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Tensile Properties Test of Geosynthetics with the Newly Developed Apparatus

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Abstract

Tensile strength of geosynthetics plays an important role in geotechnical engineering. Currently, there were several test apparatuses for the determination of tensile strength. However, outstanding problems associated with these apparatuses, for example, the clamp holding the geosynthetics moved from the soil to the outside and had relative displacement with the sleeve when moving in the sleeve, the interaction between clamp of the apparatus and soil was not be eliminated and could not simulate the in-soil stress condition of geosynthetics in real working state, which led to inaccurate measurement of tensile load of geosynthetics. To overcome these problems, a new tensile test within soil apparatus was developed to test three types of geosynthetics with testing tensile test within soil under the different confinement and tensile test in air, total 45 tensile tests for the performance of the new tensile test within soil apparatus. Results of the tensile test showed that the confinement was the important factor to improve tensile properties of geosynthetics. Under confinement, the tensile properties of geosynthetics were greater than tensile test in air. The tensile properties of plastic geogrid were better than those of the other two geosynthetics. The data obtained from the tensile test within soil was closer to the real working

conditions, which proved the new apparatus is more capable and suitable for determining the tensile properties of geosynthetics than other currently available apparatus. This provides insights into the design of engineering practices.

Keywords

tensile strength, geosynthetics, test apparatus, tensile test in air, tensile test within soil

1. Introduction

Geosynthetics have been widely used in geotechnical engineering practice to improve soil stability [24,31-32]. For engineering consideration, tensile strength is an important index to evaluate the properties of geosynthetics in geotechnical engineering [30]. Currently, the tensile strength of geosynthetics can be obtained by tensile testing apparatus [17,20] Although many tensile tests had been carried out by the tensile test apparatus, the tensile properties of geosynthetics can rarely be measured with great accuracy. [19] conducted a series of pullout tests to investigate the role of transverse and longitudinal members on pullout resistance of a polyester geogrid and concluded that the T-members contribute almost 30-60% towards pullout resistance. [27] conducted the large-scale pullout test to study the effective performance of the geogrids in passive resistance and observed that the increasing the pullout resistance of the ordinary geogrid by 65%. [22] studied the effect of geogrid geometry, ultimate tensile strength and type of polymer on the geogrid-ISFS interaction with the newly fabricated large size pullout test apparatus. [8] used a pullout box .with a transparent glass bottom and synchronized cameras to observe the displacements of the geogrid and seed, obtained relative shear displacements between the geogrid and the soil. It is important to acknowledge the limitations of existing test devices, particularly the lack of consideration for the interaction effects of the fixture with the soil and the sleeve in pull-out tests.

When the tensile properties are used in design, most of the existing specifications [3-4] evaluated the tensile properties of geosynthetics through conventional tensile test in which the geosynthetics are tests in the air. However, geosynthetics are subjected to tensile and confining stress simultaneously in real situation. [7] studied the effect of soil-reinforcement interaction coefficients on the tensile redistribution of geosynthetics, and found that the analysis of soil and subsequent reinforcement of the composite system using an appropriate value for the interaction coefficient may facilitate the estimation of mobilized reinforcement tensile force.

Many studies have also shown that the tensile properties of geosynthetics under confining stress in real working conditions are significantly different from those in air [5,11,14,21] The existing apparatus could not simulate the in-soil stress condition of geosynthetics in real working state, so a new in-soil test apparatus needs to be developed to overcome the shortcomings of the existing test apparatus.

In this paper, a new test apparatus was designed, three types of geosynthetics were tested by tensile test within soil under the different confining stress, as comparation, tensile test in air for the same three types of geosynthetics was conducted. A total of 45 tensile tests to conducted to evaluate the performance of the new tensile test within soil apparatus. The influence of the confining stress and strain on tensile load, and secant tensile stiffness were analyzed based on the test results.

2. Development of the new test apparatus

2.1 The design principles

In the design of the new test apparatus, some factors that have not been considered in the current apparatus have to be taken into consideration. Among the factors that affecting the tensile test, the soil-geosynthetics interaction must be achieved in the newly-designed apparatus.

The clamp holding the geosynthetics moved from the soil to the outside in some studies [8,15,19,22,27] and the interaction between clamp and soil was not be

eliminated, causing an excess friction to be included in the measured tensile load of geosynthetics. Moreover, the sleeves existing outside the clamp were mainly used to prevent rigid boundary effect of the front wall [19]. In most existing studies, inaccurate measurement of tensile load of geosynthetics was due to the clamp had relative displacement with the sleeve when moving in the sleeve, and there was interaction between the clamp and the sleeve [8,15,19,22,27]

