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Study on evaluation method of mud-pumping of cement concrete bridge deck pavement

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HIGHLIGHTS

- Initial surface absorption test, X-ray CT technology, and fractal theory were used to evaluate mud-pumping distress.
- Capillary water absorption coefficient is linear relation with the void ratio of volume ≤ 0.1 mm^3.
- The fractal theory reflects the complexity of the internal structure in the asphalt mixture.

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ABSTRACT

Mud-pumping is one of major distresses of concrete bridge deck pavement, which not only influences the riding comfort of vehicles but also affects the appearance of bridge pavement and endangers the whole bridge structure. Although many methods have been used to assess the mud-pumping distress, most of them remain in the qualitative assessment. Relevant researches about testing methods and quantitative assessment approaches are seldom studied. In this paper, Initial Surface Absorption Test (ISAT), X-ray CT technology, and fractal theory are adopted to assess mud-pumping pavement and study the effect of capillary force on the mud-pumping distress. In addition, the influences of voids distribution characteristics on the capillary water absorption capability are discussed. The ISAT result shows that three significant parameters of mud-pumping cores, such as the capillary water absorption mass, the capillary water absorption coefficient, and the ratio of capillary voids to air voids, are markedly different from those of the non-pumped cores. The mud-pumping cores had a relatively higher void ratio of volume ≤ 0.1 mm^3, and lower complexity of void. Quantitative evaluation indexes for mud-pumping distress are recommended by this paper.

1. Introduction

Moisture damage is a key factor in the design of durable asphalt pavements. Mud-pumping is one of the major moisture-related damages. Water with different forms, including liquid, vapor and solid, is considered as an important reason causes various damages such as raveling, rutting and cracking [1–3]. Due to the lack of understanding of water movement in the base materials, there are no established countermeasures to prevent mud-pumping. The knowledge of the water movement within base materials is of great importance to determine the mud-pumping in question and moisture migration is by far the most important control function to be addressed [4,5]. Therefore, a fundamental study of moisture mass transfer mechanisms is necessary.

The development of test methods for moisture movement analysis is the first step to clarify moisture transfer mechanisms and evaluate material properties. In some studies, the permeability test was used to indicate the ability of concrete to absorb water [6–8]. In terms of the saturated concrete, the transport of water mainly occurs through capillary absorption [9]. Therefore, most current researches are focused on the capillary water uptake.

The water uptake due to capillary action in concrete is already well-known [10,11]. However, the size and distribution of air void can modify the continuity and tortuosity of the pore structure of concrete, hence, they have a negligible influence on the capillary absorption of water [12]. The application of X-ray computed tomography (CT) brought great changes for scanning air voids. X-ray CT is an efficient tool to investigate concrete in terms of the micro-structure and performance. The internal structure in base materials can be recognized by X-ray CT, which includes the distribution of air voids. On this aspect, many studies have been

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conducted [13–17]. Thus, X-ray CT allows us to analyze the internal structure of concrete in a visual way, and the relationship between capillary water absorption and mud-pumping distress.

The main contribution of this paper is to recommend the evaluation indexes for the mud-pumping distress in bridge deck pavement. The procedure is detailed in the following steps: (1) Asphalt concrete coring samples were removed from mud-pumping sections and non-pumped sections on the bridge deck pavement. (2) Then Initial surface absorption test was adopted to analyze the material water transfer mechanism. (3) Consequently, the X-ray CT was used to measure the pore of asphalt concrete characteristics and developed the relationships between pore characteristics and pavement pumping. The studies provide effective information for preventing the mud-pumping distress and increasing the service life of the pavement.

2. Background

Mud-pumping to pavement surfaces is believed to be caused by the water transfer in the cracks of concrete under the traffic loads [18,19]. However, according to our investigation results, in the case of a new and non-serviced viaduct, the mud-pumping distress of the viaduct was found to be different from that of previous researches. As shown in Fig. 1a, asphalt pavement of the bridge deck appeared mud-pumping distress after heavy rain in the case of no vehicle load and the water permeability coefficient of mud-pumping satisfy requirements of the standards. It worth noting that samples were obtained by coring from the mud-pumping element on site to further study the water source of the bridge deck pavement (Fig. 1).

