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Experimental investigation on mechanical properties of geosynthetic cementitious composite mat (GCCM)

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HIGHLIGHTS

- A new development of geosynthetic cementious composite mat (GCCM) is introduced.
- Key physical and engineering properties of GCCM are investigated in the laboratory.
- Tensile, bending, puncture, surface friction and water impermeability are tested.
- Effect of curing time and geotextile directions are considered.
- Strength and stiffness of GCCM required for geotechnical design are reported.

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ABSTRACT

In this paper, the behaviour of geosynthetic cementitious composite mat (GCCM) made of geotextiles and cement powder was investigated. The aims of the development of the GCCM are focused on geotechnical engineering applications. Experimental study includes physical and mechanical properties investigation of GCCM under installation and loading conditions. Testing of tension and flexure by monotonic loading showed that the GCCM can be used in soil reinforced structure. Additionally, puncture and frictional resistances of the GCCM are also important properties for slope protection. In conclusion, enhancing geosynthetic with cement paste can provide both strength and durability to be used for slope stabilisation. The key properties of GCCM reported in this paper can be used as design parameters of GCCM for geotechnical engineering applications.

1. Introduction

Over the past two decades, geosynthetics have been used in a wide range of applications such as transportation, geotechnical, environmental and hydraulics, and their related products are still being developed for other private applications. Geosynthetic clay liners (GCLs) have been developed to replace compacted clay liners in cover systems and bottom liners of waste containments. GCLs are composed of a thin layer of bentonite boned to layers of geosynthetic. Because of their very low hydraulic conductivity to water, GCLs are also used as environmental protection barrier in roads or storage tanks, and as single liners for canals or ponds. The main advantages of the GCL are the limited thickness, the good compliance with differential settlements of underlying soil or waste, easy installation and low cost [1]. The use of GCL is mostly in liners for landfill and mining applications [2]. However, the low strength hydrated bentonite may not be effectively used for soil reinforcement and it can produce vulnerability to mechanical accidents.

A new composite material called textile reinforced concrete (TRC) has been developed in many manners [3,4,5]. In general, textile layers are introduced to improve tensile strength of concrete. However, the strength, ductility properties and drying shrinkage of TRC depend significantly on its components and bonding between textile and cement layers [6–9]. Recently, concrete canvas (the product invented by Brewin and Crawford in 2005 in UK) has been commercially launched (Concrete Canvas Ltd. [10]). This is an idea of using cement impregnated fabric as a new construction material. It is used to replace conventional concrete (in situ, precast or sprayed) for erosion control, remediation and construction applications. Some typical applications are ditch lining for drainage

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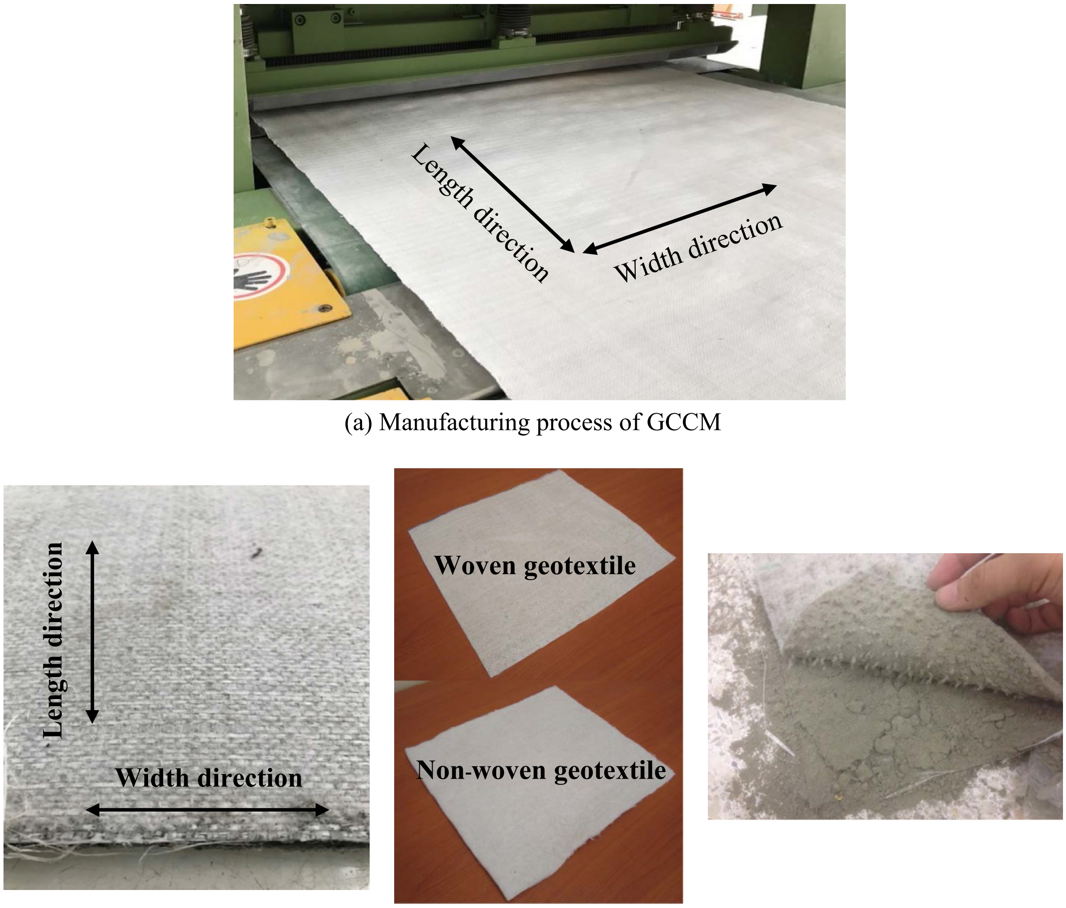

