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Original Research Article

Parametric study on cement treated aggregate panel under impact load

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ABSTRACT

The cement treated aggregate (CTA) is increasingly used as base or sub-base layer for pavement to withstand various traffic and dynamic loads. Under extreme events, the CTA layer of the pavement is expected to absorb significant amount of impact energies subjected to different loading conditions including accidents, mobile vehicles, heavy aircrafts, machinery, or even terrorist attack. However, no research has been found on the resistance of CTA under drop weight impact load. To fill up this gap, a detailed study was carried out to investigate the impact resistance of CTA under impact loading through both experimental and finite element analysis (FEA). Moreover, detailed parametric studies were carried out based on the validated model to determine the significance of selected key parameters on the impact resistance of CTA.

1. Introduction

Cement treated material such as like cement treated aggregate (CTA) has been extensively used for infrastructure constructions such as road, pavement and runway. Generally, 6–12% cement of the total mix is added in the mix of cement treated aggregate. Crushed gravel is usually used and sufficient water (water cement ratio around 0.5) is used during the mixing of cement treated aggregate. The recommended ranges of aggregate sizes of CTA mix and proportion is given in Fig. 1. It is used as the stabilized base over the sub-base layer or directly the subgrade layer of roadway and runway pavement [1]. One of the main reasons of preparing bound or treated base layer is to reduce the thickness of the base layer in pavement [2]. However, the increase in thickness of CTA layer is effective in reducing the surface deflection of pavement [3]. Numerous research investigations were carried out to explore the properties and behaviour of such introduced treated material. For example, Lim and Zollinger [4] conducted unconfined uniaxial compression tests on cement treated base material and measured compressive strength and modulus of elasticity

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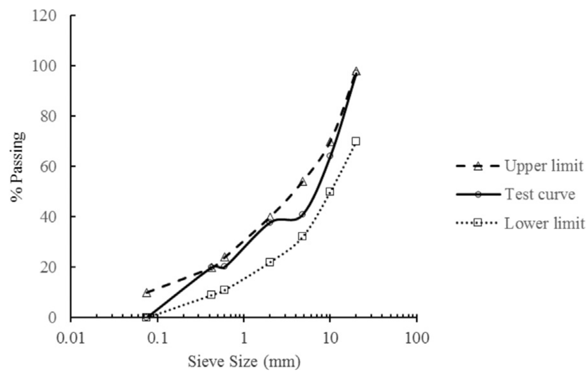

Fig. 1 – Gradation curve of aggregates.

of few mixtures. Furthermore, Lim and Zollinger [4] developed a single equation to establish a relationship between the compressive strength and modulus of elasticity of the mixture which was not dependent on the aggregate types or sizes. Furthermore, field investigation using several devices was carried out by Guthrie [5] to measure the early-age strength of cement stabilized material.

Again, Davis et al. [6] identified the significance of components of CTA in varying its compressive strength. Davis et al. [6] found the effect of mineralogy and p^H of the aggregate and also the fine content as significant in increasing the compressive strength of CTA mixture. Xuan et al. [7] reviewed the influence of components of CTA on tensile strength of CTA where the tensile strength was in correlation with compressive strength. Few research works were also conducted to study the influence of the cement content and coarse aggregate content in the CTA mix to improve the properties of CTA base layer. For instances, Wang et al. [8] found the minimum shrinkage when 3–4% cement was used in the CTA mix. Shrinkage of CTA was found to increase with the increase of cement content and consequently the probability of the cracking increases [8–10]. Li-qun and Ai-min [11] also inferred that large amount of coarse aggregate in the CTA mix is favourable in reducing the shrinkage. However, excessive coarse aggregate content reduces the optimum moisture content and thereby reduce the compressive strength of cement treated aggregate. Moreover, studies [12,13] were also carried out to understand the effect of using recycled aggregate in CTA mix and effectiveness was found in enhancing the mechanical properties of CTA by introducing recycled aggregate. On the other hand, the use of crushed clay brick as aggregate in the CTA mix was found to reduce the compressive strength and tensile strength of the mix [14,15]. In addition, the introduction of steel fibre (maximum 1.5%) was found effective in reducing the crack and increasing the fatigue life of CTA [16].

As mentioned above, the studies were conducted on CTA to explore its mechanical properties and to find the influence of aggregate type, aggregate content and cement content in varying the mechanical properties. The information helps to understand the behaviour of CTA under static load condition. However, the main use of CTA is in the pavement structure which frequently subjects to dynamic loading like from the traffic. To serve as the base layer of road or runway pavement, CTA layer is expected to be able to absorb significant amount of impact energies under different impact loading conditions like accidents, vehicles, heavy aircrafts, machinery, or even terrorist attack. The general performance of the pavement under impact load depends not only on its individual layer but also the composite actions.

Therefore, this study aims to investigate the performance of CTA under impact loading and to find out the key parameters to affect its impact resistance. The research outcome can provide knowledge on the dynamic behaviour of infrastructures using cement treated aggregate, on further improvement of the safety and service life of the infrastructures, and also facilitate future research by using accurate finite element model.

2. Experimental investigation

2.1. Materials and specimens

Experimental investigation was carried out on a CTA panels with a dimension of 490 mm × 490 mm × 300 mm. The panel was prepared with crushed aggregates by adding 9% cement of the total mix and cured for 28 days before testing. The maximum aggregate size used in the mix was 20 mm. The different aggregates used in the mix of CTA with maximum size is given in Table 1. In addition, Fig. 1 shows the gradation curve of the aggregates which remains in the standard gradation range [10] for CTA material. Gradation curve was used to assess the particle distribution size of the CTA mix. The upper limit and lower limit implies the maximum and minimum percent passing at corresponding sieve size as per [10] and test curve is the gradation curve of the aggregates used in the CTA mix.

Before conducting impact test at 28 days, the compressive and flexural tensile strengths of the CTA were tested accordingly. Fig. 2(a) and (b) show the test set-up of uniaxial compression test and third point bending test respectively. Uniaxial compression tests were conducted on five CTA cylinders at 100 mm in diameter and 200 mm in height as per AS1012.2:2014. The cylinders were tested using hydraulic compressive machine at a loading rate of 1 mm/min (Fig. 2(a)). Two linear variable differential transformers (LVDT's) were use at the opposite two sides of the cylinder to measure the average displacement under the applied compressive loads. Digital data acquisition system was used to record load and displacement data. The stress strain curve (Fig. 3(a)) was plotted based on the measurement. The average scattering or deviation of result was found around 2%.

Table 1 – Aggregates in the mix of cement treated aggregate.

Aggregate	Amount (kg/m^3)	Maximum aggregate size (mm)
W3 gravel	1.65	20
10 mm gravel	1.25	10
W6 gravel	0.5	2.36
W6.5 sand	0.5	1.18
W9 sand	1	0.425