Testing Methods For Soil-Geosynthetic Frictional Behaviour - Japanese Standard

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ABSTRACT: The Geotextiles Standardization Committee, The Japanese Society of Soil Mechanics and Foundation Engineering, prepared a new draft of the Society's Norm JSF T 941: Determination of Soil–Geosynthetic Frictional Behaviour by Direct Shear and/or Pull–out Tests. This paper describes the testing procedures of measuring a frictional resistance of geosynthetic to soils compacted in a container. The tests are applicable to geosynthetics such as geowoven, geononwoven, geoknit, geonet, geogrid and geotextile–related products. The standard test methods consists of a direct shear friction test of determining the interface friction parameters, c_s and δ_s, and a pull–out test of determining the pull–out frictional parameters, c_p and δ_p, where c and δ components are an adhesion and an angle of friction, respectively.

1 INTRODUCTION

The test data of soil/geosynthetic interface friction obtained by a direct shear test or a pull–out test can be used in the design of geosynthetic–reinforced earthstructures. The total frictional resistance of geosynthetic embedded in soils may be a combination of sliding, rolling, interlocking of soil particles and geosynthetic surfaces and shear strain within the geosynthetic specimen. It should be noted that the frictional properties of a geosynthetic can be expressed only in terms of the soil material used in the testing and a relative movement between a geosynthetic and a supporting/overlaying soil. Therefore tests should be performed under site–specific soil conditions.

This paper describes the testing procedures of a direct shear friction test and a pull–out test. In general, the direct shear box test can be used for a geosynthetic that separate the soils with it such as geowoven, geononwoven and geoknit, and that develops a necking under a tensile force, such as geonet. The pull–out test is applicable to a geogrid through which most of super/substratum soils are continuously contact. Both tests should be conducted at a temperature of 20 ± 5℃ and a relative humidity of 50 ± 5 %.

2 DIRECT SHEAR FRICTION TEST

2.1 Apparatus

(1) Shear Box: The size should be sufficiently large enough by comparison with both the maximum soil particle size and opening size of geosynthetic tested. The examples of the shear boxes are shown in Fig.1. NOTE 1: A rectangular container is recommended for geogrid and geonet. Placing more than four ribs of specimen are required in the shearing direction. NOTE 2: For a large shear box (more than 10 cm in thickness), their side walls should be coated with a silicone grease and use a thin latex rubber membrane in order to reduce the wall friction. NOTE 3: A rigid dummy spacer such as a wooden block may be placed either in the upper or the lower shear box.

(2) Normal Stress Loading Device: It should be capable of applying a normal confining pressure up to 200 kPa.

(3) Shear Force Loading Device: It must be capable of applying a horizontal shear to the specimen at a constant rate of displacement, and of moving more than 15 % of the length or the diameter of shear box.

(4) Force Measuring Devices: They should have an accuracy of ±1 % of the maximum shear or normal forces.

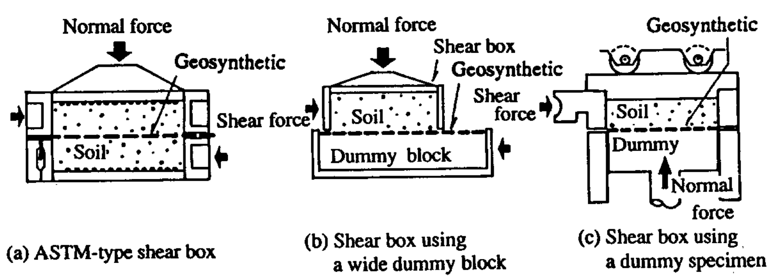


Fig.1 Examples of shear box

(5) Displacement Indicators: They must be capable of measuring normal and horizontal deformations of the specimen to accuracy of ± 0.1 mm.

(6) Compaction Rammer: A rammer with which a specimen compacted in a container.

(7) Multi-sieve Device: For testing dry sands, the device can be used in such a manner that the height of multi-layered sieves, of which the opening sizes are 3 to 5 times larger than the maximum grain size of soil, is controlled in order to produce the required density of the soil specimen.

2.2 Preparation of Test Specimens

(1) The maximum soil particle size must be less than 1/10 of the height of shear box.