In order to study the water source of the bridge deck pavement, the water permeability test was carried out up to 4 days testing. The experimental results describe the residual water situation under mud-pumping cores. Specifically, in this work, we measured the moisture source by testing the coring samples from an unopened viaduct (Fig. 1). Prior to the experiments, the hole requires drying by using dry cotton cloth, and the bottom of this hole is recorded as zero level. At several time intervals, the water level in the hole was measured, respectively, and the test results were shown in Fig. 2.

Notably, the water level shows a cyclical rise and fall in 4 days. Water will still be re-infiltration in the hole, and the water level continues increasing after being dried. Especially in 8th September, the water level rises with time and peak to10cm (orifice). As compared with the mud-pumping distress of semi-rigid base asphalt pavement, mud-pumping distress of bridge pavement has following characteristics.

(1) There are no significant cracks in the pavement and the water permeability coefficient satisfy the specification requirements, which can be considered that the moisture does not infiltrate from mud-pumping, but from side faces of bridge deck pavement. The convergence of moisture provides a “raw material” for mud-pumping distress.
(2) Since this viaduct has not been used, “squeezing” and “pumping” effects of vehicle loads can be excluded.

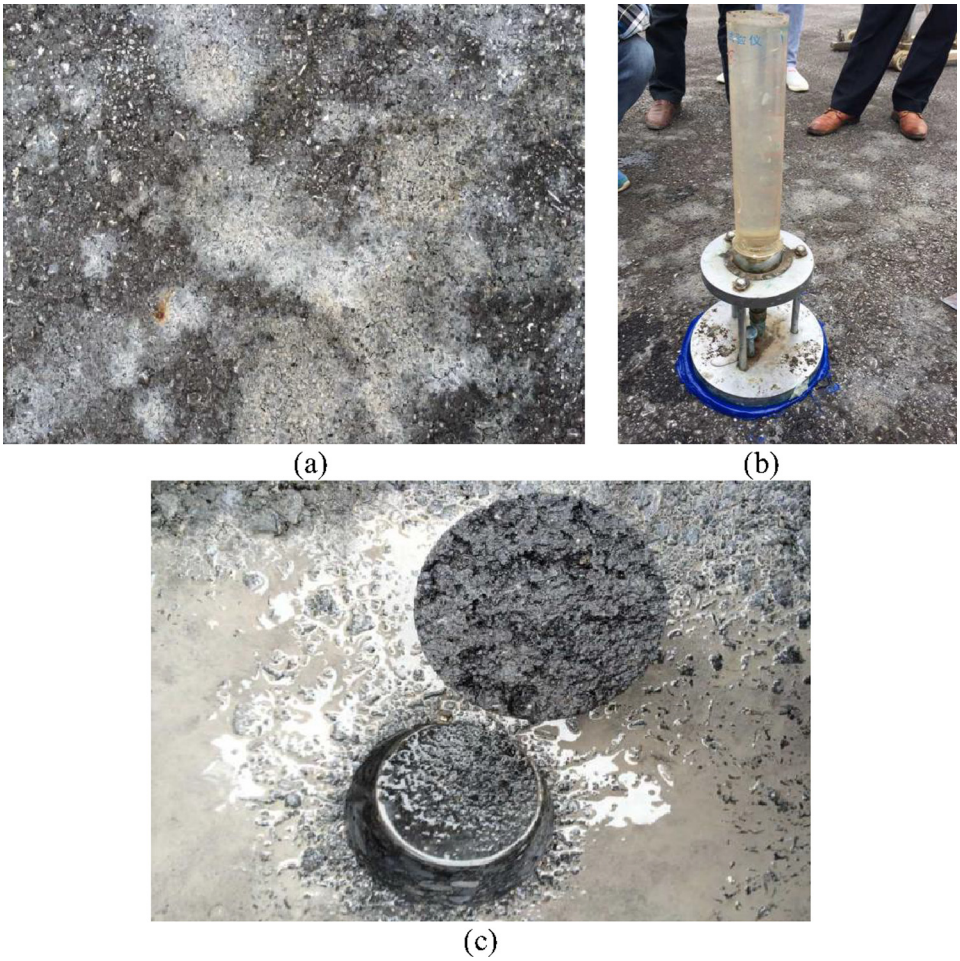

Fig. 1. Mud-pumping distress of cement concrete bridge deck pavement. (a) Mud-pumping distress, (b) Water permeability test, (c) Coring sample.