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Maximum paste coating thickness without voids clogging of pervious concrete and its relationship to the rheological properties of cement paste

Xiaogeng Xie [a], Tongsheng Zhang [a,b,c,*], Yongmin Yang [d], Ziyu Lin [a], Jiangxiong Wei [a,c], Qijun Yu [a,c]

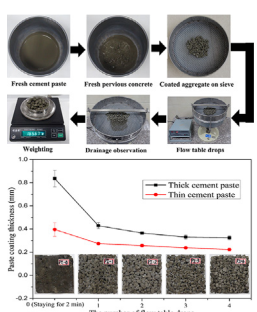
[a] School of Materials Science and Engineering, South China University of Technology, 510640 Guangzhou, China
[b] Department of Civil, Environmental and Geomatic Engineering, University College London, WC1E 6BT, UK
[c] Guangdong Low Carbon Technologies Engineering Center for Building Materials, 510640 Guangzhou, China
[d] Guangdong Research Institute of Water Resources and Hydropower, 510635 Guangzhou, China

HIGHLIGHTS

- Maximum paste coating thickness (MPCT) on aggregate without clogging of voids was defined.
- A paste drainage test was developed on a flow table to determine the MPCT.
- Test variables (the number of flow table drops, sieve size, and aggregate size) were optimized.
- Uniform relationships between yield stress, viscosity, mini-slump spread and MPCT were established.
- The reliability of relationships was validated by comparing predicted and measured MPCTs.

GRAPHICAL ABSTRACT

To evaluate the maximum paste coating thickness on aggregate (MPCT) that will not result in clogging of voids, a paste drainage test on flow table was developed, and test variables in terms of the number of flow table drops, the sieve mesh size and the aggregate size were optimized, such that the paste coating thickness measured in the test provided an estimate of the MPCT. Furthermore, uniform relationships between yield stress, viscosity, mini-slump spread and MPCT were established, which will give a better understanding of a critical criterion for mixture design and clogging prediction of pervious concrete.



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ABSTRACT

All mixture design methods for pervious concrete have been proposed under the hypothesis that cement paste uniformly coats on the surface of aggregate and does not drain off from the aggregate surface to clog the interconnected voids between aggregate particles. To evaluate the maximum paste coating thickness on aggregate (MPCT) that will not result in clogging of voids, understanding of the relationship between the MPCT and the rheological properties of cement paste was reviewed and theoretically analyzed in the present study. A paste drainage test was developed on a flow table to determine the MPCT, with specification of test variables (in terms of the number of flow table drops, the sieve mesh size, and the aggregate size) to ensure good repeatability and precision. Based on testing data of 39 cement pastes, uniform relationships between yield stress, viscosity, mini-slump spread and MPCT were established. The resulting empirical functions were validated by comparing the predicted and measured

* Corresponding author at: School of Materials Science and Engineering, South China University of Technology, 510640 Guangzhou, China.
E-mail address: mstszhang@scut.edu.cn (T. Zhang).

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MPCTs for additional tests. The results will give a better understanding of a critical criterion for mixture design and clogging prediction of pervious concrete.

1. Introduction

With rapid urbanization of a growing population, construction of residential buildings and infrastructures in urban areas is leading to a higher proportion of impervious surface areas, especially for super cities. Stormwater cannot infiltrate into underground, creating surface run-off (Fig. 1) that overloads drainage systems and causes flash flooding. According to the survey data in Table 1 [1], about 60% of 351 Chinese cities (including some in dry northwest China, as well as in rainy southeast China) had experienced flooding, with more than three incidences of urban flooding annually in 137 cities. 262 flooded cities had a maximum waterlogged depth >50 mm, and waterlogging lasted >12 h in 57 cities. In addition, with the increase of impervious surface areas, the urban heat island (UHI) effect [2] and subsidence of soils in cities have been frequently reported nowadays. Therefore, the concept of the "Sponge City" as shown in Fig. 2, "Low Impact Development", "Water Sensitive City", and "Smart City" have been proposed by researchers from China, the USA, Singapore, and the UK [3–5].