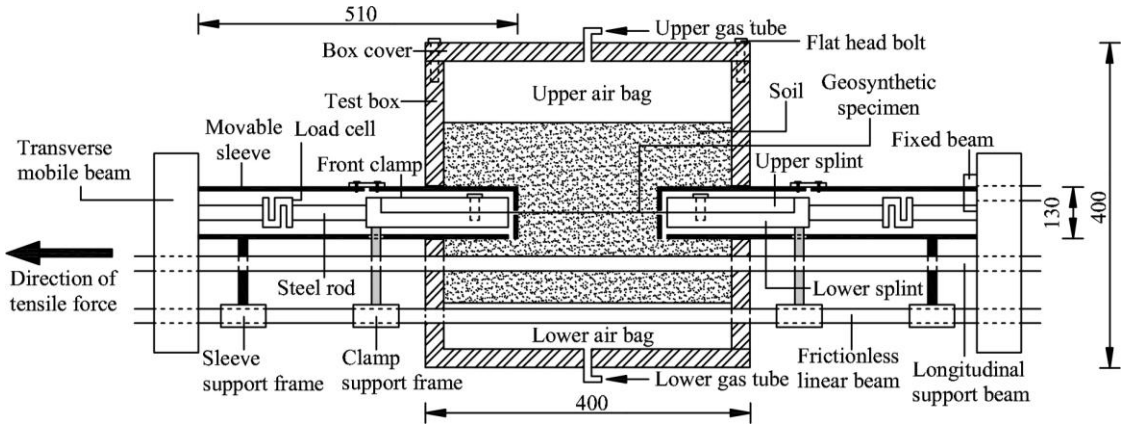
Overall, the effects of the interaction between the clamp and soil should be fully considered when designing the new tensile test within soil apparatus.

Make sure that the clamp and the sleeve move at the same time to ensure that the tensile load of the specimen was accurately measured. In addition, simple, safe and reliable operation should also be considered as factors in the design of the new tensile test within soil apparatus. Therefore, the clamp of new tensile test within soil apparatus was independent to the sleeve for other existing apparatus [2,16,23,26,28]

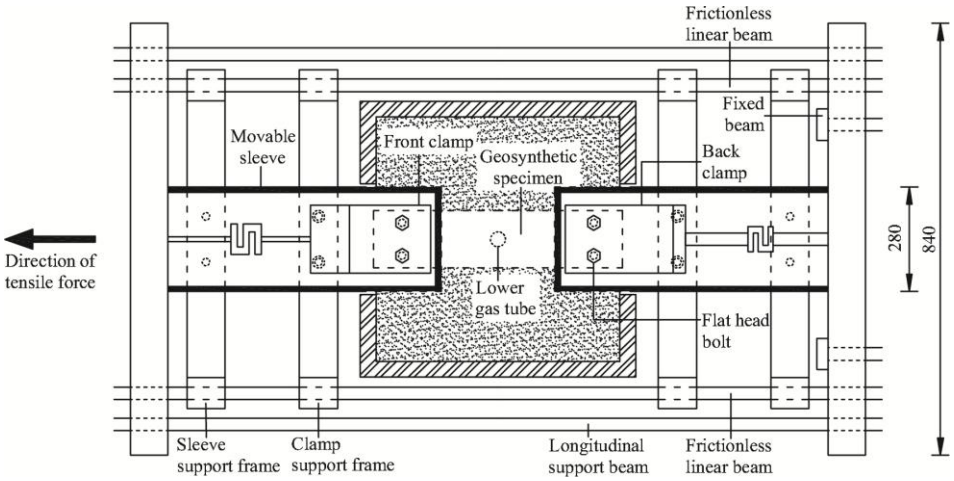
2.2 Structure of the apparatus

The apparatus consisted of loading clamps, movable sleeves, support frames, test box, normal surcharging system and data acquisition system. All the components of apparatus were supported by the high-strength steel frame beneath them. The design sketch and the picture of the tensile test within soil apparatus by [12] is shown in Figure 1 and Figure 2. Figure 1a showed the cross-sectional structure of the tensile test apparatus. Figure 1b showed the structure of the tensile test apparatus from the top view. Currently, the existing apparatus were mostly used in pullout test while less used for tensile test within soil [5,14] The in-air tensile and creep test, in-soil creep test and pullout test can also be conducted using this apparatus described in this paper.

FIG. 1 Schematic diagram of the tensile test within soil apparatus (unit: mm): (a) cross-sectional view; (b) top view.

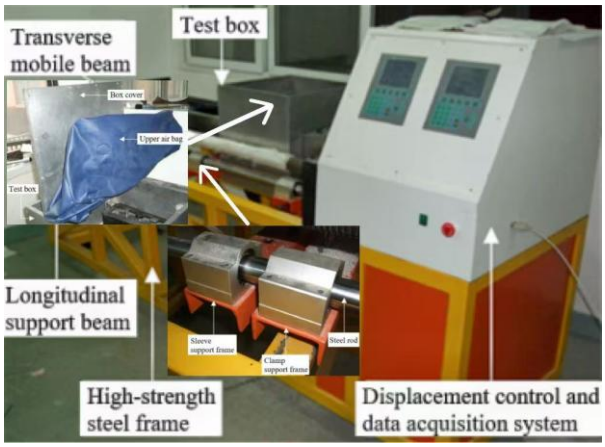


(a)



(b)

FIG. 2 Photograph of tensile test within soil apparatus.



