Construction and Building Materials 163 (2018) 724–733

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

# Effect of cationic asphalt emulsion as an admixture on transport properties of roller-compacted concrete

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## HIGHLIGHTS

- Cationic asphalt emulsion(CAE) was used as an admixture in RCC.
- Transport properties of CAE-containing RCC were investigated.
- ANOVA and intrinsically linear regression were used to evaluate results of tests.
- The SEM images were employed to interpret the results.
- If CAE is added equal to 4% or more, transport properties would be improved.

## ARTICLE INFO

*Article history:*
Received 16 September 2017
Received in revised form 19 December 2017
Accepted 22 December 2017

*Keywords:*
Roller compacted concrete
Transport properties
Electrical resistivity
Absorption
Sorptivity
Water penetration depth
Scanning electron microscopy
ANOVA

## ABSTRACT

This study aims to investigate the effect of cationic asphalt emulsion (CAE) as an admixture on durability characteristics of roller compacted concrete (RCC). To this aim, the CAE was added to the RCC mixture at 0%, 2%, 4%, 6%, 8%, and 10% of the cement mass; these mixtures were designed by the maximum density method according to ASTM D1557. The cubic and cylindrical specimens were fabricated using vibrating hammer; water absorption, sorptivity, water penetration depth, and electrical resistivity tests were conducted to evaluate the durability of the mixtures. The water penetration test was carried out on cubic specimens in accordance with BS EN 12,390-8: 2009; moreover, by cutting each cylindrical specimen, two 100 × 50 mm discs for conducting sorptivity and one 100 × 100 mm cylinder for conducting the water absorption and electrical resistivity tests were prepared. The results indicated that the decrease in the water absorption, penetration and sorptivity, and the increase in the electrical resistivity of the mixtures can be obtained by increasing the CAE content. Also, the analysis of variance (ANOVA) at 95% confidence level based on Dunnett comparison procedure denoted a significant improvement in the RCC transport properties by adding CAE. Scanning electron microscope (SEM) images were studied and it was revealed that filling the capillary pores and coating the inner surface of larger pores with asphalt exhibited a change in the structure of cement paste pores and demonstrated an improvement in the transport properties of the RCC. Performing electrical resistivity test is of great importance for evaluating the durability of concrete due to its non-destructive and rapid properties. Therefore, intrinsically linear regression models were estimated between its results and other durability indicators, which show proper fits based on their coefficient of determination (min$R^2$ > 0.83). The findings revealed that electrical resistivity test can be employed to estimate the various transport properties of the RCC.



## 1. Introduction

Roller compacted concrete (RCC) is defined as a type of concrete that, in its unhardened state, is able to support a roller while being compacted. The amount of cement paste required in this concrete is just as much as filling the voids between the aggregates and the water content is designed for having enough workability [1]. The first implementation of roller-compacted concrete pavement (RCCP) dates back to 1930 in Sweden [2]. In North America, the first experience with the construction of RCCP occurred in 1942 during the construction of an airport runway in Washington. However, in Canada, the RCC was first used as a surface layer in 1976 in the construction of a log sorting yard. The initial design was a layer of stabilized aggregates with a thickness of 14 in. as the base layer

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https://doi.org/10.1016/j.conbuildmat.2017.12.156
0950-0618/

and 2 in. of asphalt concrete surface. However, a pavement with a thickness of 14 in. consisting of an 8 in. stabilized base with 8% cement and 6 in. aggregates with 13% cement was built upon the request of the owners. This positive experience in the construction of RCCP increased the application of this type of pavement in Canada in the following years.

The main difference between the RCC and conventional concrete is the amount and gradation of the aggregates, amount of cement, and water; so that the aggregates used in the construction of the RCC are dense- or well-graded and make up 75% to 85% of the total volume of the materials. Also, the amount of fine aggregates is higher than those of conventional concrete. These factors cause high stiffness of the fresh RCC and zero (or less) value of the slump, so that it cannot be compacted using traditional concrete paving machines [3]. Due to the large surface of RCCP and its potential exposure to a variety of harsh conditions (e.g. freeze–thaw cycles), durability of this type of concrete and its proper performance under these conditions is very important. Although concrete is damaged due to various factors, water transport properties have a direct influence on concrete durability against non-mechanical damages [4,5]. Water transport in concrete is carried out by various mechanisms, including diffusion (displacement of mass or ion due to concentration difference), sorption (water displacement due to capillary action), permeability (movement of water under pressure), migration (displacement of ions due to force of electrical field) and adsorption (fixation of water molecules on the surface of materials) as the main cases among others [6–10]. The surface contact of unsaturated concrete with water leads to the absorption of moisture due to the porosity of concrete and its capillary action. This is the most important measurable property in porous solids and can be used as a suitable indicator for the evaluation of various building materials, considering the ease of testing and the reproducibility of its results [11]. The penetration depth of water under the pressure in concrete is one of the most notable properties. Low permeability of concrete can result in its durability against a variety of destructive conditions, including freezing and thawing, aggressive chemical exposure, carbonation, sulfate and chloride attack [12]. Water transport properties of concrete are directly dependent on the volume and connectivity of the pores, and these values affect the permeability and diffusion. Permeability is caused by the flow of water due to the difference in pressure, while diffusion occurs as ion flow due to the difference in concentration. Therefore, it is possible to measure the electrical resistivity by applying a voltage to the saturated concrete and creating an electric current, which can be employed as an indicator of the concrete transport properties [13].

