



Pullout performance of GFRP anti-floating anchor in weathered soil



Hai-lei Kou^{a,b,*}, Wei Guo^b, Ming-yi Zhang^c

^a School of Civil Engineering and Architecture, Weifang University, Weifang 266033, China

^b School of Civil and Environmental Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798, Singapore

^c Institute of Geotechnical Engineering, Qingdao Technological University, Qingdao 266033, China

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ABSTRACT

Anchors are often used as anti-floating reinforcements in civil engineering structures. However, conventional steel bars present disadvantages concerning corrosion and poor adaptability to aggressive environments. Glass fiber-reinforced polymer (GFRP) components could provide a solution to these problems. In this paper the feasibility of GFRP anti-floating anchors is evaluated. Four full scale pullout tests were performed in moderately decomposed granite (MDG). Bare Fiber Bragg grating (FBG) sensors were embedded into the specimens during the pultrusion process to monitor the stress–strain distribution along their lengths. Based on the results the behavior of the anchors was assessed, including the relationships between the pullout force and the head displacement, the axial strain along anchors and the shear stress at the GFRP-grout interface. The stress distribution of anchors showing interlaminar shear failure was then analyzed based on a maximum shear stress criterion. It was proved that the load transfer mechanism of GFRP and steel anti-floating anchors differs significantly. GFRP anti-floating anchors reach failure due to interlaminar shear failure, while conventional steel anchors generally fail as a result of shear at the grout–soil interface. The test results also showed that the embedded FBG technique is reliable for monitoring the stress–strain state of an anisotropic material.

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1. Introduction

Building floating issues have recently attracted attention due to the wish for ever larger and deeper underground basements in areas of high ground water level. Ground anchor retaining systems are designed to stabilize and support underground structures to restrain their movement with the groundwater buoyancy using tension-resisting elements. The ground anchor primarily designed to resist uplift water pressures and rotational loadings is called anti-floating anchor in function. It consists of transferring the resisting tensile forces generated in the inclusions into the ground through the friction mobilized at the interfaces. In the past few decades anti-floating anchors have been used widely, as they have been shown to be an effective tool to counteract buoyancy in large sub-structures (Bobet and Einstein, 2011; Tóth et al., 2013). This system presents several advantages when compared with other anti-floating methods, such as dewatering, load ballasting and anti-floating piles. Some of these advantages are the anchors good adaptability to different soil strata, their convenience of

construction, investment savings and the fact that the layout of these restraints is flexible and hence can be designed efficiently for each project.

The cement grout used in anti-floating anchors supplies shear resistance at the bar-grout interface and can give some erosion protection to the bars. However, anchors are generally used in aggressive environments, being under water or in the dry-wet cycling zone all year round. Therefore, the structures can suffer erosion due to chemicals in the soil reaching the steel through microcracks in the grout. This phenomenon can seriously weaken the strength of the structure and is a risk for permanent anti-floating anchors, especially when used in buildings with a long design life. Additionally, in urban rail transit projects such as underground railways engineering, stray currents due to by DC power around the electrified rail and the surrounding rock will also cause electrochemical corrosion of metal anchors. Many passive corrosion protection measures, for example electrolytic zinc plating and placing corrugated sheathing covers around the steel bars, have been proposed. However, these solutions still cannot fundamentally solve this problem and therefore guarantee the long-term effectiveness of anchors in aggressive soil environments. Instead, corrosion resistant materials, such as glass fiber reinforced polymer (GFRP), could be used to replace steel to resolve these issues.

* Corresponding author at: School of Civil Engineering and Architecture, Weifang University, Weifang 266033, China.

E-mail addresses: hikou@ntu.edu.sg (H.-l. Kou), Guowei@ntu.edu.sg (W. Guo), zmy58@163.com (M.-y. Zhang).