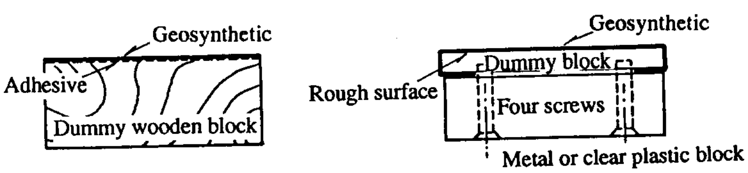
(2) The moisture content of the soil used in the test should be adjusted before compaction.

(3) A uniform soil specimen at the required density is prepared by a multi-sieving method for dry sands or by a rammer compaction method for other soils.

(4) Prepare a geosynthetic having a sufficient size to facilitate clamping and testing. For an anisotropic material, a minimum of five specimens shall be taken in each direction.

(5) When the geosynthetic is to be used in the wet or submerged conditions and moreover anticipated to be changed in its strength, size, surface texture and other properties, put the specimen in the wet atmosphere or soak it in water for a minimum of 24 h prior to testing. NOTE 4: For specimens tested in the saturated state, leave the wetted specimen for 15 min and then place it in a shearbox within 30 min.

(6) Assemble the shear device after compacting the soil and placing the geosynthetic in the testing box. NOTE 5: In the case of using a dummy block, gluing or clamping of the geosynthetic specimen to a dummy substratum is an acceptable technique. The examples are shown in Fig.2. It is required to maintain a sufficient friction so that coarse sands are adhered to the surface of block.



(a) Adhesion to wooden block (b) Fixing by four screws

Fig.2 Examples of fixing method of geosynthetic

2.3 Test Procedure

(1) Apply the normal compressive stress, σ_N, to the soil specimen.

(2) Record the normal displacement, ΔH, during the consolidation. NOTE 6: For coarse grained soils, the compression may be finished for 10 min. NOTE 7: Compression time can be estimated in such a manner that, after determining the most steep tangent line of ΔH – log t curve plotted in a semi-logarithm graph, the line is slidden in parallel 3 times on the time axis, and the compression time is given as the intercept of the line versus ΔH – log t curve.

(3) After the consolidation, the shear test is conducted using a constant rate of displacement. In the absence of any specification, Use a standard displacement rate of 1 mm/min.

(4) Record the shear friction force as a function of displacement and run the test until a residual shear measuring device shows a peak value, or until the shear displacement reaches 15 % of the length or diameter of shear box.

(5) At the end of the test, record the soil specimen to determine the moisture content.

(6) Repeat several tests at a different normal compressive stresses under new specimens.

2.4 Calculations

(1) Plot the test data as a graph of apparent shear stress calculated for each recorded shear force versus horizontal displacement.

(2) Plot applied normal stress, σ_N, versus shear frictional strength, τ_{smax}, for each test conducted.

(3) Connect the data points with a best fit straight line using the following equation, and determine the shear frictional parameters (c_s, δ_s) of the soil-geosynthetic interface.

$$\tau_{smax} = c_s + \sigma_N \tan \delta_s \quad [1]$$

where; c_s : adhesion (kPa), viz. τ -axis intercept of the shear stress vs. normal stress

δ_s : angle of friction (°)

3 PULL-OUT TEST

3.1 Apparatus

(1) Pull-out Test Apparatus: The size of the upper and lower boxes must be larger than 30 cm in width (B_B), 30 cm in length (L_B), 20 cm in total height. NOTE 8: A typical example of the apparatus is shown in Fig.3. For reducing the wall friction, the same procedure may be followed as described in 2.1 (1) NOTE 2.

(2) Normal Stress Loading Device: as directed in 2.1 (2). A rubber pressure bag is used as a standard loading device.

(3) Pull-out Device: It should be capable of moving about 20 % of the length of the box, at a constant rate of displacement. A standard displacement rate is 1 mm/min.

