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Review

Mechanism of cement on the performance of cement stabilized aggregate for high speed railway roadbed

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HIGHLIGHTS

- Mechanical, shrinkage and frost behaviors of CSA were studied.
- UPV was used to study the strength mechanism of cement.
- The microstructures were characterized in 3D by the X-CT.
- The optimum cement and water contents were proposed.

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ABSTRACT

Field frost-thaw deformation tests show that the frost susceptibility of graded aggregate is a major factor contributing to the instability of high speed railway track. This paper is aimed at studying the effect of cement content (0%, 3%, 5%, 7% and 9%) on the mechanical, dry shrinkage behavior and frost heave susceptibility of cement stabilized aggregate (CSA) used for high speed railway roadbed and the strengthening mechanism of cement. An ultrasonic pulse velocity (UPV) technique was employed to continuously and nondestructively monitor the microstructure formation process of CSA. The experimental results show that compressive strength, flexural strength and frost heave resistance property increase with the cement replacement. However, reverse phenomenon is observed in the shrinkage behavior. Based on the UPV development test, the microstructure evolution process of CSA can be clearly identified into three stages. The mechanism of cement can be classified into "filling effect" and "binding effect" and the latter effect is more dominant. The optimum cement content and water to cement ratio (w/c) are estimated to be 5% and 1, respectively. At these value, an efficient compaction, denser structure and reduced frost susceptibility can be simultaneously achieved. In addition, X-ray tomography technology (XCT) was also employed to characterize the microstructure quantitatively.

Contents

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1. Introduction

The high speed railway construction in China is undergoing a revolution. These high-speed railway trains (350 km/h) have made the country's vast territory substantially smaller, and changed the lifestyle socially and economically. As shown in Fig. 1, a novel type ballastless slab form which consists of concrete track slab, cement asphalt mortar, concrete roadbed and anti-frozen layer is commonly used. This new type ballastless track form has also been applied in Germany, Japan and Spain due to the following advantages: reduction in structural height, lower maintenance costs, and increased durability [1–3].

Seasonal frozen soil is distributed so widely in the north region of China (where the average frozen depth is over 2.0 m) that it occupies almost 55% of the whole country land. Engineering practices and researches have shown that numerous railway and highway roadbed damages in these seasonal frozen regions are caused by the frost heaving. Therefore, seasonal frozen soil is believed to be a major factor threatening the stability of roadbeds [4,5]. Therefore, the methods of preventing and reducing frost heave are very important to high-speed railway construction due to the extremely strict requirements of smoothness and stability.

Graded aggregate (GA) and cement stabilized aggregate (CSA) are widely used as anti-frozen and low-cost construction material to replace the frost susceptible soil. CSA primarily consists of graded aggregate, fines, a specified percentage of cement and a proper amount of water. The differences between CSA and normal concrete is that CSA contains a small amount of cement and is field prepared by rolling compaction. Although there are similarities between CSA and roller compacted concrete (RCC) in preparing method and component materials, RCC usually has a similar cement content with which utilized in normal concrete. An increasing interest has been focus on CSA recently. From the literatures available, the preparation mixtures, mechanical, thermal, durability of CSA have been extensively focused. Yu and Huang [6] found that the 28 day's shrinkage coefficient of CSA is susceptible to cement content when the cement content is less than 3%. Wang et al. [7] investigated the impact of fines contents on frost heave properties of coarse grained soils (without cement) and proposed a optimum fines content (9%) at which the coarse grained aggregate has the low frost heave susceptibility. Ahmed et al. [8] studied the flexural characteristics of rubberized cement-stabilized aggregate for pavement structure and found that material toughness was improved and stiffness was reduced after the rubber modification.

Regarding to the composition of CSA, cement is a hydraulic material and the hydration and microstructure formation process is time dependent. The formation of the structure of CSA mainly depends on the cement hydration, which determines the properties of mechanical and durability of this semi-rigid material in serving time. Although many investigations have related to the effect of cement content on the macro-properties of CSA [5–8], a very limited number of studies have been conducted regarding the CSA microstructure process from the point of cement hydration and it's strengthening mechanism.

This paper presents the results of a laboratory-based investigation of the effects of cement content (0%, 3%, 5%, 7% and 9%) on the mechanical, shrinkage behavior and frost heave susceptibility of cement stabilized aggregate used for high speed railway roadbed (anti-frozen layer as shown in Fig. 1). A specially designed ultrasonic testing apparatus (UTA) was used to monitor the early age microstructure development continuously and nondestructively. The evolutions of ultrasonic pulse velocity (UPV) propagating through the samples were in-situ examined. A X-ray tomography technology was also employed to characterize their microstructure quantitatively.

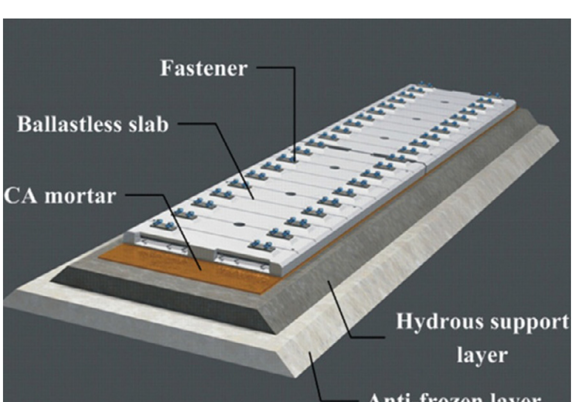

Fig. 1. The illustration of new type ballastless slab structure.

2. Field study of the frost-thaw deformation of ballastless track roadbed

In order to provide a smooth and safe travelling experience, a large number of field works have been done to monitor and control the frost-thaw deformation of high-speed railway roadbed. A typical frost-thaw deformation curve together with corresponding atmospheric temperature and frost depth of ballastless track roadbed in one testing point of the Harbin-Dalian high-speed railway during a frost-thaw cycle are shown in Fig. 2. It should be noted that only graded aggregate (GA) was used in this roadbed section. From Fig. 2, it could be obviously found that five stages can be divided to describe the frost-thaw process of high-speed railway roadbed. The frost displacement was initially relatively small (less than 4 mm) during the first stage (Initial fluctuating