MGT1000-based geotextile free-end anchorage pullout test study

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Abstract. The pull-out test is a methodology employed for the evaluation of various critical mechanical performance parameters of materials, and it holds significant importance in the realms of material selection, design, and quality control. In this study, the tensile testing standards were combined with the characteristics of the MGT1000 testing apparatus. Test sand and geotextile material were selected to investigate the influence of normal pressure, geotextile free-end wrapping height, and length on the tensile strength of the geotextile material. The experimental results reveal that, under various normal pressures, the relationship between tensile displacement and tensile force exhibits consistent trends. Without wrapping, the tensile force of the reinforcement material gradually stabilizes after reaching its peak. Conversely, when wrapping is employed, the tensile force of the reinforcement material progressively increases with the increase in tensile displacement. Employing wrapping at the free end of the geotextile material significantly enhances anchoring strength.

Keywords: MGT1000, geotextiles, pullout testing, wrapping, testing machine

1 Introduction

Geotextiles represent a civil engineering material composed of polymer materials, widely utilized in various engineering domains, including ground reinforcement, slope stabilization, road construction, railway projects, water resources management, and environmental preservation[1].In both domestic and international standards, the testing conditions for geotextiles predominantly involve subjecting the materials to tension within ambient air conditions to assess the tensile strength of the reinforcement[2]. Nie Rusong studied the frictional characteristics of the interface between windblown sand and geogrid using pull-out tests[3]. Wang Jiaquan conducted pull-out tests on coarse grained soil with five different coarse particle contents of P5 based on a visual pull-out

H. Bilgin et al. (eds.), *Proceedings of the 2023 5th International Conference on Civil Engineering, Environment Resources and Energy Materials (CCESEM 2023)*, Advances in Engineering Research 227,
https://doi.org/10.2991/978-94-6463-316-0_44

system and digital photography measurement technology[4]. Mirzaalimohammadi and Ghazavi conducted tensile tests on four reinforcing materials such as geogrids, GGB reinforcement, plain geocomposites, and GCP, and investigated their efficiency in interacting with fine-grained sand[5].

The free-end anchor pullout test represents a pivotal method for assessing the tensile and anchoring performance of geotextiles. This test provides crucial information to structural designers and engineers regarding the performance of anchors within concrete, ensuring structural safety and stability. By conducting anchor pullout tests on geotextiles using MTG1000, a deeper understanding of the mechanical properties and engineering behavior of geotextiles can be gained. This, in turn, serves as a scientific basis for the design and application of geotextiles.

2 Introduction to pullout test

2.1 Introduction to pullout test equipment

In this experiment, a multi-functional geosynthetic material tensile testing machine, referred to as MGT1000, was employed, as depicted in Figure 1. Table 1 provides an overview of the main performance specifications of the testing machine.

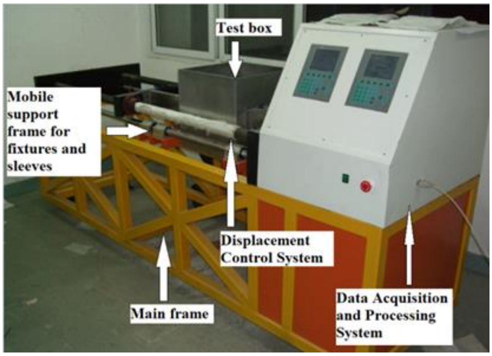


Fig. 1. Multi-functional geosynthetics in-soil tensile tester

Table 1. The main performance index of the tester

Test chamber dimensions /mm³	Procedure for pulling force /kN	Measurement accuracy /%	Displacement rate /mm/min	Elongation resolution /mm	Maximum normal load /kPa
400×400×400	100	0.02	0.01~100	0.001	200

The main features of this equipment are:

It can meet the testing requirements under various conditions, encompassing a range of tests such as conventional tensile testing, in-soil tensile testing, pullout testing, and creep tests.

The installation of upper and lower pneumatic bags facilitates the uniform application of stress perpendicular to the object surface, thereby enabling precise control of air pressure.

The internal dimensions of the model box are relatively large, allowing for the effective reduction of boundary effects that may occur under certain conditions.