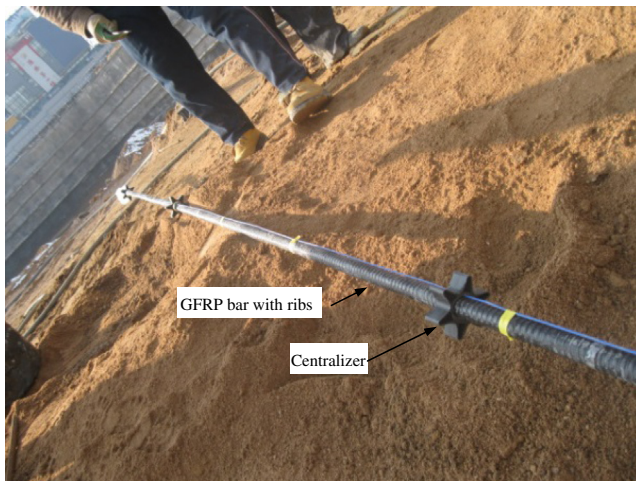
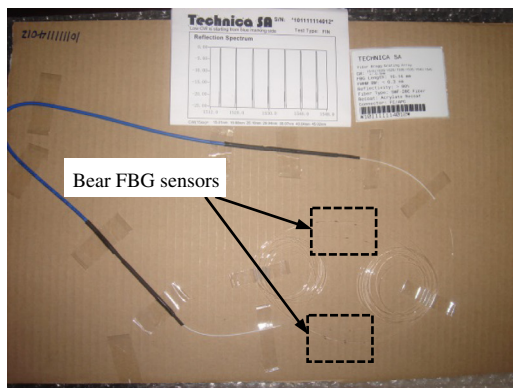


Fig. 1. GFRP bars.

GFRP materials are composed of a resin matrix embedding glass fibers. They have many advantages compared with steel, including a higher strength-to-weight ratio, better corrosion resistance and low electromagnetic properties. GFRP components have been widely used in geotechnical engineering in recent years (Sen et al., 1991; Iskander and Hassan, 1998; Weber et al., 2006; Ashford and Jakrapiyanun, 2001; Xue et al., 2011; Chai et al., 2011). Many researchers studied the performance of GFRP soil nails and their difference with steel soil nails. Benmokrane et al. (1996) presented the results of laboratory and field pull-out tests of GFRP and steel bars anchored with cement grout. The results indicated that the bond strength of GFRP anchor bolts is close to that of steel anchor bolts. The authors also showed that at failure the slip of GFRP bars relative to the cement grout is greater than that of steel bars. This was argued to be due to the lower modulus of elasticity of GFRP. Beekman et al. (2007) conducted pullout tests on GFRP soil nails to evaluate the material pullout performance. Their results indicated that GFRP soil nails behave differently from steel soil nails in those conditions. Fiber Bragg Grating (FBG)



(a) Fiber line with bare FBG sensors



(b) GFRP bar embedded with FBG sensors

Fig. 2. Close-up view of installation of bare FBG sensors.

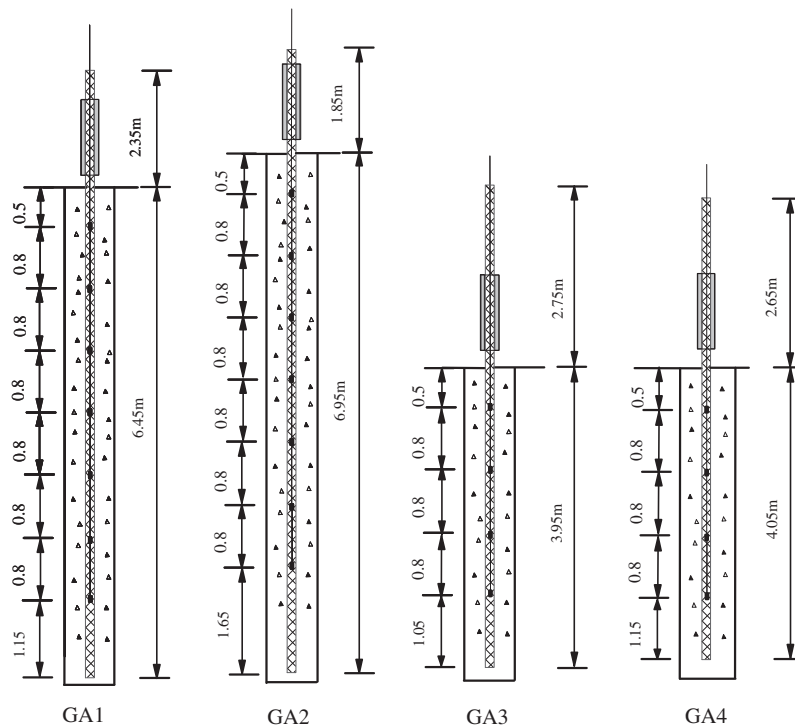


Fig. 3. Details of GFRP anti-floating anchor instrumented with bare FBG sensors.

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