The clamp is uesd to hold the geosynthetics and made from steel plates. There were many regular inlay grooves inside the clamp, which can increase the friction between the clamp and the geosynthetics. The clamps were mounted on a couple of frictionless linear beams by clamp support frames to maintain the

horizontal displacement of the geosynthetic specimen. The overall size of the movable sleeves was 510 by 280 by 130 mm (length by width by depth). The movable sleeve was designed to make the clamp move simultaneously with it instead that the clamp moving through the fixed sleeve, which ensured that the tension part of geosynthetic specimen was always in soil. The clamp attaching the load cell and holding specimen was contained in the movable sleeve, aiming at accurate measurement of the tensile load for geosynthetic during the tensile test not including the friction between the clamp and soil or the friction between the clamp and sleeve. The test box has two openings on the front and back sides for the sleeves passing through. The normal surcharging system can apply the required confining stress to the soil inside the test box, consisting of two pressurized air bags and an air compressor. The air bag inflated by the upper and lower gas tubes could apply confining pressures as much as 200 kPa. The confining stress was mostly applied by the air bag while some apparatus [5,6,16,22] were not. Compared to the previous test apparatus, the flexible surcharge loading arrangement (using air bag) was selected to ensure that soil dilatancy was not suppressed [18] and the uniform and bilateral confining stress were applied. More details as shown in Figure 2. Figure 2 showed the test box part of the tensile test apparatus, consisting of the test box, box cover and upper air bag. Figure 2showed the movable sleeves part of the tensile test apparatus, consisting of the sleeve support frame, clamp support frame and steel rod.

There were two longitudinal beams on the front and back sides of the test chamber independently. The frictionless linear beam was available for sleeve support frame and clamp support frame to move on it. The longitudinal support beam was used to make transverse mobile beam move along it. The fixed beam on the right side of test box was adopted to fix the clamp for preventing the stretching of geosynthetic specimen on this side, which achieved the unilateral tensile test. When the fixed beam was not used, the bilateral tensile test can be achieved.

2.3 Technical configuration of the apparatus

The technical characteristics of the new tensile test within soil apparatus in this study can be summarized as following: The movable sleeve was designed to make the clamp move simultaneously with it instead that the clamp moving through the fixed sleeve, which ensured that eliminate the relative displacement between clamp and soil. The new tensile test within soil apparatus can simulate the real working state of geosynthetics and apply uniform confining stress to the upper and lower soil in the test box. The new apparatus can safely achieved the kinds of tests, including the tensile test within soil, the tensile test in air, the pullout test, the unilateral tensile test and the bilateral tensile test. Comparisons between the new apparatus and existing apparatus (i.e., tensile test within soil apparatus and pullout apparatus) in literature are listed in Table 1. Compared to the existing apparatus, the new tensile test within soil apparatus has the advantages of eliminating the interaction between clamp and soil, ensuring that the sleeve moved simultaneously with the clamp to ensure the tensile load of the specimen was accurately measured and can be operated easily and safely.

TABLE 1 Comparisons between the new apparatus in this study and existing apparatus available in literature.

Reference	Test type	Stretched geosynthetics: always in soil (yes/no)	Clamp: in soil	Interaction between clamp and soil: be eliminated	Effect of clamp weight: be eliminated	Sleeve: exist outside the clamp	Sleeve: movable	Effect of sleeve weight: be eliminated	Relation between clamp and sleeve	Interaction between clamp and sleeve: be eliminated	Confining stress: be applied by air bag
The test apparatus in this study	tensile test within soil (bilaterally or unilaterally)	[a] √	√	√	√	√	√	√	1[c]	√	√ (Bilaterally)
Pant et al [19]	Pullout test	[b]×	√	×	×	√	×	√	2[d]	×	√

Morsy et al [16]	Pullout test	×	×	N. A.	N. A.	√	×	√	3[e]	N. A.	×
Roodi et al [23]	N. A.	×	×	N. A.	N. A.	√	×	√	3	N. A.	N. A.
Taghavi Taghavi and Mosallanezhad [27]	Pullout test	×	√	×	×	√	×	√	2	×	√
Balakrishnan and Viswanadha [5]	tensile test within soil (only unilaterally)	×	×	N. A.	N. A.	×	N. A.	N. A.	N. A.	N. A.	×
Prasad and Ramana [22]	Pullout test	×	√	×	×	√	×	√	2	×	×
Chen et al [6]	Pullout test	×	×	N. A.	N. A.	√ (Replaced by plastic membrane)	N. A.	N. A.	N. A.	N. A.	×
Abdi and Zandieh [1]	Pullout test	×	×	N. A.	N. A.	×	N. A.	N. A.	N. A.	N. A.	√
Ezzein and Bathurst [8]	Pullout test	×	√	×	×	√	×	√	2	×	√
Izawa and Kuwano [10]	Pullout test	×	×	N. A.	N. A.	×	N. A.	N. A.	N. A.	N. A.	√

Mendes et al [14]	tensile test within soil (only unilaterally)	×	×	N. A.	N. A.	×	N. A.	N. A.	N. A.	N. A.	√
Teixeira and Bueno et a [28]	Pullout test	×	×	N. A.	N. A.	√	×	√	3	N. A.	√
Moraci and Recalcati [15]	Pullout test	×	√	×	×	√	×	√	2	×	√
Sugimoto et al. (2001) and Alagiyawanna et al [26,2]	Pullout test	×	×	N. A.	N. A.	×	N. A.	N. A.	3	N. A.	√ (Bilaterally)

[a] Yes;

[b] No;

[c] The clamp inside the sleeve moved simultaneously with it;

[d] The clamp moved through the sleeve and had relative displacement with it;

[e] The clamp was independent to the sleeve.

