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Impact resistance and evaluation of retained strength on geotextiles

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ABSTRACT

Over the last few decades, geotextiles have progressively been incorporated into geotechnical applications, especially in the field of coastal engineering. Geotextile materials often act as separator and a filter layer between rocks laid above and subgrade beneath. This versatile material has gradually substituted traditional granular materials because of its ease of installation, consistent quality and labour cost-efficiency. However, geotextiles often suffer damage during installation due to high dynamic bulk loading of rock placement. This can degrade geotextiles' mechanical strength. The properties considered in this paper include the impact resistance and retained strength of geotextiles. In general, the greater the impact energy applied to geotextiles, the greater the potential for damage. Results highlight the inadequacy of using index derived values as an indicator to determine geotextile performance on site because test results shows that geotextiles (staple fibre (SF) and continuous filament (CF)) with better mechanical properties did not outperform lower mechanical strength materials. The toughest CF product with a CBR index value of 9696N shows inferior impact resistance compared to SF product with the least CBR strength (2719N) given the same impact energy of 9.02 kJ. Test results also indicated that the reduction of strength for CF materials were much greater (between 20 and 50%) compared to SF materials (between 0 and 5%) when subjected to the same impact energy of 4.52 kJ.

1. Introduction

For more than 40 years, the use of geotextiles in coastal engineering applications has been increasing. The versatility (bi-dimensional and flexible), ease of installation, consistent material properties (mechanical and hydraulic) and cost-effectiveness of geotextiles offer great advantages as construction materials (Giroud, 1984; Palmeira et al., 2008). As such, geotextiles have gradually replaced granular materials as separator and filter layer beneath revetments armour, gabions and riprap (Christopher and Fischer, 1992). Unfortunately, geotextiles are often damaged during installation/construction phase. Past studies and on-site investigations (Chew et al., 1999; Heerten, 2008; Hornsey, 2012; Wong et al., 2000) led authors to agree the mechanical action during placement of rock armour can cause noticeable damage to geotextiles in one form or another. This justifies the need to examine geotextiles' damage during installation to estimate the short term performance of geotextiles. Identifying the retained strength of the material straight after installation allows engineers to be able to isolate installation damage from hydraulic, physical, chemical and biological damage that accounts for the deterioration of installed geotextiles. The expected serviceability of the material can be achieved with greater confidence when engineers are provided with the retained strength of the initially installed material.

The key factor ensuring geotextile to perform its function is the impact resistance of the material to resist the perforation of the rocks during installation. Rosete et al. (2013) point out that not only can installation damage on geotextile affect mechanical (tensile) strength, but also the functionality of geotextiles such as separation and/or filtration can be undermined. In 1992, Christopher and Fischer inferred that any design efforts for structures with geotextile filters would be useless if the material is damaged during installation process and further asserted that "*Swiss cheese does not make a good filter*". Similarly, Heerten (2008) asserts that any

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geotextile filtration design would be meaningless if the material suffers puncturing during installation.

Engineers and designers often rely on index values specification, design guidelines and installation height limitations to minimise damage inflicted on geotextiles during installation process. Specifying minimum index values as survivability requirement is risky as index tests fail to simulate field conditions. Furthermore, the extensive drop testing completed in Singapore revealed that geotextiles with better mechanical properties such as tensile strength and CBR force do not necessarily have better performance (Chew et al., 1999; Wong et al., 2000). Wong et al. (2000) found a negative correlation between tensile strength and CBR force of geotextiles with the expected damage. Results reveal that geotextile with superior mechanical strength did not outperform materials of lower strength properties. Hence, index test values should not govern the impact resistance of geotextiles.

Design guidelines and charts available are mostly based on physical parameters such as mass and thickness of geotextiles. Mass of geotextile represents the amount of polymer used in manufacturing of the geotextile product (Wong et al., 2000). Though the mass of geotextile is often associated with its mechanical performance this parameter is merely a relative indicator. It is only relevant if the same manufactured form of fabric is compared. Combined technological developments, reformed manufacturing techniques and improved quality of raw materials could result in better performing geotextile given the same amount of mass (Palmeira et al., 2008; Wong et al., 2000). As such, mass does not necessarily reflect the impact resistance of geotextile.

