Development of Ground Improving Geomaterial Using Recycled Glass Fibers

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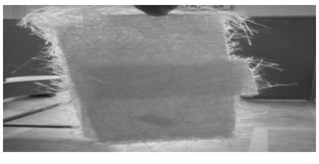
1. INTRODUCTION

The use of glass fibers as reinforcing agent started to catapult as researchers discovered their unique properties in terms of durability, lightweight and non-biodegradability (Mujah, 2010). Glass fibers amorphous structures are able maintain internal stability along and across the fibers without further intrusion by foreign addictives thus ensuring structural durability. In contrast to carbon fibers, glass fibers are able to undergo considerably more elongation before rupture when demonstrated by tensile test. Lutz & Grossman (2001) reported that fiberglass is an attractive reinforcing agent because of their high strength, stiffness, high ratio of surface area to weight and dimensional stability. Although previous studies of glass fibers (Lutz & Grossman 2001; Pinzani & Sauli 2006) mentioned its unique properties however none of them described their potential use as reinforcing agent for ground improvement. In this paper, a new geomaterial (geomat) called 8FGMAT made from recycled glass fibers derived from industrial glass wastes is proposed as a sustainably driven innovative effort for ground remediation technique whereby its mechanical properties in terms of the tensile strength and pullout resistance force were verified through laboratory tests in various soil conditions.

2. 8FGMAT PREPARATION AND TESTING

Polymeric glass fibers were sterilized in an autoclave in a temperature of 120 – 150 ^{0}C for 1 hour to get rid of micro-organism impurities. Some portions of the fibers were coated with acrylic butadiene styrene (ABS) thermoplastic. Subsequently, fiberglass yarns were molded into '8' shape form using a prefabricated mold 1000 mm length, 200 mm width and 150 mm height and glued together using resin to ensure that glass fibers were intently intact. Any presence of air bubbles were closely observed as they may lead to voids formation which may result into a lower volume of glass fibers thus affecting geomat's overall strength. The sample was then allowed to harden for two hours before mold was removed. Samples of fiberglass geomats were prepared as shown in Figure 1. Tensile strength of glass fibers' polymeric yarns were tested and compared to coated glass fibers and natural fibers extracted from oil palm empty fruit bunch (OPEFB) according to ASTM C1557-03: Standard Test Method for Tensile Strength and Young Modulus of Fibers. Meanwhile, the '8' shape fiberglass geomat was carried out according to the modified version of ASTM D7004-03: Standard Test Method for Grab Tensile Properties of Reinforced Geomembranes. The pullout resistance force of fiberglass geomat was observed through pullout test based on ASTM D6706: Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil.

(a) Polymeric glass fibers



(b) Strand layer

(c) '8' shape glass fibers geomat

Figure 1. Preparation of '8' shape 8FGMAT

3. RESULT AND DISCUSSION

Typical properties of soils used in the experiment are shown in Table 1. Figure 2 and Figure 3 show the stress-strain relationship of the effect of fibers' coating and layer thickness to geomat's tensile strength. It was observed that the uncoated glass fibers exhibited higher tensile stress at the same corresponding strain. The addition of layer thickness in molded specimens contributed to the increased values in tensile stress. However, alterations of glass fibers into '8' shape form recorded lower tensile stress values than uncoated glass fibers suggesting that the process of converting glass fibers into bundle of layered strands does not necessarily enhance the overall tensile strength of glass fibers in bulk.

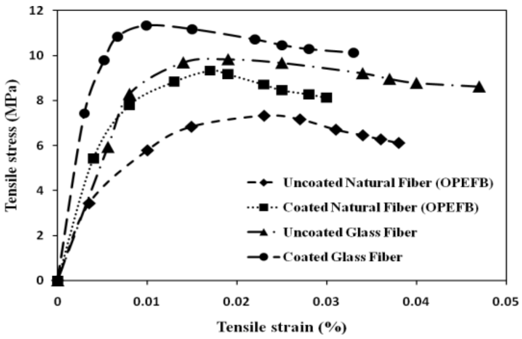


Figure 2. Stress-strain relationship of glass fibers

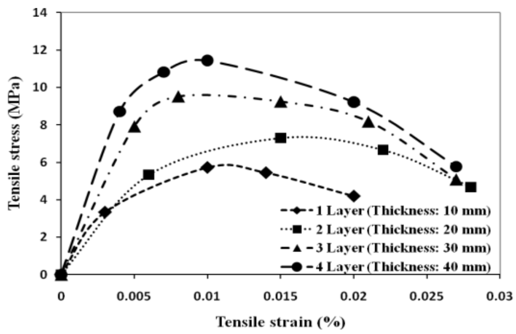


Figure 3. Stress-strain relationship of '8' shape 8FGMAT

The ultimate tensile strength of all specimens in ascending order were recorded as 0.59 kN, 0.61 kN, 0.76 kN and 0.86 kN respectively as shown in Figure 4. The tensile strength of