3. Results and discussion

3.1 Test material and procedures

In order to test the performance of the new tensile test within soil apparatus, the tensile test within soil under the different confinement and tensile test in air were set up. In the present study, clean sand was used. The sand had a uniformity coefficient C_u of 3.82 and a curvature coefficient C_c of 0.99, which was classified as poorly graded sand (SP) according to the Unified Soil Classification System

(USCS). Direct shear tests were performed at a strain rate of 0.8 mm/min and with confining stresses of 50 kPa, 100 kPa, 150 kPa and 200 kPa, respectively. In these experiments, the internal friction angle φ was measured to be 38.17° and cohesion c was 4.59 kPa. Figure 3 shows three types of test geosynthetics, which are the plastic geogrid, geomembrane and geonet. Table 2 lists three types of geosynthetics (plastic geogrid, geomembrane and geonet) were-used in this study, which were commonly used in engineering practice [,5,9,14].

FIG. 3 Picture of three types of test geosynthetics: (a) plastic geogrid; (b) geomembrane; (c) geonet.



(a) (b) (c)

TABLE 2 Properties of different geosynthetics.

Properties	Plastic geogrid	Geomembrane	Geonet
Thickness (mm)	N. A.	0.5	N. A.
Mass per unit area (g/m^2)	N. A.	N. A.	637
Ultimate tensile strength MD[a] (kN/m)	15	7	5.8
Ultimate tensile strength XMD[b] (kN/m)	15	7	5.8
Maximum tensile strain MD[a] (%)	15	N. A.	N. A.
Maximum tensile strain XMD[b] (%)	13	N. A.	N. A.

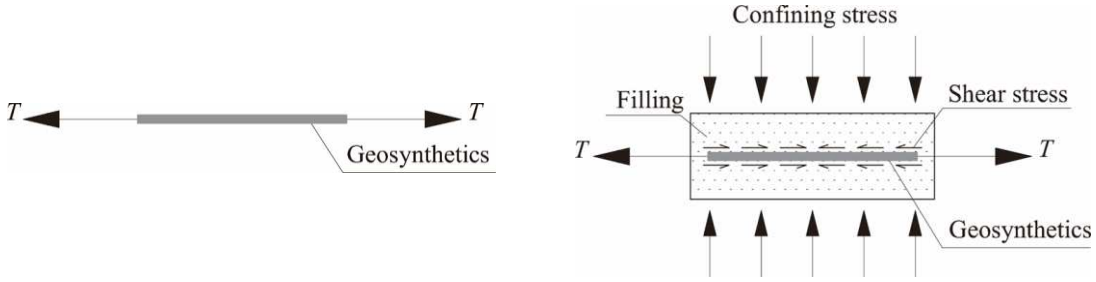
[a] MD-machine direction.

[b] XMD-cross machine direction.

The tensile test within soil and tensile test in air of three different types of geosynthetics were conducted by the tensile test within soil apparatus. Figure 4 shows the stress diagrams of two types of bilateral tensile tests, of which

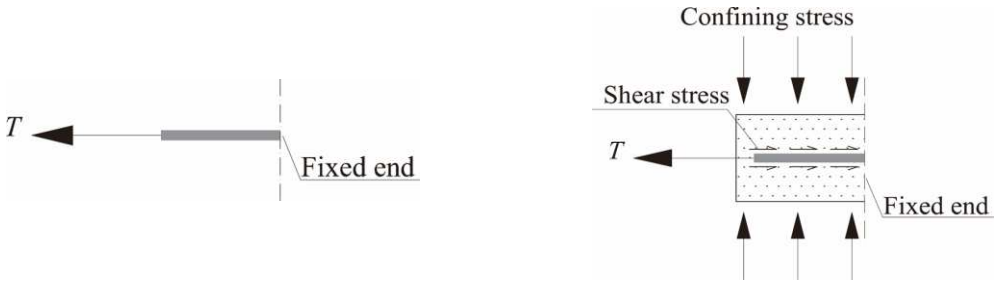
boundary condition was simplified as unilateral tensile tests (See Figure 5) to be used in this study. The tensile test in air shown in Figure 5a was a common method used to measure the tensile load of geosynthetics. The tensile test within soil was presented in Figure 5b.

FIG. 4 Stress diagrams of bilateral tensile tests: (a) in-air; (b) in-soil.



(a) (b)

FIG. 5 Stress diagrams of unilateral tensile tests: (a) in-air; (b) in-soil.