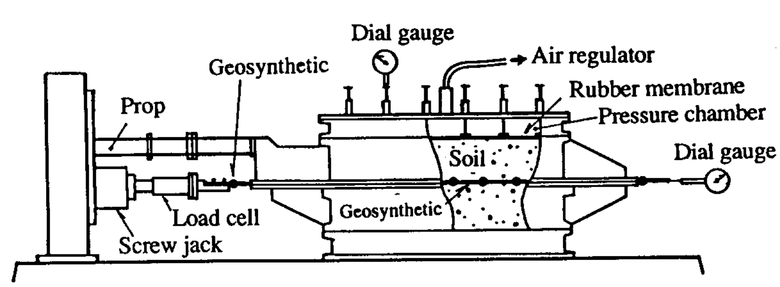


Fig.3 An example of pull-out test apparatus

(4) Clamping Device: It must be wide enough to hold the whole width of specimen, and capable of applying a uniform pull-out stress to a specimen without sliding or any damage.
(5) Pull-out Force Measuring Device: It should have an accuracy of ±1 % of the tensile breaking strength of geosynthetic used in the test.
(6) Displacement Indicators: as directed in 2.1 (5).
(7) Miscellaneous Equipments: Wires and guidetubes for measuring elongations of geosynthetic specimen. NOTE 9: friction between a wire and soils may be reduced using a guidetube. A stainless steel wire of about 0.2 mm in diameter and a thinflex or metal guidetube is recommended to be used.
(8) Compaction Rammer: as directed in 2.1 (6)
(9) Multi-sieve Device: as directed in 2.1 (7)

3.2 Preparation of Test Specimens

(1) A soil specimen is prepared in the similar way to the direct shear friction test as described in 2.2 (1) to (3).
(2) Prepare a geosynthetic specimen having a slightly short width than that of pull-out test box, and having in general at least 20 % longer length than that of test box. In the case of the apparatus in which the rear of a geosynthetic specimen is unable to be hung down in its outside, prepare a specimen having at least 1.2 times longer than the limit length of pull-out resistance mentioned in 3.4.2 (4). For an anisotropic material, a minimum of five specimens shall be taken in the same direction.
(3) When the geosynthetic is to be used in the wet or submerged conditions, a specimen is prepared in the similar way to that described in 2.2 (5).

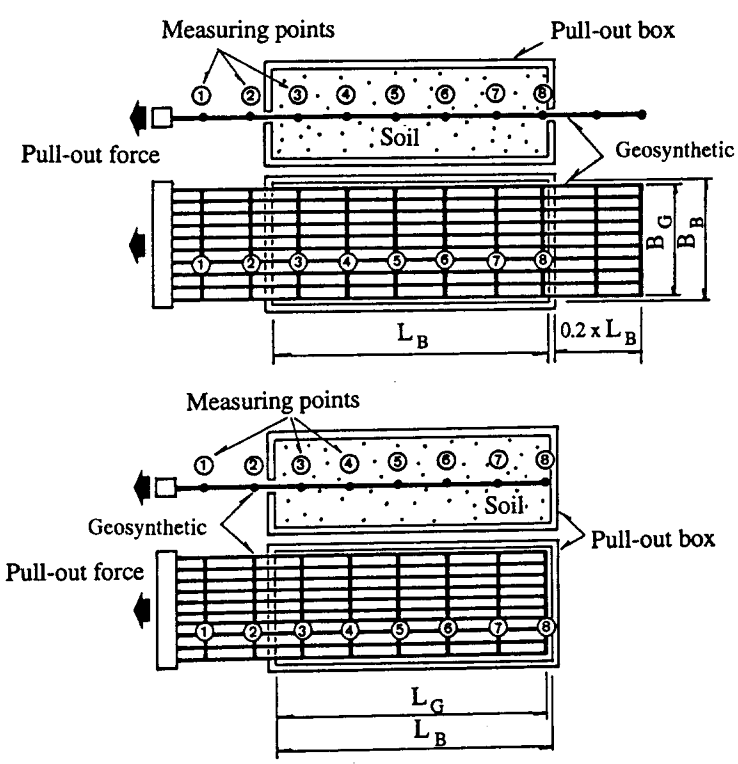


Fig.4 Examples of measuring points of displacement

(4) After compacting a soil in the lower box, a geosynthetic specimen shall be placed on the soil and connected to a clamping. A wire covered with a guidetube is tied at each position for measuring its elongation and drawn out towards its rear side. And then compact a soil in the upper box. NOTE 10: Five or six measuring positions are desirable to be selected at regular intervals within the box, and two points shall be selected at the front and the rear of specimen, respectively. An example of measuring the elongations is shown in Fig.4.

