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Quality evaluation tests for pervious concrete pavements' placement

Milena Rangelov [a], Somayeh Nassiri [a,*], Zhao Chen [a], Mark Russell [b], Jeffery Uhlmeyer [b]

[a] Washington State University, 2001 East Grimes Way, Pullman, WA 99164-5815, United States
[b] WSDOT Pavement Office, PO Box 47365, Olympia, WA 98504-7365, United States

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Abstract

Pervious concrete pavements are gaining popularity for stormwater management. Therefore, there is an impending need for the development of quality control and acceptance specifications. In this study, the necessary initial steps are taken towards this goal. The procedures to conduct fresh and hardened density/porosity (φ) and 28-day compressive strength (f'_c) were evaluated. The proper methodology for casting specimens in the field was identified by examining the agreement between the fresh (D) and hardened density (ρ). The effect of cylindrical size, and curing methods as combinations of air and moist curing during the four-week period on f'_c was studied.

Both cylinder sizes demonstrated comparable values of hardened porosity ($\varphi = 16$ percent) and hardened density ($D = 2.11$ kg/m^3), as well as strong linear φ–D correlations (R^2 range 0.60–0.90). The values of D agree well with those of the fresh density (two percent or less difference), which confirmed the suitability of the implemented casting and compaction procedure. Small cylinders presented higher 28-day f'_c than large cylinders by 7.7 to 19 percent, depending on the curing category. The two-week air followed by two-week moist curing (2A2 M) method yielded the highest 28-day f'_c for both specimen sizes, however, longer periods of moist curing did not result in higher strengths. Cylinders from 1A3M, which were exposed to the longest moist curing, demonstrate the lowest f'_c. Thermogravimetric analysis (TGA) confirmed the trends seen in 28-day f'_c and proved (that) longer moist curing resulted in the loss of C–S–H and $Ca(OH)_2$.
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Keywords: Pervious concrete; Porosity; Density; Compressive strength; Curing

1. Introduction

Pervious concrete pavements (PCP) are permeable pavement structures, simultaneously serving stormwater management and bearing pedestrian/traffic loads, depending on the application. In this pavement system, a 150–300 mm pervious concrete (PC) layer with a high air void content is placed on a highly voided stone bed as the base layer, to allow for a rapid infiltration of runoff through the pavement system rather than allowing it to pond or run on the surface [1,2]. For sidewalks, reduced icing and therefore pedestrian slipping, and for parking lots/bike trails and light traffic streets, reduced hydroplaning and wet weather accidents are among the additional expected outcomes of using PCP [2,3].

PC's prominent characteristic is the high content of hardened air void, typically ranging between 15 and 25 percent of the total volume [2]. Porosity is an essential property of PC, impacting its hydraulic, mechanical and durability characteristics, and is highly dependent on the mixture design parameters and the method of compaction [1]. PC mixture design is based on limiting the coarse aggregate grade to single-sized or grade 9.5–19 mm, and either completely removing or using a minimal amount of fine aggregate for added strength [1]. The end result is a matrix

* Corresponding author.
E-mail address: snassiri@wsu.edu (S. Nassiri).
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of coarse aggregate (that are) bridged by the paste as opposed to the conventional portland cement concrete (PCC), where the aggregate is fully embedded in the paste. Naturally, the voided structure of PC results in lower mechanical properties and higher variability comparing to PCC. The effects of different mixture design parameters, such as mixture proportioning, aggregate type and size, binder type and content on the compressive strength were investigated [4–7]. Several research efforts focused on improving the mechanical and durability properties of PC by using various supplementary materials: polypropylene fibers [8,9], latex [10], addition of low contents of fine aggregate (five to 10 percent of the mass of the coarse aggregate) [11,12], and the addition of carbon fiber composite elements [13]. While the research on optimizing PC mixture design for better performance is needed, equally important is the development of standardized test procedures for specimen casting, curing and mechanical testing, so as to the research efforts are harmonized and the test results are comparable. In the wake of PCP's fast growth in popularity, project owners are need of standardized acceptance and quality control test procedures. Currently, only a handful of standardized test procedures is available for testing PC's fresh and hardened properties, the determination of fresh density [14], hardened density and porosity [15], and infiltration rate [16]. As for mechanical properties, standardized procedures are not available for casting and curing PC specimens, neither exists mechanical testing procedures that would result in reliable and meaningful test results within tolerable test variations. As a result, the procedures available for conventional PCC are typically followed for PC in the absence of more appropriate methodologies [17,18]. Consequently, a variety of methods has been used to cast specimens and conduct mechanical testing, which often yields unreliable and incomparable results among the studies.

