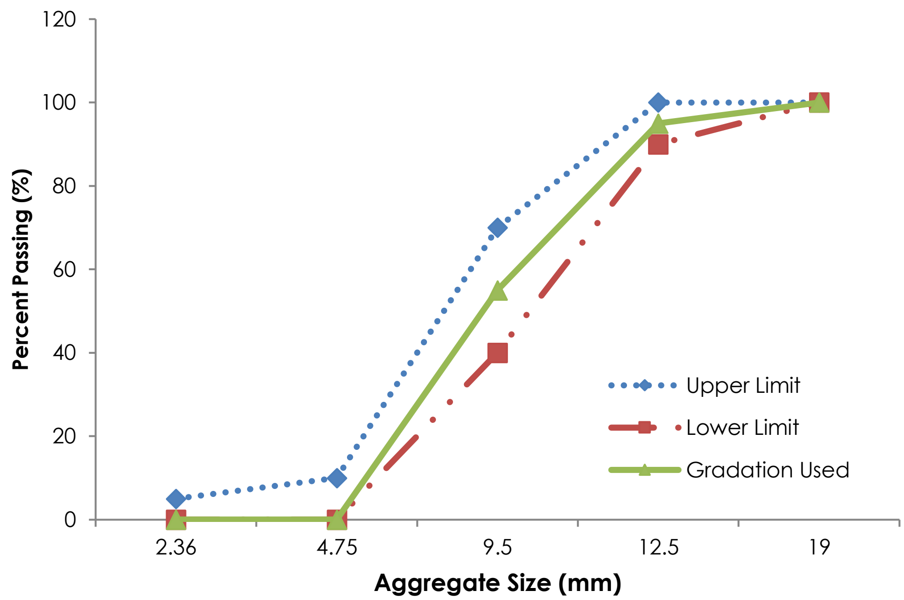



**Figure 1** Aggregate gradation

## 3.0 RESULTS AND DISCUSSIONS

In this study, the specimens for Method 3 have been used as control specimens. The compressive strength, tensile splitting strength and flexural strength results from these specimens become an indicator to make a comparison between all 5 methods. Method 3 are conducted refer to standard method for making and curing no-fines test cubes [11].

### 3.1 Compressive Strength

The compressive strength comparisons of 7, 14 and 28 days-age specimens between 5 methods are plotted in the Figure 2. It can be seen that, the different curing method gives different reaction speed. For 7 days-age result, concrete strength for Method 3 and 5 are lower than Method 2 and 4 respectively. It is differ for 14 days-age where the Method 3 and 5 start to higher than Method 2 and 4 respectively. For 28 days-age specimens, Method 3 shows the highest strength development among specimens tested. Based on Figure 2, it reveals that the most effective curing process was Method 3. The compressive strength of Method 3 for 7, 14 and 28 days-age show better reaction for porous concrete pavement specimens than other methods. On the other hand, the most ineffective curing technique is Method 1. The compressive strength of Method 1 start to decrease after 7 days-age and for 28 days-age, Method 1 has the lowest strength. Differs to other methods, the strength of Method 1 decrease after 7 days-age where the other method increase its strength after 7 days-age. This is likely because the water in the curing tank is not changed. When the water in the curing tank is not changed in certain time, the pH of water will change [12]. The pH value of the water in the curing tank will affect the strength of concrete cubes [13].