3.3 Test Procedure

(1) The consolidation process of the soil specimen is the same as directed in 2.3 (1) to (2).
(2) After the consolidation, a pull-out test is carried out at the constant rate of deformation.
(3) Record a pull-out force, F_T, and displacements, X_i, at each measuring point under a constant normal stress, σ_N. NOTE 11: A normal displacement shall be recorded during the test.
(4) The pull-out test should be conducted until the strain at the clamping reached to 20 % or until the break failure of the geosynthetic occurred.
(5) At the end of the test, record the soil specimen to determine the moisture content.
(6) Repeat tests at a different compressive stresses under more than four new specimens.

3.4 Calculations

(1) A pull-out force distribution in the box can be considered as shown in Fig.5 (a), where T_i' is a resistance force concentrated at lateral rib, i-point, and τ_{ij} is a friction of longitudinal rib between nodes. Therefore a resultant force at each node, $T_i = T_i' + \tau_{ij} \times$ node interval, can be determined as shown in Fig.5 (b). NOTE 12: For geosynthetics without nodes, any points selected arbitrarily can be supposed to be the nodes.
(2) The distributions of elongation, X_j, and strain, ε_{ij}, can be obtained from the measured displacements at each node, as shown in Figs.5 (c) and (d).
(3) As shown in Fig.5 (f), the tensile force, F_{ij}, corresponding to the strain, ε_{ij}, can be estimated from an index stress-strain curve shown in Fig.6 (e), which is obtained by its tensile test under no lateral confining pressure.
(4) A limit length of pull-out resistance, L_T, is given by the following equation.

$$L_T = F_U / 2 (c + \sigma_N \cdot \tan \phi) \qquad [2]$$

where; F_U : the breaking strength of geosynthetic (kPa)
c : apparent cohesion of the soil (kPa)
ϕ : angle of shear resistance of the soil (°)

NOTE 13: The relation between the limit length of pull-out resistance and the normal stress of Toyoura sand is shown in Fig.6.
(5) The effective length of pull-out resistance, L_E, and the maximum effective force of pull-out resistance, F_{TE}, are defined as follows;

a) In the case that the geosynthetic was entirely pulled-out with no breaking:

$L_E = L_B$ (the length of pull-out box)

$F_{TE} = F_{Tmax}$ (the maximum pull-out force)

b) In the case that the geosynthetic was pulled-out associated with breaking or that the elongation of geosynthetic reached almost 20 % of the pull-out box but no movement of the rear part of geosynthetic occurred:

$L_E = L_T$, $F_{TE} = F_{Tmax} - F_R$

where; F_R: The pull-out force generated at the rear outside of the limit length of pull-out resistance

NOTE 14: The methods a) and b) are called by the names of the total area method and the effective area method respectively. NOTE 15: An example calculating the maximum effective force of pull-out resistance, F_{TE}, is illustrated in Fig.7.

(6) The pull-out frictional strength, τ_{pmax}, is expressed by the following equation;