(a) (b)

Each geosynthetics was subjected to three parallel tensile tests, total of 45 tensile tests were conducted in this study under air and soil confinement conditions as shown in Table 3. Initially, tensile test in airs (the soil and air bags were not used, confining stress was 0 kPa) were carried out on three types of geosynthetics. Then, the tensile test within soils (confining stresses was 25 kPa, 50 kPa, 100 kPa and 150 kPa, respectively) were carried out to evaluate the effect of confinement on the tensile properties of geosynthetics.

TABLE 3 Details of tensile tests.

Specimen types	Confinement condition	Confining stress (kPa)
Plastic geogrid, Geomembrane, Geonet	Unconfined (in air)	0
	Confined (in soil)	25
		50
		100

During the tensile test within soil, the geosynthetics mainly subjected to the confinement of soil and the friction of the reinforcement-soil interface due to the geosynthetics contacted with the soil. The tensile tests were performed in strain-control mode at the strain rate of 40 mm/min. To ensure that the tensile test within soil was carried out, the test box was filled with sand to a certain height. The geosynthetic specimen was clamped by both ends of the clamps with fixed beam for tensile test, keeping the geosynthetic specimen of dimensions 400 by 200 mm (length by width). Continued filling the test box with sand until 15mm from the top opening of the test box, to accommodate the upper air bag reserved position. The flat head bolts were set to anchor box cover on the top of test box. After that, the air compressor was connected to the two air bags through the gas tubes to input air. When the total displacement was 20 mm or geosynthetics appeared fracture, the test termination. In the following analysis, the results of every tensile test were the average of the experimental group and parallel test group.

3.2 Analysis of tensile test results

The effects of the confining stress on the tensile properties of plastic geogrid, geomembrane and geonet were investigated by in-air tensile and tensile test within soils under the confining stress of 0 kPa, 25 kPa, 50 kPa, 100 kPa and 150 kPa. The test results of three types of the geosynthetics are shown below.

Figure 6shows the variation of tensile load of three types of the geosynthetics under different strains. The tensile load shows an overall increasing trend during the growth of strain from 0% to 10%. The variation of tensile load in air with the strain are obtained by the tests are shown in Figure 6a. With the strain from 0% to 10%, the tensile load value of plastic geogrid increases the most, while that of geonet increases the least. The geomembrane is between the plastic geogrid and geonet. Compared with the tensile load corresponding to the strain greater than 2%, the tensile load of plastic geogrid and geomembrane increases rapidly when

the strain is 0-2%, while the tensile load of geonet does not fluctuate greatly. It indicates that the tensile properties of plastic geogrid are better than those of the other two geosynthetics. Figure 6b shows the variation of tensile load of plastic geogrid in air and in soil (under confinement) with the strain. The tensile load of each curve increases with the increase of strain and has a maximum value at strain equal to 10%. It is found that the tensile load of plastic geogrid increases with the increase of confining stress by comparing the curves of tensile load in air and in soil. The maximum tensile load of 20.35 kN/m under the confining stress of 25 kPa, which is 40.15% higher than that in air. When the confining stress is 50 kPa, 100 kPa and 150 kPa, the maximum tensile load of the plastic geogrid is 74.66%, 120.18% and 156.34% greater than that in air, respectively. Figure 6c shows the variation of tensile load of geomembrane in air and in soil (under confinement) with the strain. The tensile load of each curve increases rapidly when the strain is 0%-2% and then tends to a stable value. The tensile load of geomembrane in soil increases with the increase of confining stress and is greater than that in air. The maximum tensile load of geomembrane is 5.19 kN/m in air and the maximum tensile load of 8.21 kN/m under the confining stress of 25 kPa, which is 58.19% greater than that in air. When the confining stress is 50 kPa, 100 kPa and 150 kPa, the maximum tensile load of geomembrane is 9.26 kN/m, 15.63 kN/m and 21.66 kN/m, respectively. Figure 6d shows the variation of tensile load of geonet in air and in soil (under confinement) with the strain. The tensile load of geonet in soil increases rapidly when the strain is 0%-2% and then tends to a stable value. The tensile load of geonet in soil increases with the increase of confining stress and the maximum tensile load of geonet is 5.84 kN/m under the confining stress of 25 kPa, which is 565.64% greater than that in air. When the confining stress is 50 kPa, 100 kPa and 150 kPa, the maximum tensile load of geonet is 52.22%, 37.80% and 68.57% higher than the previous stage, respectively. The tensile load of three geosynthetics in soil is greater than that in air, which indicates that the tensile properties of geosynthetics are improved under the confining stress.

FIG. 6 Tensile load of three types of geosynthetics under different strain: (a) in-air; (b) plastic geogrid; (c) geomembrane; (d) geonet.