Engineers and designers would often carry out field trials to determine the appropriate drop height in installation to minimise the risk of punctures inflicted on geotextiles (Ameraunga et al., 2006; Holtz et al., 1997). Chew et al. (1999) and Wong et al. (2000) agreed that there is neither a standard methodology for field test nor a standard damage evaluation approach adopted by the industry. This led Chew et al. (1999) to propose a standardized drop test (SDT) to measure the puncture resistance of geotextiles in a quantifiable and empirical manner. However, despite the reproducible results obtained from SDT, it has been shown that geotextile puncture is a random event and a repeated number of tests may be necessary to capture the risk of puncturing the geotextile. Though, SDT may closely simulate field conditions, the variation of overlaying armour rocks in size and shapes and subgrade conditions makes it harder to determine the safe puncture threshold. Hence, there is a need to design a test apparatus to isolate and control the parameters so that governing factors of damage are identified.

In 1978, BAW developed a standard impact test to simulate the dynamic impact of a falling armour rock on geosynthetics (current issue: RPG (1994)). Heibaum (2014) describes the dynamic impact is simulated by releasing a drop hammer with a tip edge onto the geotextile sample laid above a soil sample at determined drop energy. The BAW guideline highlights the use of drop energy as a function of rock size and drop height, a functional versatile approach to simulate dynamic impact. However, damage simulated from this approach does not fully replicate the damage sustained by geotextiles during installation. The cylindrical drop hammer with a tip edge remains in dispute: the question of the armour rock represented with a cylindrical drop hammer still invites contention.

When designing geotextiles for coastal applications the effect of possible damage should be taken account, including mechanical damage during installation. Hence long term observational studies have taken place to determine the extent of damage after a certain number years in service, this typically ranges from 5 to 14 years (Christopher, 1983; Lawson, 1982; Loke et al., 1995; Mannsbart and Christopher, 1997). Studies suggest that there is a substantial deterioration in geotextiles' mechanical strength from samples that were exhumed from project sites. Results gathered from these studies provide engineers the relevant information to develop safety factors and design guidelines. However, it is difficult to determine the durability of geotextile during installation as various damage factors are correlated when it is examined after a number of years. These damages could include tension loading (during installation and/or operational phase), heavy wave attacks on armour rocks and/or creep under permanent loading. It will be useful if engineers are able to identify the initial material strength reduction upon installation, as design engineers could account for the mechanical deterioration of the material during operational stage.

This study utilizes a new approach, Drop Rock Test (DRT) (Cheah et al., 2015; Kendall et al., 2014b) to simulate damage on a geotextile during installation. The impact resistance of the material is examined by recording the amount of samples that survived (no punctures) for a series of drop rock tests. Surviving samples are directly exhumed and tested for changes in mechanical strength using CBR puncture tests. Results of experimental investigations on impact resistance and retained CBR strength are presented in this paper.

2. Materials and experimental description

2.1. Drop Rock Test

Fig. 1 illustrates the DRT apparatus which consists of a gantry crane with a lifting capacity of 1550 kg, concrete block and a subgrade containment unit. As shown in Fig. 1, two A-frames of rectangular hollow sections are bolted to concrete blocks to provide support to the girder section. The concrete block was constructed with a 90° tip facing downwards to represent the worst possible damage inflicted onto geotextile by rock armour. Three concrete blocks weighing 922 kg, 438 kg and 93 kg are available with this apparatus. The DRT apparatus has a maximum drop height capacity of 2.0 m.

The DRT procedure adopted in this study is summarised as follows:

i. A concrete block of 922 kg with a 90° tip was used in DRT to deliver constant impact energy onto geotextile for a specified drop height. This orientation ensures the greatest mechanical stress inflicted on geotextile.
ii. Each geotextile sample measured 1.8 m by 2.0 m and was stencilled with a grid of 50 mm by 50 mm, where the concrete block is targeted to fall. Any physical changes can be observed by measuring the change in the length stencilled on the geotextile.
iii. The subgrade confined box was filled with sand compacted using a hand tamping system. A 4.2 kg tamper of 200 mm × 300 mm × 700 mm (L × W × H) was released from a height of 0.5 m and repeated 30 times (6 × 5 grid pattern). The centre region of the subgrade was repeatedly emptied and refilled due to the falling of concrete block; this area was tamped again by a 3 by 5 grid pattern to ensure consistent compaction.
iv. The concrete block was electrically winched up to the desired drop height and was laterally moved across with a trolley along the crane rail. The drop height was measured from the bottom tip of the test block to the surface of the geotextile with a T-gauge. The testing block was then disengaged from the quick release mechanism once in position.
v. After the drop, the concrete block and G-clamps were removed, any punctures found on the geotextile sample were