This study takes a step back from the research reviewed above and focuses on evaluating rudimentary procedures that are essential to any mechanical testing of PC conducted for quality control. In this study, proper tests to establish the fresh PC properties are evaluated and identified. The effect of the specimen size, casting method, curing during and condition, and finally the strength test procedure are evaluated. The main objectives of this study are to:

– Examine the method of casting and compacting specimens in the field based on experimentally determined fresh density.
– Evaluate the effect of cylindrical specimen size on hardened density and 28-day compressive strength (f'_c).
– Investigate the effect of air and moist curing duration on 28-day f'_c.

The results of this research are expected to help with the development of reliable quality control and acceptance tests for PCP placement in the future.

2. Background

Concrete quality assurance tests are commonly conducted on cylindrical specimens, cast at the job site and cured for later testing of hardened properties. Small-size cylindrical specimens (100 mm in diameter by 200 mm in height) relative to large cylinders (150 mm in diameter by 300 mm in height) are more desirable because they are cast faster as they require less material, less number of lifts and lower compaction efforts. Further, they weigh less: anywhere from 2.8 to 3.8 kg for a typical small PC cylinder compared to 9.5 to 12.7 kg for a large PC cylinder [5,6], and thereby are easier to transport, store and cure. Fresh density is one of the acceptance tests that is commonly conducted for quality assurance of pervious concrete [1]. Specimen size may affect the ease of achieving the target density, depending on the compaction procedure. Similar to conventional PCC, PC is placed and compacted in two lifts when casting small cylinders, while it is placed in three lifts to cast large cylinders [19]. To achieve the target density as per the mixture design, and a nearly uniform distribution of density throughout the specimen's height, each lift needs to be pre-weighed and placed in the mold to fit the required volume. Depending on the workability, the mixture is placed and fit in the mold by certain drops of the Proctor hammer and/or by several strikes of the mallet. With varying number of lifts between the two cylinder sizes, it is critical to make sure that both sizes yield reliable density for acceptance evaluation. An empirical relationship can be developed to correlate the hardened density of the two size cylinders.

While not as commonly used, 28-day f'_c test can still be conducted as an acceptance test for PC and to provide insight into mechanical properties of the mixture [4–7]. However, f'_c results obtained on the two size cylinders inherently vary, and therefore it is important to ensure that small cylinders still provide reliable test results for acceptance evaluation. Similar research studies conducted in the past on conventional PCC show that generally a linear relationship exists between f'_c of small cylinders ($f_{c\text{-}small}$) and that of large cylinders ($f_{c\text{-}large}$):

$$f_{c-small} = k_s \times f_{c-large} \tag{1}$$

Experimentally determined values of k_s from the literature range from 0.68 to 1.19, with k_s being greater than unity for PCC strengths below 40 MPa [20], which is the case for PC mixtures. This relation needs to be investigated to establish a proper value for k_s for pervious concrete.

In addition to cylinder size, another factor that can substantially affect f'_c results is the curing method and duration. As opposed to conventional PCC, pervious concrete requires a longer wait before demolding to avoid dislodging of aggregate and breakage of the matrix due to demolding, handling and transporting. Commonly, freshly paved PC pavements are kept under the sheets of impermeable plastic seven days upon casting after which the pavements are open to the traffic [1,2]. Hence the same period is

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