Some Observations on Sorption-Desorption Behaviors of Roller-Compacted Concrete Mixtures

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ABSTRACT

Water transport in concrete is a crucial phenomenon that to a great extent dictates the durability of concrete. The experimental program described in this paper compares the time rate of change of sorptivity (water uptake) and desorptivity (water loss) and the related coefficients for four distinct mixes with differing cement contents. All the mixes are roller-compacted concrete (RCC) mixes. Studies are being conducted on specially formed and preconditioned samples to simulate three distinct kinds of sorptivity behaviors in real-world circumstances. Different coating methods are also applied. The objective of this study is to appreciate the nature of water uptake and loss by capillary actions.

Over the studied cement content range, it has been observed that the sorptivity and desorptivity behaviors are strongly influenced by the cement content of the mixtures. At the same time, the nature and the direction of water uptake and loss depends on the sample preparation and preconditioning. Sorption and desorption isotherms are obtained to understand the water movements for 500 consecutive hours. This study indicates that the sorption and desorption behaviors could further be generalized by relating them with the desorptivity index, a relatively new index defined in this paper. Data obtained from individual mixes are further utilized for developing mathematical models to describe the water transport behavior. It is anticipated that successful completion of this study would answer several of the questions related to water transport in dry concretes.

Key words: desorption—pavements—roller-compacted concrete (RCC)—sorptivity
INTRODUCTION

Roller-compacted concrete (RCC) is a stiff, dry concrete and a construction technology that utilizes roller compaction for densifying and finishing the concrete. Relatively lower cement and water contents, higher aggregate/cement ratios, the absence of suitable chemical admixtures, and the inherent nature of laying and compaction operations makes the final material relatively open structured. In addition to this, due to roller-compaction operation, there are irregular-shaped entrapped air voids left in the final structure of RCC mixtures. Drier paste makes it much more difficult to entrain useful air for enhancing the workability and/or freeze-thaw (F-T) resistance. Moreover, larger quantities of air-entraining admixtures are required for entraining even a small amount of air in these mixtures. All these factors combined together offer a final structure of RCC that renders easier pathways to water movement than the conventionally compacted and finished structural concrete.

In general, durable concrete will result if it has low water to cementitious ratio, has achieved adequate thermal and moisture curing, and has achieved a discontinuous capillary structure free of significant micro and macro defects (DeSouza et al. 1998). The mechanisms responsible for the deterioration of building materials are largely mediated and critically determined by the volume and rate of water movement. The conjugate action of mechanical and chemical damages may lead to rapid degradation of bulk mechanical properties of building materials and significantly reduce the service life of constructions. As such, good resistance to capillary absorption (unsaturated flow) of water (and other fluids) is of paramount importance. This is usually characterized by the property called as sorptivity, $S$, which expresses the tendency of a material to absorb and transmit water and other liquids by capillarity (Hall et al. 2002). If the relationship between normalized water uptake ($I_A$) and the square root of time is well represented by a straight line, the sorptivity, is usually the slope of the least square regression line of $I_A$ against $t^{1/2}$ and is given by

$$S = \frac{(I_A - b)}{t^{1/2}},$$

where $b$ is a constant intercept on I axis due to several minor edge surface and ambient moisture effects.

The penetration of water into the concrete via sorption and diffusion may have major implications on its F-T performance. Basheer et al. (1994) have observed good correlation between concrete performance in ASTM C 666 and sorptivities and air permeability. Moreover, sorptivity is seen to play a major role in the F-T scaling of field concrete (Bentz et al. 1999).

RESEARCH FOCUS AND MIXTURE PROPORTIONS

RCC is being applied for a variety of pavement applications, including pavement bases, shoulders, wearing course, in composite pavements, etc. Binder type, binder content, mixture composition, and construction practices vary according to the structural role of RCC layer and the geography of application. A varied range of applications are required for a comprehensive quantification and analyses of various properties. A broad study was thus undertaken for appreciating some of the influences of cement content, surface finish, type of preconditioning, and age of concrete.
METHODS

The sorptivity samples were drawn out of the curing room at the age of 14 days to simulate field conditions of curing. Preconditioning was done by keeping these samples in oven at 50 ± 2°C for 3 days and then in sealed containers for next 21 days. To measure relative amount of drying of specimens, equivalent specimens were kept in the oven for 24 days at 50 ± 2°C. This oven drying was used as reference drying. The densities obtained from these specimens were then utilized in calculating the desorption ratios. Specimens T and B (as shown in Figure 1) were coated with a concrete sealer on the curved surfaces, while the top and bottom sections were left uncoated. Coating was done after preconditioning was completed so as to ensure uniform and effective drying and for obtaining close to real-world water uptake. Subsequently, one-dimensional capillary absorption (1-DCA) was measured for all the mixes in accordance with ASTM C 1585. Quadruplicate samples were used for measuring the mass changes due to water absorption and subsequent evolution of water transport profiles.

![Figure 1. Pavement simulation for water movement samples](image)

RESULTS

Typical results are shown in Figures 2 and 3. Similar results were obtained for other mixtures and analyses were performed.
SUMMARY AND CONCLUSIONS

The following conclusions can be drawn based on the limited scope of this study:

- This comprehensive study leads to the generation of sorptivity database for RCC.
- In general, the coefficient of sorption decreases with the increase in the cement content. The optimum values are obtained for cement contents ranging between 300 ± 50 kg/m³.
- The desorptivity values also follow similar trends.
- Combined picture obtained from these two sets of values could help in appreciating the durability performance of concrete mixtures.
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