The instrument is easy to use and provides accurate data measurements.

2.2 Introduction to pullout test materials

In this experiment, standard sand was employed as the fill material for pullout testing, with the specific particle size distribution data detailed in Table 2. Conventional geotechnical tests provided us with certain mechanical and physical properties of the sand, as indicated in Table 3.

Table 2. Grading table of sand and soil particles

Particle size /mm	5	2	1	0.5	0.25	0.075
Percentage of particles smaller than a certain size /%	100	92.5	70.8	34.05	32.59	0.59

Table 3. Physical and mechanical indicators of fillers

Material type	Moisture content /%	Maximum dry density /g·cm^{-3}	Cohesive force /kPa	The angle of internal friction /°
Sandy soil	0.3	1.88	0.15	34.5

In this experiment, both woven and non-woven geotextiles were utilized as reinforcement materials for pullout testing. Conventional tensile tests were conducted on both materials, with two specimens for each material. Comparative curves are illustrated in Figure 2 and specific physical and mechanical parameters are detailed in Table 4.

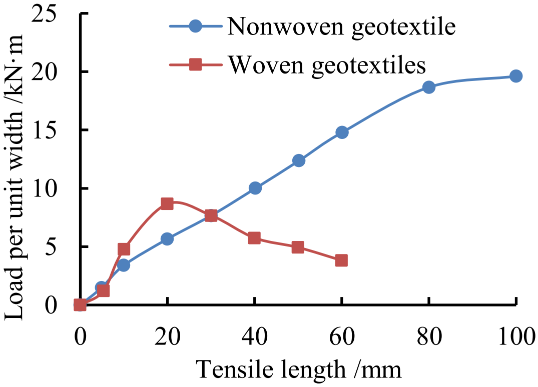


Fig. 2. Geotextile tensile test curve

Table 4. Main mechanical index of geotextile

Material type	Tensile strength /(kN/m)	Ultimate Tensile Ratio /%	The thickness of a single layer /mm	Mass perunit area (g/m^{-2})
Woven geotextiles	9.55	11.77	1.7	300
Nonwoven Geotextiles	20.76	44.78	2.82	400

2.3 Introduction to the pull-off test program

In this experiment, non-woven geosynthetic material was used as the reinforcement material for the pullout tests. Two parallel tests were conducted for each group. If the results of the two tests were close, their average was considered; otherwise, an additional test was performed. Consistency in the procedural steps was maintained as much as possible for each test group to minimize human-induced testing errors. The specific experimental plan is detailed in Table 5.

Table 5. Arrangement of drawing test program

Material type	Normal stress *P*/kPa P1 P2 P3 P4	Specimen size (Fixed length 100)/mm×mm	Backpacking height *h*/mm	Backpacking length *d*/mm
Nonwoven geotextile	25,50,75,100	200×200	0	0
	25,50,75,100	350×200	100	50
	25,50,75,100	400×200	100	100
	25,50,75,100	350×200	50	100

Figure 3 illustrates a schematic representation of the geotextile's free-end wrapping-back.

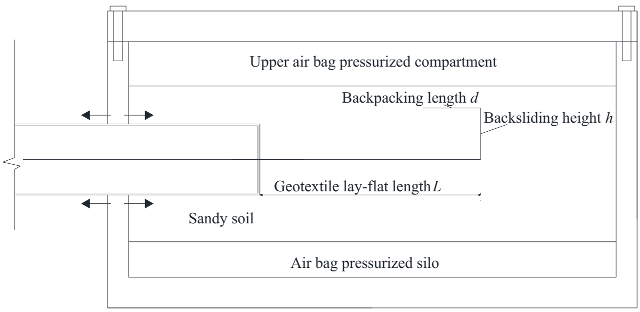


Fig. 3. shows a schematic diagram of the free end wrapped-back of geotextile.

By the specifications outlined in SL235-2012 "Testing Standards for Geosynthetic Materials", the test specimens were buried at a depth of *100-150mm* within the soil, ensuring that the geotextile's position in the soil was centered. For sandy soils, a pullout rate of *0.5mm/min* was applied. The perpendicular pressure was designated as *P*, with the geotextile's flat length denoted as *L*, the wrapping-back height as *h*, and the wrapping-back length as d.