(a) Manufacturing process of GCCM

(b) Final product

(c) Geotextiles

(d) Cement powder layer bounded with needlepunching

Fig. 1. A typical product of geosynthetic cementitious composite mat (GCCM) and its components.

and irrigation, surface erosion control for slope protection and remediation of cracked and damaged concrete infrastructure.

In this study, an idea to improve the performance of GCL on strength and stiffness by replacing bentonite with cement leads to a development of a geosynthetic cementitious composite mat (GCCM). The product aims to mainly use for reinforcement and erosion control of soil slope. The GCCM can provide a hard-wearing erosion control surface for protecting slopes and can delay infiltration rates of rainfall causing deep slip failure of slopes. The GCCM is typically used as an alternative to shotcrete, and where vegetated slopes are unsuitable due to high flow rates, arid climate or poor soil conditions. The objective of this work is to investigate performances of the developed GCCM for slope protection and stabilisation. The investigation programme includes physical and mechanical properties of the GCCM. The study was focused on the loading under slope protection and stabilisation including tensile strength test, bending test, puncture test, and friction resistance test as well as water impermeability test. The experimental results suggest that the GCCM can be reasonably used for reinforcement and protection of natural soil slope.

2. Materials and methods

2.1. Materials

The GCCM is comprised of two layers of fabric, which are woven and non-woven geotextiles, and a cement powder layer bounded with needlepunching as shown in Fig. 1. The cement powder is firstly placed on the bottom woven geotextile layer. To control the thickness of cement layer, the cement powder is placed slightly thicker and then sliced of until reaching the thickness of 10 mm. Next, the top non-woven geotextile is placed on the top cement layer before punching by hot needles. The manufacturing process of GCCM is operated by rolling machine. In the final product, the uniform 10-mm thick non-compacted cement layer is contained by the geotextiles on both sides in a sandwich manner. The needlepunching process causes some fibres from the top non-woven geotextile to extend through the cement and bottom woven geotextile. It is noted that the warp and weft directions in woven geotextile are associated with the length and width directions of the GCCM, respectively.

In this study, manufactured non-woven and woven geotextiles supplied by Siam Cement Group Co. Ltd. (SCG) are used as fabrics. The detail properties of fabrics are summarised in Table 1. The cement powder for the matrix used in this study is a hybrid cement from SCG. Chemical compositions of cement powder were analysed by X-ray fluorescence (XRF) as summarised in Table 2. The particle size information of hybrid cement was examined using laser particle size analyzer. The results of D10, D50 and D90 for hybrid cement are 3.9, 15.3 and 43.8 μm, respectively. D10, D50 and D90 are diameters corresponding to 10%, 50% and 90% by mass of particles which are smaller than the reported particle size. The results of particle size can be confirmed with SEM photograph as shown in Fig. 2.