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Laboratory evaluation of cement treated aggregate containing crushed clay brick

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Abstract: The waste clay bricks from debris of buildings were evaluated through lab tests as environmental friendly materials for pavement sub-base in the research. Five sets of coarse aggregates which contained 0, 25%, 50%, 75% and 100% crushed bricks, respectively, were blended with sand and treated by 5% cement. The test results indicated that cement treated aggregate which contains crushed clay brick aggregate had a lower maximum dry density (MDD) and a higher optimum moisture content (OMC). Moreover, the unconfined compressive strength (UCS), resilience modulus, splitting strength, and frost resistance performance of the specimens decreased with increase of the amount of crushed clay brick aggregate. On the other hand, it can be observed that the use of crushed clay brick in the mixture decreased the dry shrinkage strain of the specimens. Compared with the asphalt pavement design specifications of China, the results imply that the substitution rate of natural aggregate with crushed clay brick aggregate in the cement treated aggregate sub-base material should be less than 50% (5% cement content in the mixture). Furthermore, it needs to be noted that the cement treated aggregate which contains crushed clay bricks should be cautiously used in the cold region due to its insufficient frost resistance performance.

Key words: cement treated aggregate; crushed clay brick aggregate; sub-base material; compaction property; frost resistance performance

1 Introduction

Civil engineering construction often consumes large quantities of natural resources, including aggregates, which become insufficient to meet ever increasing construction demands. At the same time, a lot of old

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buildings have reached the end of their service life facing to be demolished, which bring mountainous wasted clay bricks in many countries. Some waste bricks were used as backfill material, and a great proportion of them were sent to landfills. Recycling waste clay bricks used as aggregates could considerably reduce the problem of waste disposal and simultaneously help the preservation of natural aggregate resources (Moriconi et al. 2003; Levy and Helene 2004; Poon and Chan 2007; Yang et al. 2011; Aliabdo et al. 2014).

Over the last two decades, with increasing environmental awareness, many researches have been undertaken to investigate the possibility of using waste brick in cement concrete. Kibriya and Speare (1996) used three different types of brick aggregates to assess their impacts on strength and long-term durability of concrete. The results indicated that the concrete containing crushed brick aggregate had compressive, tensile, and flexural strengths comparable to those of normal concrete, but the modulus of elasticity was drastically reduced. Test results which use crushed brick as 100% replacement of coarse natural aggregates in concrete indicated that the tensile strength of brick concrete was higher than that of normal concrete by about 11%. However, the modulus of elasticity was 30% less than that of normal concrete (Akhtaruzzaman and Hasnat 1983). Padmini et al. (2001) studied the relative influence of different parameters on strength of concrete using low-strength bricks as aggregates. It was found that the strength of brick concrete was most influenced by the cement content, the aggregate conditions, and the strength of brick from which the aggregates were derived. Since the strength of brick varies considerably, it is therefore very difficult to quantify the quality of the resulting brick concrete. Compared with the natural aggregate, crushed brick aggregate has lower strength and higher water absorption (Khaloo 1994; Cachim 2009; Bekta 2014). This leads to some potential problems when using crushed clay brick in concrete. And some international agencies restrict the amount of crushed brick that can be used in concrete, which hinders the recycling of this masonry waste.

Pavement is a multi-layered structure composed of a concrete or an asphalt slab resting on a foundation system comprising various layers such as the base, sub-base, and sub-grade. Conventionally, natural materials such as crushed rocks, selected gravels are widely used as road materials (Nataatmadja and Tan 2001; Kuo et al. 2002; Molenaar and van Niekerk 2002; Park 2003; Leite et al. 2011; Arulrajah et al. 2014). Road construction often needs large quantities of aggregate. Thus, incorporating construction and demolition debris in road materials can consume a greater amount of these waste materials, which can induce great environment protecting effects. Many researches have been undertaken to investigate the possibility of using recycled aggregates in road base or sub base courses (Bennert et al. 2000; Chini et al. 2001; Poon and Dixon 2006; Huang et al. 2007; Velasquez et al. 2009; Jankovic et al. 2012; Soutsos et al. 2012; Rahardjo et al. 2013). As for waste clay brick, Poon and Chan (2005) researched unbound road sub-base using crushed clay brick and recycled concrete. The results showed that recycled sub-base had a lower maximum dry density and a higher optimum moisture content when compared to the maximum dry density and optimum moisture content of the sub-base prepared with natural materials. Sub-base using crushed clay brick as fine aggregate had a lower California bearing ratio (CBR) value compared to the sub-base using recycled concrete aggregate as the fine aggregate. Disfani et al. (2014) studied the performances of cement-stabilized blends with recycled concrete aggregate and crushed brick as supplementary material. The laboratory evaluation comprised pH, plasticity index, foreign materials content, particle size distribution, linear shrinkage, CBR, modified proctor compaction, repeated load triaxial test, unconfined compressive strength (UCS) test, and flexural beam tests. Results indicated the cement stabilized blends with 50% crushed brick content and 3% cement could meet the local state road authority requirements.

Cement treated material which is a family of compacted mixtures with granular materials, Portland cement and water has been used for road sub-base for many years. In this paper, aggregates containing crushed waste clay bricks were treated by cement as road sub-base course material. The objective of the