Although some studies have been conducted on the evaluation of water transport properties in the RCC, there is a necessity of more attention in this area. For example, Karimpour examined the effect of using a ground granulated blast furnace slag (GGBFS) on the optimal time span between mixing and compacting and considered concrete transport properties as a criterion for choosing this time span. This study showed that, in the case of increasing the time interval between mixing and compacting, replacement of cement by GGBFS can improve the RCC's transport properties [14]. Hazaree et al. investigated the capillary water transport characteristics of RCC and their association with freeze-thaw durability. In this study, various variables including cement content, water to cement ratio, curing time and surface finishing were considered and a wide range of capillary transport values were obtained. The results of this study showed that sorptivity of RCC was comparable to conventional concrete and decreased with increasing cement content as well as decreasing water to cement ratio. Furthermore, the results of the freeze-thaw durability test had a satisfactory correlation with sorptivity, so that the increase in the amount of capillary absorption reduced the durability [15]. Yerramala and Babu examined the transport properties of high volume fly ash RCC with cement content of 50 to 260 kg/m3, consisting of 40% to 85% of the fly ash. Permeability, water absorption, sorptivity, and chloride diffusion tests showed that mixtures containing moderate cement and fly ash had a better performance in terms of transport properties [16]. Mardani-Aghabaglou et al. evaluated the high-volume fly ash RCC mixtures with two alternative approaches of replacement of either cement or aggregate with fly ash. The mixture proportions obtained from the maximum density method included a water to cement ratio of 0.39 to 0.47. The results indicated improvement of transport properties as well as freeze–thaw resistance of the mixtures in the case of replacing aggregate by fly ash and inversely in the case of replacing cement by the fly ash [17]. Recently, studies have also been carried out to evaluate the use of trass as a natural pozzolan. For example, Ghahari et al. concluded that the use of a trass as a pozzolan in RCC mixture could improve its transport properties [18]. Ramezanianpour et al. reported a negative effect on the use of trass as a cement material on transport properties of RCC and showed that this pozzolan material increases permeability and capillary absorption of the mixture [19].

A number of studies have been conducted on the use of the asphalt for concrete construction to improve its properties. Kosior-Kazberuk and Jezierski demonstrated that the addition of cutback asphalt up to 13% of cement weight could significantly improve the scaling resistance of the mixtures [20]. Bołtryk et al. reported improvement of the durability and transport properties of concrete mixture containing 5% and 10% asphalt dissolved in organic solvent, and ascribed the improvement of properties to the hydrophobic property of asphalt and improvement of the pores structure of concrete as the major causes [21]. Bołtryk and Małaszkiewicz investigated the effect of using anionic asphalt emulsion as 2% and 4% on concrete properties. The results of this study showed a decrease in compressive strength of the mixtures and improvement of their microstructural properties, reducing the dimensions of concrete pores and improving its durability. An examination of scanning electron microscopy (SEM) images shows the fibrous structure of asphalt in a hardened cement paste. The reason for the improvement of transport properties and durability of mixtures is the presence of hydrophobic and insulating layer on the wall of cement paste pores [22]. In the course of their work, Bołtryk et al. began to build the concrete surface layer of multimodal reload terminal in the duty-free zone in Małaszewicze, Poland. In order to reduce the water absorption and increase the resistance of concrete against corrosive environmental conditions, anionic asphalt emulsion was used as an admixture in the concrete mixture. The superplasticizer was also employed to achieve the desired mechanical performance. The results of the study indicate a decrease in water absorption of the mixture and improvement of the frost resistance. In this research, the implementation of concrete pavement containing anionic emulsion asphalt was successfully tested, which revealed a high bearing capacity in corrosive environments [23].

Due to the fact that road pavement is exposed to a variety of destructive conditions as well as the use of various aggregates to produce RCC mixtures during construction of the project, its durability is of particular importance. In this research, cationic asphalt emulsion (CAE) was used in constructing RCC as an admixture to improve the transport properties since they control the durability of the mixture and their improvement can guarantee mixture performance under harsh conditions. A rapid-setting CAE has been selected due to its high production and reasonable prices in Iran.

According to the studies carried out so far by Huang et al., it is observed that the presence of asphalt in concrete can have a negative effect on its mechanical properties [24,25]. Therefore, the mechanical properties of the mixtures were also evaluated and