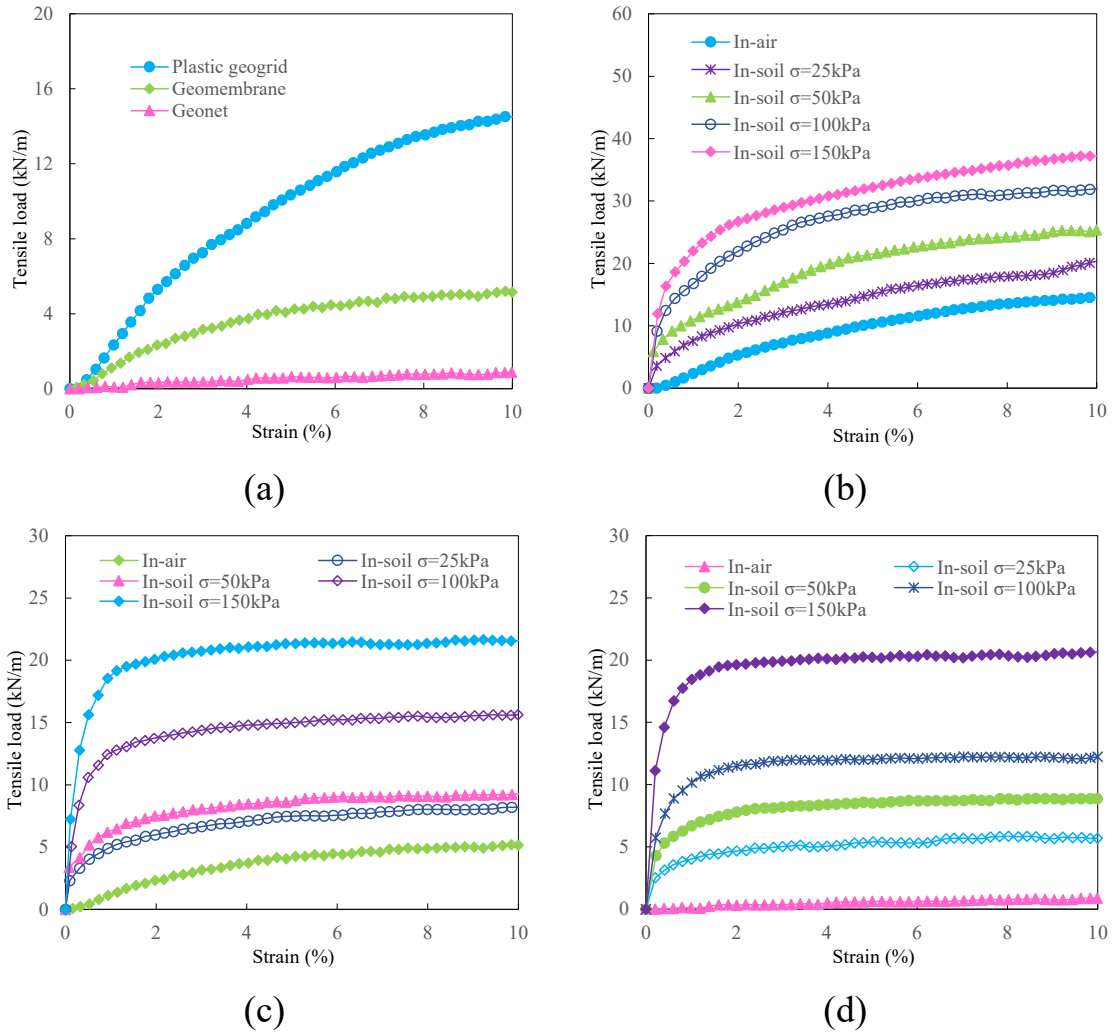


Figure 7 shows the variation of secant tensile stiffness of three types of the geosynthetics under different strains. The variation of secant tensile stiffness in air and in soil (under confinement) with the strain are obtained by the tests are shown in Figure 7a. The secant tensile stiffness of the plastic geogrid decreases rapidly with the increase of the strain when the strain is 0%-2%, and then gently decreases. The secant tensile stiffness of plastic geogrid increases with the increase of confining stress. When the confining stress is 0 kPa and 150 kPa, there is a minimum value of 146.79 kN/m and a maximum value of 2197.18 kN/m, respectively. Figure 7b shows the variation of secant tensile stiffness of geomembrane in air and in soil (under confinement) with the strain. The secant

tensile stiffness of geomembrane decreases rapidly with the increase of strain and increases with the increase of confining stress, especially when the strain is less than 4%. The maximum secant tensile stiffness of geomembrane is 1690.91 kN/m under the confining stress of 150 kPa when the strain is 1%. Figure 7c shows the variation of secant tensile stiffness of geonet in air and in soil (under confinement) with the strain. The maximum secant tensile stiffness of geonet is 1828.85 kN/m under the confining stress of 150 kPa when the strain is 1%. The secant tensile stiffness of geonet decreases rapidly with the increase of strain and increases with the increase of confining stress. The secant tensile stiffness of three geosynthetics in soil is greater than that in air, which indicates that the secant tensile stiffness of geosynthetics is improved under the confining stress.