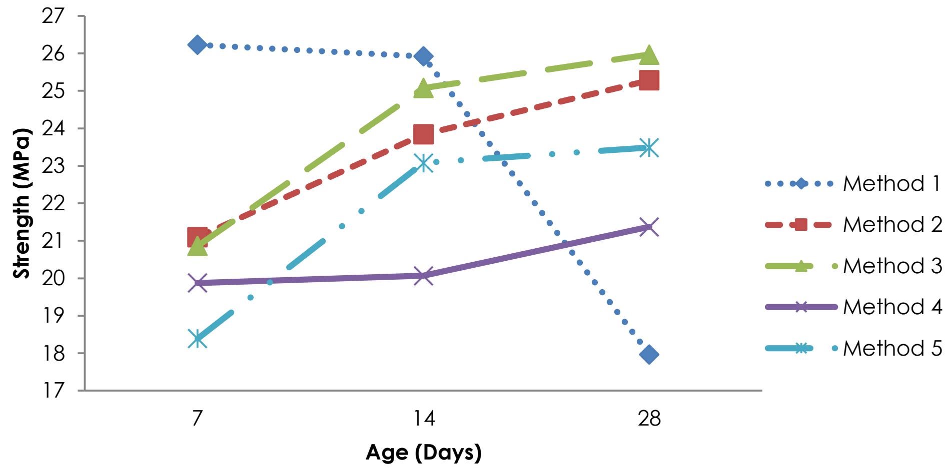



**Figure 2** Compressive strength comparisons between 5 methods

### 3.2 Tensile Splitting Strength

Figure 3 shows the tensile splitting strength comparisons for 7, 14 and 28 days-age between 5 methods. It can be seen that concrete specimen cured using Method 3 has the highest tensile splitting strength for 28 days-age. At 7 days-age, Method 1 has the highest strength. The strength for Method 1 starts to decrease drastically after 14 days-age. At 28 days-age, Method 1 has the lowest strength. Similar to compressive strength result, only Method 1 decreases its strength whereas the other methods increase its strength for 7, 14 and 28 days age. The data plotted at the graph show that the effective curing method for porous concrete pavement specimens was Method 3 as it is method provided by British Standard while the ineffective curing method was Method 1.

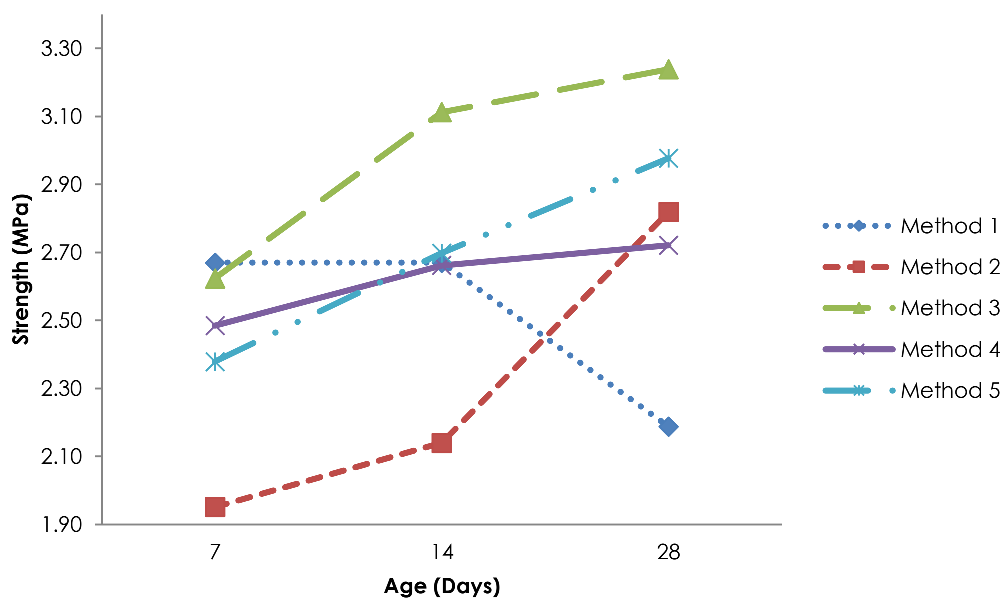



**Figure 3** Tensile splitting strength comparisons between 5 methods

### 3.3 Flexural Strength

Figure 4 shows the flexural strength comparison for 28 days-age for all method. Method 3 has the highest strength while Method 4 has the lowest strength. It differs to compressive strength and tensile splitting strength where the Method 1 has the lowest strength.