In each test, the geotextile specimen had a width of *b=200mm*, and the fixed length of the specimen clamp was 100mm. The geotextile was laid flat in the soil with a length of *L=100mm*, and the pullout rate was set at *0.5mm/min*. The geotextile's intended standard configuration involved a wrapping-back height of *h=100mm* and a wrapping-back length of *d=100mm*. To the pullout test specifications and the characteristics of the pullout apparatus, the specific operational procedures are outlined as follows:

Cut the specimen: Trim the material to the required specimen dimensions as per the test group's specifications.

Layer the soil within the testing box, with each layer having a thickness of *50mm*. After reaching a depth of *200mm*, level and compact the soil. Then, place the geosynthetic material in the center and gently cover its surface with a layer of sand to secure its position.

Test A (No wrapping-back): After filling with soil, the geotextile is laid flat, and one end of the geotextile is secured using a sliding fixture. Layered soil is then further filled into the test box until it is full, and the test box cover is subsequently secured.

Test B (Wrapping-back): The parameters for the planned wrapping-back pullout test in the standard configuration include a wrapping-back length of *d=100mm* and a wrapping-back height of *h=100mm*. The specimen is trimmed to a length of 400mm and a width of 200mm, with the fixed length of the specimen clamp set at *100mm*. After filling the box to a depth of *200mm*, the sand is leveled and precompressed. Subsequently, the geotextile is unfurled, and sand filling continues until it reaches *100mm* above the geotextile plane. Carefully, *100mm* is wrapped inward, and one end of the geotextile is secured using a sliding fixture. Filling continues until the box is full, and the test box cover is then affixed.

Horizontal minute loads were applied to ensure that the horizontal displacement apparatus was uniformly tensioned at all points. The pullout rate was configured on the display control unit, with a set speed of 0.5mm/min. Horizontal displacement was then applied while measuring and documenting the pullout force and displacement.

The test concluded when a pullout displacement of *10mm* was reached, serving as the termination criterion. Switching to another specimen, the preceding steps were repeated to complete the testing for all specimens.

3 Results and Discussion

3.1 Analysis of results for different normal loads

Figure 4 depicts the relationship curves between pullout force and displacement for non-woven geotextiles under four distinct normal pressure conditions. Analyzing the graph, it becomes evident that the effect of normal pressure on enhancing the pullout force of the reinforcement material is somewhat influential but not highly significant. Under varying normal pressures, the pullout force exhibits a rapid increase at geotextile pullout displacements of approximately *0-1mm*, displaying an approximately linear correlation between pullout force and pullout displacement. Based on the pullout test results, it is evident that the greater the normal pressure, the higher the pullout force that the reinforcement material can provide, making it more resistant to being pulled out.

Figure 5 illustrates the pullout force-displacement relationship curves for non-woven geotextiles with a free-end wrapping-back height of *h=100mm* and a wrapping-back length of *d=100mm* under four distinct normal pressure conditions. As the normal pressure increases, the peak pullout force of the geotextile also increases. According to Figure 5, it can be observed that when the geotextile has a free-end wrapping-back, the normal pressure does have some influence on the pullout force that the reinforcement material can provide, although this effect is not highly significant.

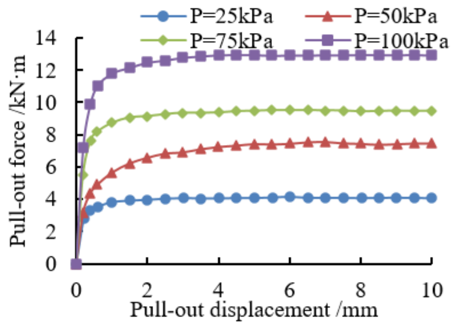


Fig. 4. Nonwoven geotextile pullout force vs. pullout displacement graphs (left image)