It can be seen from Figure 6 and Figure 7 that the tensile load and secant tensile stiffness of geosynthetics under the confining stress are significantly greater than those in air without the confining stress, which indicates that the conventional air tensile test can not fully reflect the tensile properties of geosynthetics under the confining stress constraint in the treatment of karst collapse. Many studies have also shown that the tensile properties of geosynthetics under confining stress in real working conditions are significantly different from those in air. The tensile load and secant tensile stiffness of geosynthetics in soil are greater than those in air, which is mainly due to the constraint of confining stress and the interaction between reinforcement and soil interface. Geosynthetics deform under the action of tensile force and produce relative displacement with soil particles, so the interfacial friction of reinforced soil can increase the tensile properties of geosynthetics. For geosynthetics such as plastic geogrid and geonet, the passive resistance between geogrid and soil will be generated in addition to the interface friction of geogrid and soil under confining stress, which limits the displacement of plastic geogrid to increase their tensile load. In addition, the constraint effect of confining stress limits the displacement and neck shrinkage of geosynthetics, and makes soil embedded in

nonwoven materials and woven materials, increases the interfacial friction effect of reinforced soil, so as to improve the tensile load and secant tensile stiffness of geosynthetics.

FIG. 7 Secant tensile stiffness of three types of geosynthetics under different strain: (a) plastic geogrid; (b) geomembrane; (c) geonet.

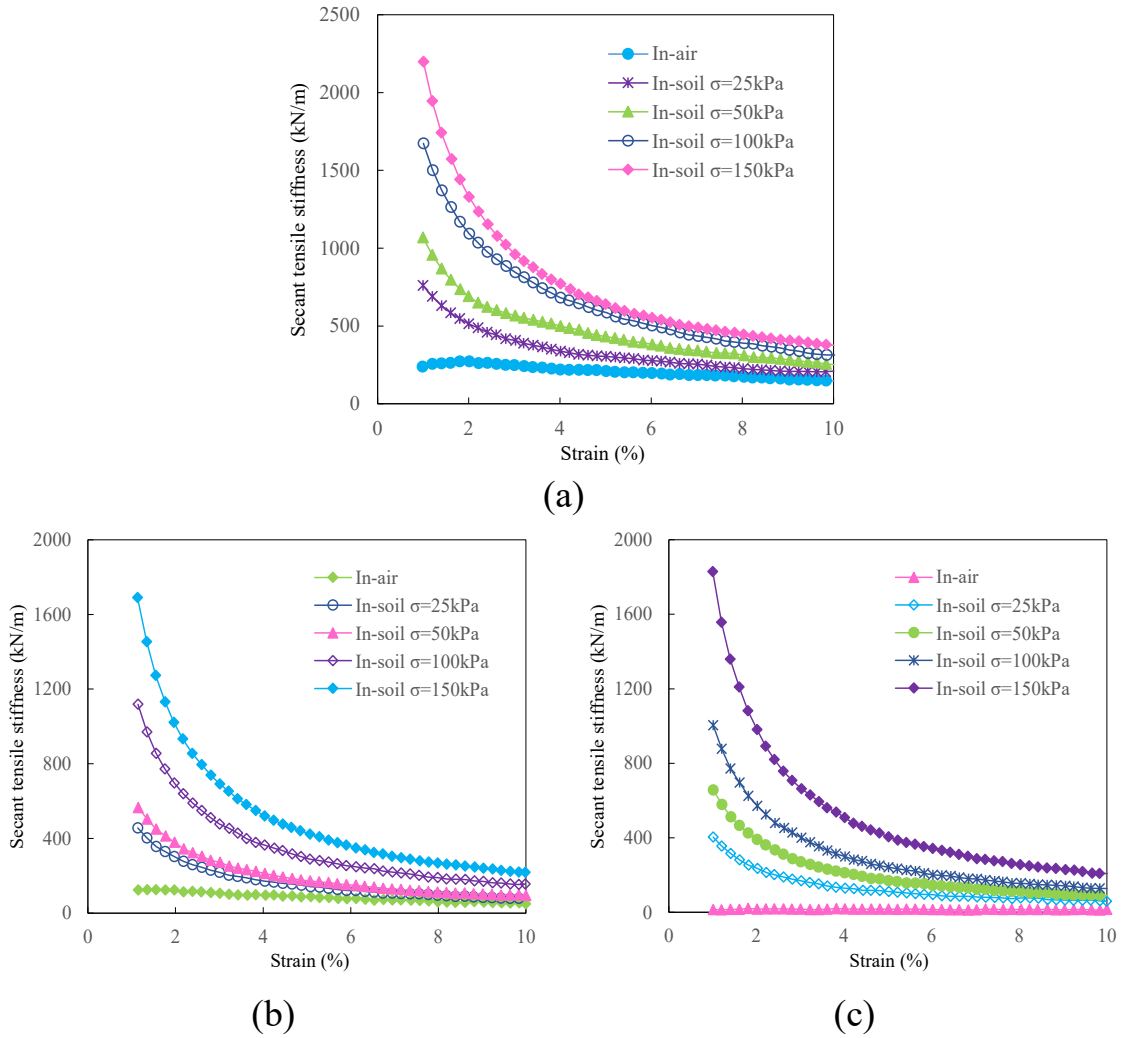
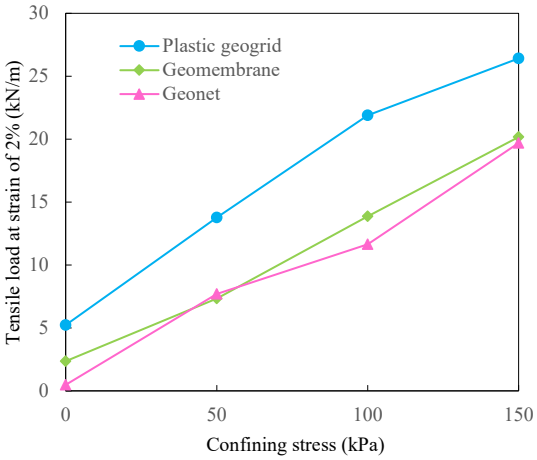