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Table 1. Typical properties of soil media

Soils	Specific Gravity	Dry Unit Weight (kN/m^3)	Water Content (%)	Friction Angle (^{0})	Cohesion (kPa)	USCS
Perlis Clay	2.28	14.43	52	46	20	S-CL
Penang Sand	1.73	18.65	14	28	−	SP-SM
Malaysian Peat Soil	1.47	1.41	68	23	3	PT

8FGMAT is shown to be affected by its construction joint; the line where layers of fiberglass strands were connected using resin to harden. The occurrence of failures in all samples of 8FG Mat at the construction joint regardless of their layer thickness proved joint's susceptibility in resisting applied force.

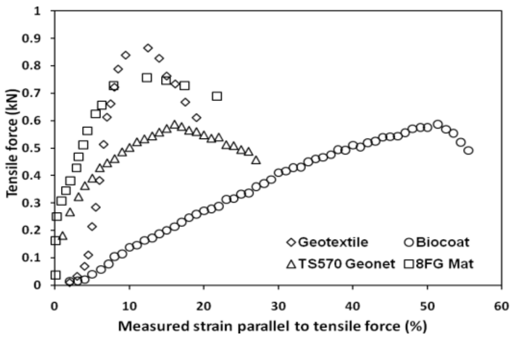

Figure 4. Comparison of tensile strength with other geosynthetics

Figure 5 shows the pullout – displacement relationship of reinforced soil media with 8FGMAT in two confining vertical stresses conditions σ_v = 100 kN/m^2 and σ_v = 50 kN/m^2 respectively. The results clarify that the pullout force is directly proportional to the applied confining pressure. The increase of confining pressure was observed to increase the corresponding pullout force for all soil samples.

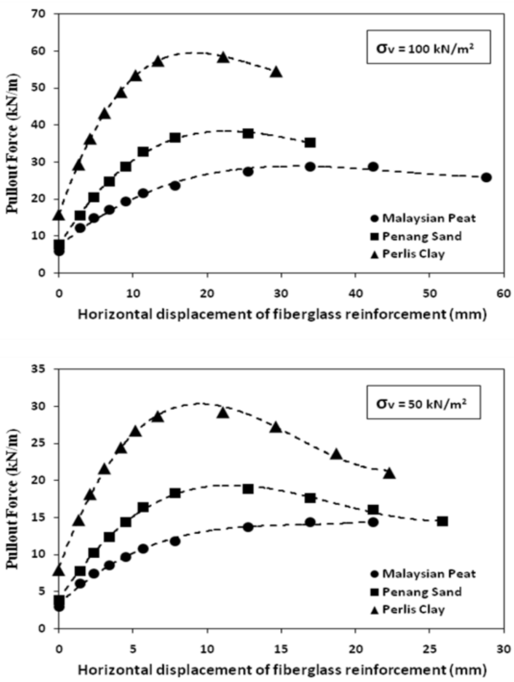

Figure 5. Pullout force - displacement relationship in different confining vertical stresses

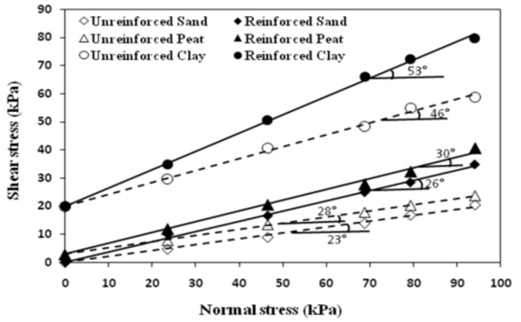

Figure 6. Failure envelope of soil media reinforced with 8FGMAT

Figure 6 shows the increased in internal angle of frictions for all soil samples in reinforced and unreinforced conditions. The shearing effect is greatly observed in cohesive soil such as clay and peat where the presences of organic material are expected.

4. CONCLUSION

8FGMAT offers a promising alternative for ground improvement in significantly improved the various soil samples failure envelopes and internal friction angles. Also, the tensile strength of glass fibers is shown to be increased at the expense of fibers' alteration and layer thickness. The pullout force values in different soil samples revealed a linear relationship as the thickness of strands' layers and confining pressures were increased.

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