$$\tau_{pmax} = F_{TE} / (2 \cdot L_E) \quad \text{[3]}$$

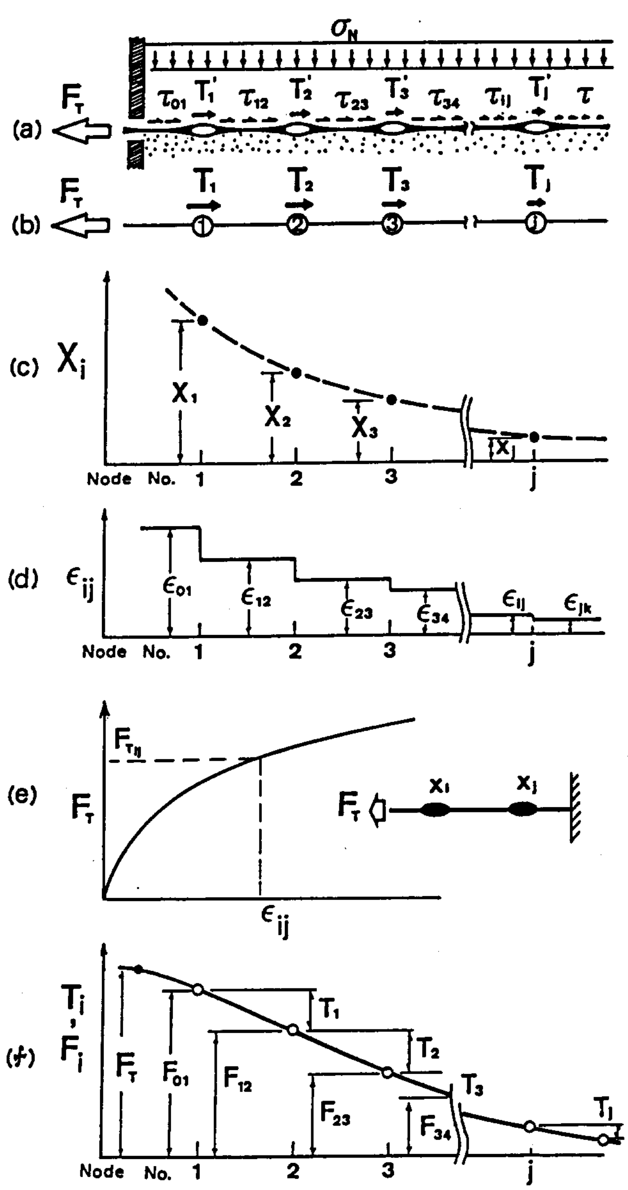


Fig.5 Procedures of pull-out test data analysis

(7) Using the relation of pull-out frictional strength and normal stress, The pull-out frictional parameters (c_p, δ_p) of geosynthetic in the soil are given as follows;

$$\tau_{pmax} = c_p + \sigma_N \cdot \tan \delta_p \quad \text{[4]}$$

where; c_p: τ -axis intercept in equ.[4] (kPa)

δ_p: angle of friction in equ.[4] (°)

NOTE 16: An example calculating the pull-out frictional parameters is shown in Fig.8.

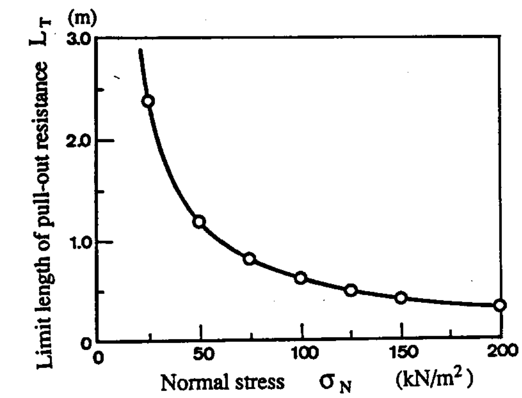


Fig.6 An example of limit length of pull-out resistance vs. normal stress

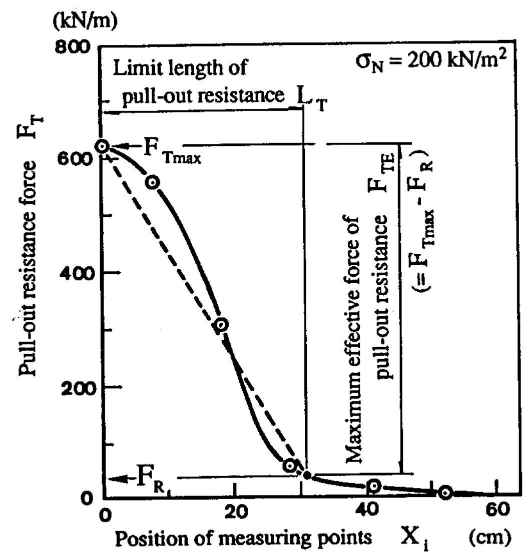


Fig.7 An example of determining maximum effective force of pull-out resistance

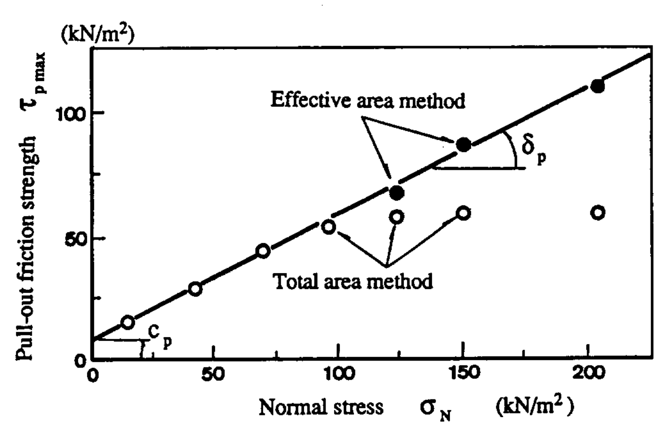


Fig.8 An example of determining pull-out frictional parameters