Figure 8 shows that the tensile load of three types of geosynthetics under different confining stresses at strain of 2%. The analysis of the tensile load at strain of 2% is based on the studies of [14,20] The tensile load at strain of 2% is usually used to study the properties of geosynthetics. For the plastic geogrid, the tensile load is 5.29 kN/m in air and the tensile load of 13.74 kN/m under the confining stress of 50 kPa, which is 159.74% greater than that in air. The tensile load of 21.91 kN/m under the confining stress of 100kPa is 59.46 % higher than

that under the confining stress of 50 kPa. Under the confining stress of 150 kPa, the tensile load of 26.71 kN/m is 21.91% greater than that under the confining stress of 100 kPa. The tensile load of the geomembrane in air is 2.32 kN/m when the strain of 2% and the tensile load of 7.50 kN/m under the confining stress of 50 kPa, which is 223.28% greater than that in air. When the confining stress is 100 kPa and 150 kPa, the tensile load increases by 83.07% and 46.25% compared with the previous stage, respectively. The tensile load of the geonet in air is 0.31 kN/m when the strain of 2% and the tensile load of 7.78 kN/m under the confining stress of 50 kPa, which is 2409.68% greater than that in air. When the confining stress is 100 kPa and 150 kPa, the tensile load increases by 47.94% and 70.63% compared with the previous stage, respectively. Under the confining stress of 150 kPa, the tensile load of the three geosynthetics reaches the maximum value, and reaches the minimum value in air without confining stress, which is consistent with the results of previous studies. [5,14] The tensile load of plastic geogrid is greater than that of geomembrane and geonet in air and soil, which indicates that the tensile property of plastic geogrid is better than that of the other two geosynthetics.

From the above, the new tensile test within soil apparatus can accurately test the tensile load of the three geosynthetics into testing tensile test within soil under the different confinement and tensile test in air, realize the intended functions and operate safely. During the operation of the new tensile test within soil apparatus, the sleeve move simultaneously with the clamp to ensure the tensile load of the specimen was accurately measured and the interaction between clamp and soil is eliminated.

FIG. 8 Tensile load of three types of geosynthetics under different confining stresses at strain of 2%.



4. Conclusion

To address the deficiencies of the currently existing tensile test apparatus, especially when used for geosynthetics, we develop a new tensile test within soil apparatus that can reflect the stress in the soil under the real working condition for geosynthetics. The loading clamps, movable sleeves, support frames, test box, normal surcharging system and data acquisition system are used of the proposed apparatus. The movable sleeve is designed to make the clamp move simultaneously with it is recommended to avoid possible existing the relative displacement between clamp and soil during testing while ensure apply uniform confining stress to the upper and lower soil in the test box. The design principles and structural arrangement in this new apparatus are ingenious, and the relative displacement of reinforced soil that is a common problem with the currently available apparatus is minimized. Subsequently, we test three types of geosynthetics with testing tensile test within soil under the different confinement and tensile test in air, total 45 tensile test for evaluate the tensile properties of the geosynthetics. Under confinement, the tensile properties of geosynthetics increase with the growing confinement, which are greater than tensile test in air. Performance of the conducted tests indicate that confinement is the major factor to improve tensile properties of geosynthetics. The data obtained from the tensile test within soil is closer to the real working conditions, which proves the new apparatus is more capable of and suitable for determining the tensile properties

of geosynthetics than other currently available apparatus, which provided an insight in the design of engineering practice.

Abbreviations

SP is the poorly graded sand

USCS is the unified soil classification system

MD is the machine direction

XMD is the cross machine direction

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Conflict of Interests

The authors have no potential or actual conflict of interests to declare with respect to the research, authorship, and publication of this article.

Data availability statement

Data will be made available on reasonable request.

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Competing interests

All the authors declare no competing interests.

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Data availability

The datasets used in the present study are not publicly available, but they are available from the corresponding author upon reasonable request.

Author contributions

D. W., Methodology, Visualization, Project administration. T. L., Data curation, Validation, Formal analysis, Writing—original draft preparation, Writing—review and editing. F. J., Methodology, Visualization. Y. Y., Methodology, Visualization. Q. P., Validation, Investigation, Supervision. J. W., Formal analysis; Investigation, Resources.