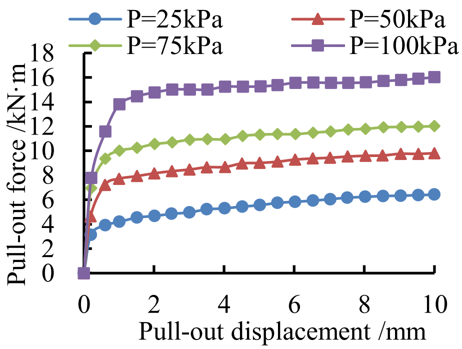
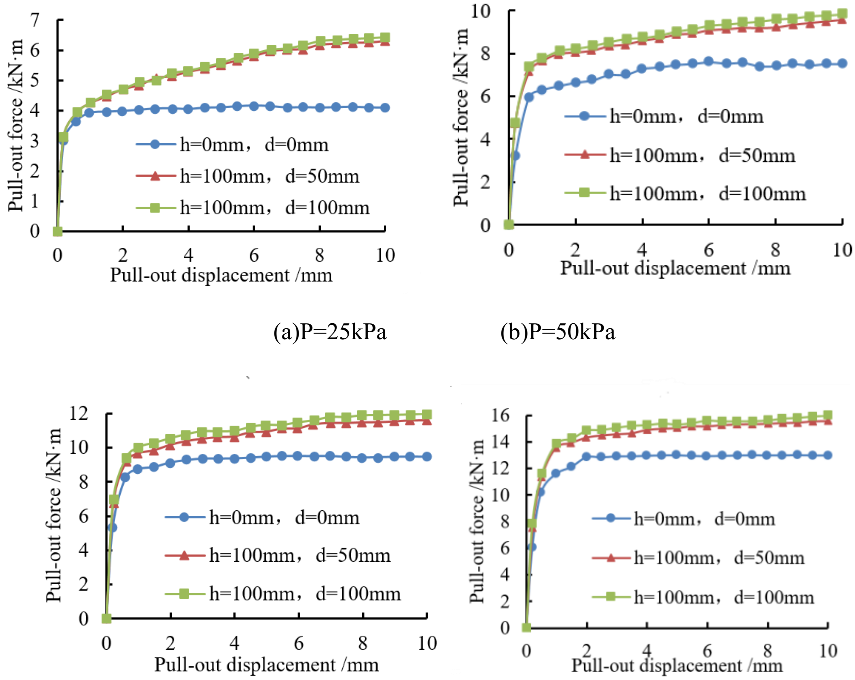


Fig. 5. Curves of pullout force and pullout displacement of nonwoven geotextile with backwrap at the free end (right image)

3.2 Analysis of results for different backpacking lengths

From the Figure 6, it is evident that under various normal pressure conditions, the trends in pullout force and displacement for geotextiles with and without free-end wrapping-back are generally similar. When the geotextile adopts a free-end wrapping-back configuration, it results in a larger effective contact area between the geotextile and the soil, leading to increased frictional and interlocking forces at the geotextile-soil interface. Hence, a greater pullout force is required to transmit the tension from the pullout end to the free end, thereby causing the geotextile to be pulled and induce displacement. From Figure 6 and data in Table 6, it can be deduced that the use of a free-end wrapping-back configuration in geotextiles effectively enhances the pullout force of the reinforcement material. Particularly, at lower normal pressures, the increase in pullout force with free-end wrapping-back is more pronounced, highlighting the more significant impact of the wrapping-back configuration.