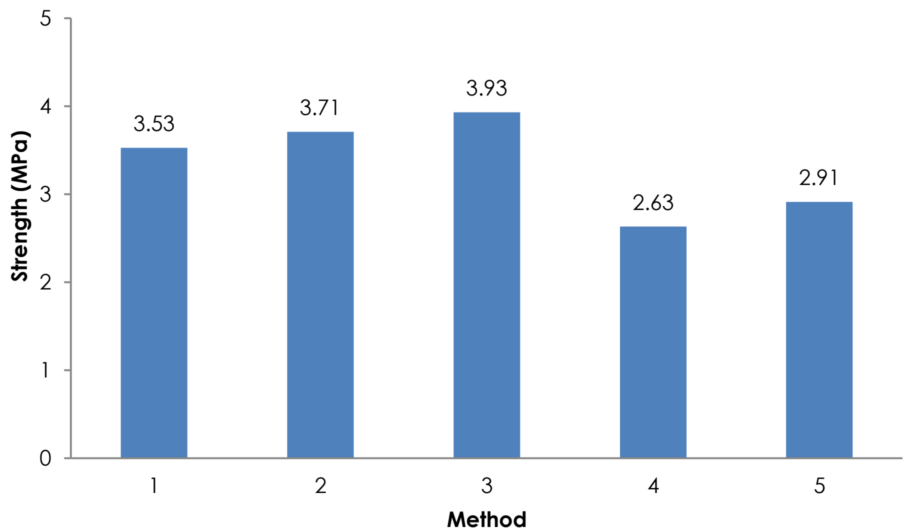



**Figure 4** Flexural strength comparisons at 28 days-age

## 4.0 CONCLUSIONS

The objective of this study is to evaluate the influence of curing method and make a comparison between five different curing methods on the strength of porous concrete pavement specimens. From the result, it revealed the better curing method for porous concrete pavement specimens. As expected, Method 3 gives the best results for compressive strength, tensile splitting strength and flexural strength because this method has been designed for curing porous concrete specimens. To cure porous concrete pavement specimen in the laboratory, the suitable curing methods need to be considered. Different curing methods give different reaction to specimens. Porous concrete pavement specimen different to normal concrete specimen where the drier curing condition didn't confer great strength at a younger age and most humid curing condition didn't give great strength in the medium and long term. Hence, the suitable curing methods need to be considered.

## Acknowledgement

The support provided by Malaysian Ministry of Higher Education and Universiti Teknologi Malaysia in the form of a research grant Vote Number Q.J130000.2522.09H67 and Q.J130000.2422.02G89 for this study is very much appreciated.

## References

[1] Mohd Ibrahim, M. Y., Ramadhansyah, P. J., Mohd Rosli, H. and Mohd Haziman, W. I. 2014. An Overview on the Performance of Nano Silica Materials on the Properties of Porous Concrete Pavement. *Advanced Review on Scientific Research*. 1(1): 34-42.

[2] Ramadhansyah, P. J., Mohd Ibrahim, M. Y., Mohd Rosli, H., Muhamad Naqiuddin, M. W. and Wan Ibrahim, M. H. 2014. Porous Concrete Pavement Containing Nano-silica: Pre-Review. *Advance Materials Research*. 911: 454-458.

[3] Kevern, J. T., Schaefer, V. R., Wang, K. and Suleiman, M. T. 2008. Pervious Concrete Mixture Proportions for Improved Freeze-Thaw Durability. *Journal of ASTM International*. 5(2).

[4] Wang, K., Cables, J. K. and Ge, Z. 2006. Evaluation of Pavement Curing Effectiveness and Curing Effects on Concrete Properties. *Journal of Materials in Civil Engineering*. 18: 377-389.

[5] Prommas, R. and Rungsakthaweekul, T. 2014. Effect of Microwave Curing Conditions on High Strength Concrete Properties. *Energy Procedia* 56: 26-34

[6] Bingöl, A. F. and Tohumcu, I. 2013. Effects of Different Curing Regimes on the Compressive Strength Properties of Self Compacting Concrete Incorporating Fly Ash and Silica Fume. *Materials and Design*. 51: 12-18.

[7] Neville, A. M. 1983. *Properties of Concrete*. UK: Longman Scientific & Technical.

[8] Kevern, J. T., Schaefer, V. R. and Wang, K. 2009. The Effect of Curing Regime on Pervious Concrete Abrasion Resistance. *Journal of Testing and Evaluation*. 37(4).

[9] Burg, R.G. 1996. *The Influence of Casting and Curing Temperature on the Properties of Fresh and Hardened Concrete*. No. R&D Bulletin RD113T, Portland Cement Association.

[10] BS EN 12390-2:2009. Testing of Hardened Concrete – Part 2: Making and Curing Specimens for Strength Tests. BSI Group, London, UK.

[11] BS 1881-113:2011. Testing Concrete – Part 113: Methods for Making and Curing No-Fines Test cubes. BSI Group, London, UK.

[12] Wan, C.N.C., Jaya, R. P., Jayanti, D. S., Bakar, B. H. A. and Arshad, M. F. 2014. Strength of Concrete Containing Rice Husk Ash Subjected to Sodium Sulfate Solution Via Wetting and Drying Cyclic. *Applied Mechanics and Materials*. 534: 3-8.

[13] Dewi, S. J., Ramadhansyah, P. J., Norhidayah, A. H., Md. Maniruzzaman, A. A., Hainin, M. R. and Che Norazman, C. W. 2014. Performance of RHA Blended Cement Concrete Under Sodium Chloride via Wetting and Drying. *Applied Mechanics and Materials*. 554: 106-110.