Pervious concrete, also known as porous or permeable concrete, is well recognized as one of the key building materials of a Sponge City or Low Impact Development system area [6]. High permeability of this type of concrete is achieved by intentionally creating interconnected voids through gap grading the coarse aggregate, either eliminating or minimizing the fine aggregate, and lowering the water-to-cementing materials ratio (W/C) [7,8]. The large, open pore structure (typically in the range of 15–25% interconnected porosity, and pore size ranging from 2 to 8 mm) of pervious concrete allows air and fluids to pass easily from the surface to underlying layers (Fig. 3), thereby helping to: reduce stormwater run-off [9], allow the natural recharge of the groundwater and the evaporation of water from the soil beneath [10–12], limit the costs for roadway systems [3,13], increase acoustic absorption [14], reduce the UHI effect, filter out contaminants in water, and protect tree growth [15].

Effects of cementitious materials [16,17], W/C, chemical admixtures [18,19], aggregate [20–22], mixing and compacting methods [23,24], on the mechanical properties, permeability, porosity of pervious concretes [25] were extensively investigated. Generally, all factors can be attributed to the volume and flowability of cement paste and the size and gradation of aggregates. For instance, Chindaprasirt suggested suitable cement paste with high viscosity and high flowability for making pervious concrete with the use of W/C of 0.20–0.25 and an incorporation of 1% superplasticizer, then pervious concretes with void ratio of 15–25% and strength of 22–39 MPa can be produced using appropriate paste content and flow [23]. Increasing of volume proportion of cement paste remarkably improves the mechanical properties of pervious concretes, in terms of compressive strength, abrasion and freeze-thaw resistance, but decreases the permeability significantly.

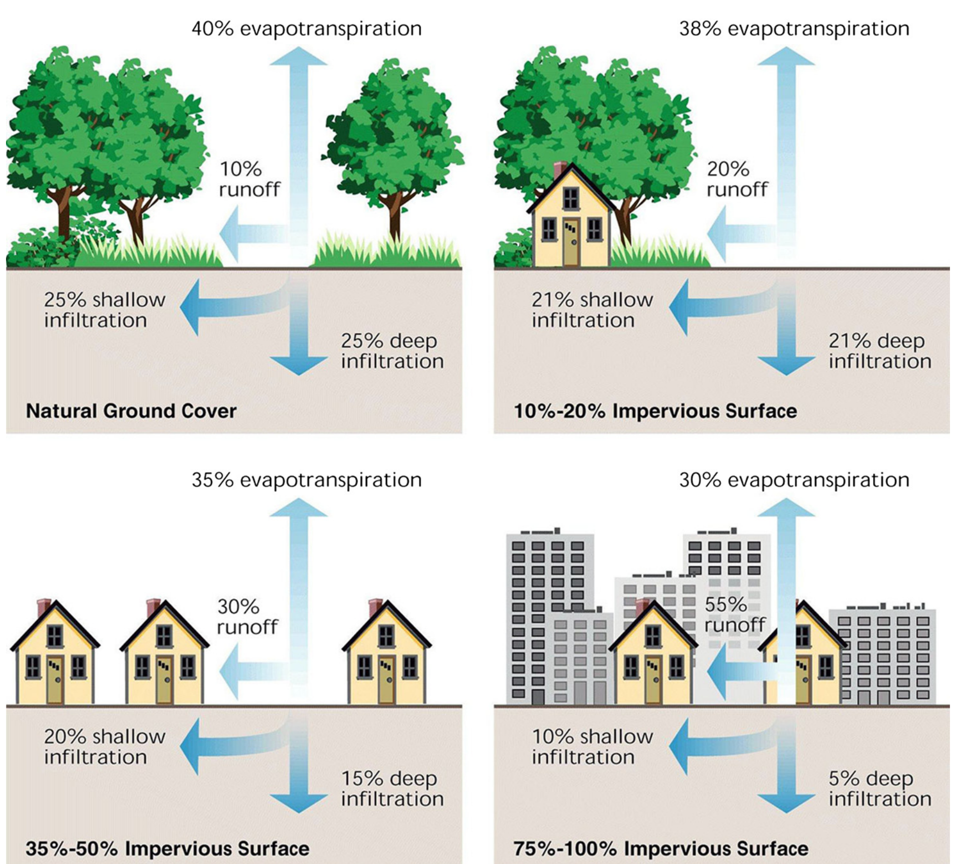

Fig. 1. Stormwater in cities with different proportion of impervious surface [2].