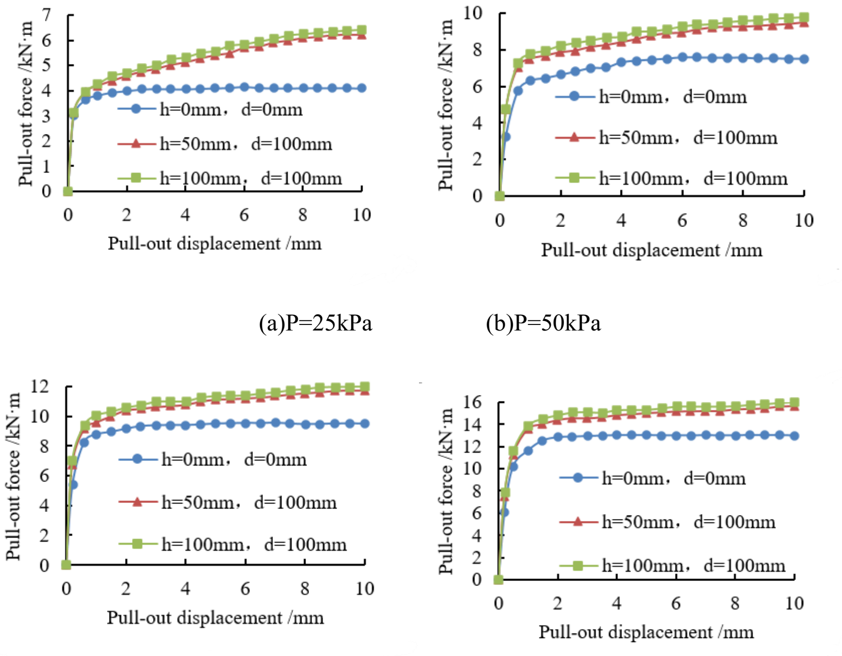
(a)P=25kPa (b)P=50kPa

(c)P=75kPa (d)P=100kPa

Fig. 6. Curves of pullout force versus pullout displacement for different backpacking lengths under four normal pressures

3.3 Analysis of results for different backpacking heights

From the Figure 7, it can be observed that the pullout force increases with the increasing pullout displacement. In the initial stages of pullout, the rate of increase is relatively high, and for the non-wrapping-back configuration, the pullout force gradually stabilizes after reaching its peak, approximating a linear state. In contrast, the pullout force during wrapping-back continues to increase, indicating that employing the wrapping-back configuration effectively extends the anchorage length of the reinforcement material. This results in a stronger interaction between the free end of the reinforcement material and the soil, leading to an increase in the tensile strength of the reinforcement material. The pullout force has not been fully transmitted to the free end by the end of the pullout, whereas for the non-wrapping-back geotextile, the pullout force is transmitted from the pullout end to the free end at the end of the pullout, resulting in the geotextile being pulled as a whole.



(a)P=25kPa (b)P=50kPa

(c)P=75kPa (d)P=100kPa

Fig. 7. Curves of pullout force versus pullout displacement for different backpacking heights under four normal pressures

As observed from the graph, when the normal pressure is relatively low, the use of a wrapping-back configuration at the free end of the geotextile yields a more pronounced effect. A wrapping-back configuration effectively increases the anchoring force at the free end, requiring a greater tensile force when the geotextile is pulled. Moreover, when the wrapping-back length at the free end of the geotextile is held constant, increasing the wrapping-back height does not yield a significant improvement in the tensile force of the reinforcement material.

Table 6. Comparison of peak pullout force with and without backpacking under different normal pressures

backwrap height *h*/mm	backwrap length *d*/mm	Peak pull-out force /kN·m			
		25kPa	50kPa	75kPa	100kPa
0	0	4.15	7.58	9.51	12.96
100	50	6.29	9.57	11.64	15.57
100	100	6.39	9.81	11.99	15.96

4 Conclusion

In this study, the following conclusions have been drawn:

- In the initial stages of the tensile process, the tensile force increased rapidly, showing an approximate linear relationship. As the displacement increased, the slope of the curve gradually decreased, leading to a gradual reduction in the rate of tensile force growth.
- At the same displacement, the greater the normal pressure, the higher the peak tensile force of the geotextile. The displacement corresponding to the peak tensile force increases gradually with the increase in normal pressure.
- The use of end-wrapping at the free end of geotextiles significantly enhances anchoring force. When the end-wrapping height is constant and the end-wrapping length is constant, altering the end-wrapping height does not yield a significant improvement in tensile force.

Acknowledgments

Financial support for this work is gratefully acknowledged by Funding for the Innovation and Entrepreneurship Training Program for College Students at Guilin University of Electronic Science and Technology (S202310595222), Guangxi Science and Technology Major Program Grant (No. AB23026028), and Science and Technology Project of Jiangxi Provincial Department of Transportation(No. 2022H0030).

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