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Durability against wetting-drying cycles for cement-stabilized reclaimed asphalt pavement blended with crushed rock

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Abstract

Pavement rehabilitation and reconstruction generate large quantities of reclaimed asphalt pavement (RAP). The improvement of the engineering properties of this RAP is required in order to enable it for use as environmentally friendly alternative construction material in road pavements. The durability of RAP when blended with crushed rock (CR) and stabilized with Portland cement was investigated in this paper. The CR replacement was found to improve the compactibility and durability of the stabilized RAP/CR material. For a particular RAP:CR ratio, the compaction curves of cement-stabilized RAP/CR blends were found to be essentially the same for all cement contents, but different for unstabilized blends; i.e., the maximum dry unit weight of cement-stabilized RAP/CR blends is higher than that of unstabilized RAP-CR blends. The wetting-drying (w-d) cycles led to a loss in weight of the cement-stabilized RCA/CR blends and to a subsequent reduction in strength. The w-d cycle strengths ($q_{u(w\text{-}d)}$) for a state of compaction (dry side, wet side or optimum water content) at any w-d cycle could be approximated from the corresponding initial soaked strength (prior to w-d tests) (q_{u0}). The q_{u0} of cement-stabilized RAP/CR blends increased with an increasing CR replacement and an increasing cement content. Assuming that the CR replacement also results in an increasing cement content, $w/[C(1+kCR_c)]$ was proposed as a critical parameter for developing q_{u0} and $q_{u(w\text{-}d)}$ predictive equations where w is the water content at the optimum water content, C is the cement content, k is the replacement efficiency, and CR_c is the CR content. Based on the $q_{u(w\text{-}d)}$ predictive equation developed here, a design procedure for the laboratory mixing of cement-stabilized RAP/CR blends was proposed, which would be valuable for an accurate determination of the ingredients (RAP:CR ratio and cement content) required to attain the necessary strength at the design service life.

Keywords: Reclaimed asphalt pavement; Crushed rock; Strength; Durability; Cement stabilization

1. Introduction

Pavement rehabilitation and reconstruction generate large quantities of reclaimed asphalt pavement (RAP). RAP is defined as the damaged pavement materials that are removed and/or reprocessed from an existing asphalt

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pavement. Thus, RAP comprises a mixture of pavement aggregates and aged bituminous additives. Typically, an existing pavement is either removed by the milling of the upper surfaces or by a full-depth removal of the entire pavement section itself. A milling machine is used to remove the top 50 mm of the pavement surface in a single pass, whereas a rhino horn on a bulldozer is used for the full-depth removal of the entire pavement in several broken pieces (Viyanant et al., 2007). These pieces are subsequently subjected to crushing, screening, conveying, and stacking in stockpiles, a process that usually occurs at a central processing plant (Mulheron and O'Mahony, 1990). The sustainable usage of RAP leads to significant economical savings for the construction of new highway pavements (Hajj et al., 2010). RAP can be utilized as a construction material in road bases or subbases, asphalt cement binders, asphalt concrete aggregates, and as embankment or fill material (Arulrajah et al., 2013, 2014; Attia, 2010; Cosentino et al., 2003; Maher et al., 1997; Papp et al., 1998).

When used as a total substitute for natural aggregates, however, RAP materials often do not meet the minimum base material requirements specified by international and local state road authority guidelines (Rana, 2004; Hoy et al., 2016a, 2016b), and hence, require some form of improvement. Chemical stabilization by Portland cement is widely used in both the construction of new roads and the rehabilitation of damaged roads, as the engineering properties can be improved rapidly after the stabilization of the RAP materials (Horpibulsuk et al., 2006, 2010, 2011, 2012; Shen et al., 2013, 2017; Du et al., 2014; Yoobanpot et al., 2018). The performance of cement-stabilized RAP satisfies the requirements of pavement base/subbase applications (Hoyos et al., 2011; Diefenderfer and Apeagyei, 2014; Taha et al., 1999; 2002; Puppala et al., 2011, 2012; Suebsuk et al., 2014).

Suebsuk et al. (2017) reported that bitumen, when adhering to RAP particles, retards the cement hydration and results in the need for high-cement contents. To reduce construction costs and to improve the engineering properties of cement-stabilized RAP bases/subbases, RAP should be replaced with a higher quality material. In Thailand, crushed rock (CR) replacement is a preferred option in terms of lower material and haulage costs as compared to Portland cement (Bureau of Trade and Economic Indices, 2016). In other words, replacement with small quantities of CR can reduce the amount of carbon-intensive Portland cement and can also significantly improve the engineering properties of the cement-stabilized RAP base/subbases.

The pavement recycling technique to restore damaged pavement has been widely used in Thailand. It involves about 20 cm of pavement (RAP and some base material) being dug up, mixed with CR and cement, and immediately field compacted with rollers. This technique is economical because cement is readily available at a reasonable cost in Thailand (Horpibulsuk et al., 2014). Horpibulsuk et al. (2006) have studied the development of strength of cement-stabilized coarse-grained soils in the laboratory and in the field. They reported that the field strengths were 0.5–1.0 times lower than the laboratory strengths under the same dry unit weight, soil-water/cement ratio, and curing time. This was due to several field factors, including non-uniformity in the soil mixed with cement and differences in the compaction methods and curing conditions between the laboratory stabilization and the field stabilization. In practice, many laboratory trial mixes are needed to arrive at the proper strength before the execution of the soil-cement pavement. This laboratory strength must be high enough to compensate for conditions which are controllable in the field. Horpibulsuk et al. (2006) also suggested a procedure for the pavement recycling technique and recommended a reduction in field strength of 2.0 for determining the cement content from laboratory tests.

Dempsey and Thompson (1967) defined durability as the ability of materials to retain their stability and integrity and to maintain an adequate amount of long-term residual strength so as to provide sufficient resistance to climatic conditions. The durability of cement-stabilized RAP/CR blends under severe climatic conditions is a crucial parameter when used in road construction applications. To date, however, there is little knowledge of the durability of cement-stabilized RAP/CR blends.

Cyclic wetting-drying (w-d) tests simulate the changes in weather over a geological age, and are considered capable of simulating critical scenarios that can induce damage to pavement material (Allam and Sridharan, 1981; Sobhan and Das, 2007). A durability study on the w-d cycles of chemically stabilized RAP blended with virgin aggregates has been reported by Ganne (2009). Results of the study show that the loss in strength was approximately 10–15% on average after 14 cycles of w-d tests for all the mixes studied. Kampala et al. (2014) investigated the influence of w-d cycles on the durability of clays stabilized with calcium carbide residue (CCR) and fly ash (FA) in pavement applications, and reported that the optimal CCR and FA contents were found to be 7 and 20%, respectively. However, high FA contents were found to result in a reduction in strength. Furthermore, despite the input of FA enhancing the pozzolanic reaction, the strength of the CCR-stabilized clay was found to be significantly reduced by an increasing number of w-d cycles. Al-Obaydi et al. (2010) and Al-Zubaydi (2011) reported that the cyclic w-d cycles caused crack propagation, resulting in severe effects on the engineering properties of the materials, particularly in terms of their residual strength and stability.

In general, tropical countries, such as Thailand and parts of Australia, are frequently subjected to changes in weather during the wet (rainy) and dry (summer) seasons. Therefore, an investigation of the service life of cement-stabilized RAP/CR blends via w-d cycle tests is significant and is the focus of this research. Tests with a wide range of water contents, RAP:CR ratios, and cement contents for cement-stabilized RAP/CR were undertaken to understand the importance of these parameters on the w-d cycle strengths. Based on an analysis of the test results, a rational

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