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INDEX AND PERFORMANCE TESTS FOR SOIL REINFORCING GEOSYNTHETICS

TEST DE INDEX ET DE PERFORMANCE POUR LE RENFORCEMENT DU TERRAIN AVEC LES GEOSYNTETIQUES

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Synopsis: The paper presents the main properties to be addressed by testing when designing a reinforced soil structure. Different test methods are presented as indication of the state of the art in Europe and USA.

INTRODUCTION

While geotextiles and geogrids are gaining more and more importance and acceptance all over the world, the tests to characterize those materials are still far from being known and accepted by their users.

New standardized testing procedures on geosynthetics are of primary importance to users, engineers, specifiers and final clients because standardized procedures will allow engineers to select the most performing material, the specifier to specify a suitable class of products, the contractor to select among technical alternatives and finally the clients to obtain both technical and economical benefits.

A whole new body of standards have been generated by different technical committees working mainly in U.S.A. and in the E.E.C..
In particular, for soil reinforcement applications, geosynthetics testing for index properties have been widely defined. Additional work is needed to define long term testing such as tensile creep, survivability tests such as installation damage test, the soil/geosynthetics interaction tests such as the direct shear and the pullout test. Finally, the more challenging task is the definition of the geosynthetic durability assessment tests for chemical, hydrolysis, soil burial, and weathering exposure resistance.

The gathering of the European Countries in a whole market, the EEC, has rushed CEN (European Standards Committee) and consequently ISO (International Standard Organization) to generate new standards and to study them with interlaboratory trials.

This paper deals with the analysis, the application in practice, the results of interlaboratory tests performed with these new proposed testing methods.

REQUIREMENTS FOR THE USE OF GEOTEXTILES AND GEOGRIDS FOR SOIL REINFORCEMENT

A geosynthetic performs as a reinforcement when it improves the mechanical stability of an earth structure through its tensile strength and physical interaction with the soil.
The main properties to be addressed by testing, when designing a geosynthetic reinforced soil structure, are shown in the Table 1.

Table 1. Principal properties and testing of geosynthetics for soil reinforcement

TENSILE STRENGTH
Wide width tensile strength
Long term tensile strength
Joint or seam tensile strength
Junctions strength
INSTALLATION SURVIVABILITY
Static Puncture Test
Dynamic Puncture Test
Installation Damage Test
SOIL/GEOSYNTHETIC INTERACTION
Direct Shear Test
Pullout Test
GEOSYNTHETIC DURABILITY
Chemical Degradation
Hydrolysis Resistance
Biological Resistance
Weathering Exposure Resistance
Thermal Oxidation
PERFORMANCE TEST
In Soil Creep Test
In Soil Tensile Test or Long Term Pullout Test

TENSILE STRENGTH TESTING

When considering tensile testing of polymer based materials like the geosynthetics, it is necessary to understand that they are all visco-elastic materials. Their load-strain performance is dependent on the ambient temperature, the duration of the applied load, the rate at which the load is applied.

The internationally adopted tensile test is the wide width tensile te: having specimen width of 200 mm and length of 100 mm, as shown

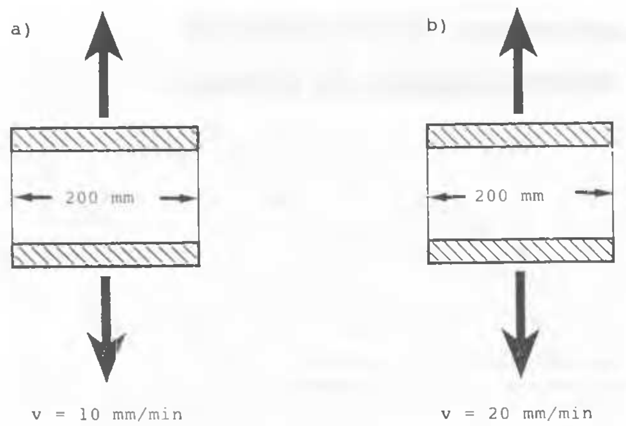

Fig. 1. a) ASTM D4595 wide width tensile test specimen dimensions and speed.
b) ISO and CEN wide width tensile test specimen dimensions and speed.

This 2:1 dimension ratio reduces the effects of high transverse strains (neck down), common in the narrow strip test methods. It is well accepted that the wide width tensile test produces results more closely related to anticipated stress/strain characteristics in the field. However this is only an index test since field conditions such as temperature, strain rate and tensile loading periods may be different considering a soil reinforced structure; moreover, the loading time may vary from significantly less than 1 second for road traffic, to months for construction time and consolidation of weak foundation and even up to 100 years for highway structures and retaining walls. As shown in Fig. 1 the strain shall be measured using extensometers, starting from a preload value (usually 1% of the peak force). This is to reduce the effects of slacks between the specimen and the testing device.
Particular care shall be taken while measuring the geosynthetic tensile modulus at low strain (2% and 5%).

Properties that shall always be considered, while designing a geosynthetic reinforced structure, are the strength of any joints or seams used to connect together different geosynthetic layers, and the strength of the structural junctions such as the geogrid nodes. The seaming of a geotextile shall withstand an allowable load greater than the anticipated stresses. The strength of a geogrid junction shall transfer to the tensile carrying members the bearing forces generated against the junction itself by the soil shear stress and passive pressure. If two geogrid layers are connected by overlapping (usually 0.3 m to 1.0 m of overlap is used), then such a connection shall be investigated by performing a pullout test to assess that the overlapping length is appropriate for the materials used (soil and geogrids).

Tensile testing can be divided in two categories:

- rapid tensile testing for designing dynamic and rapid periodic loading applications and for quality control testing.
- long term tensile testing to design reinforced soil structures subjected to constant loads during the overall service life.

Synthetic polymers used in geosynthetics are prone to creep, that is to increase elongation with the time under a constant tensile load: the geosynthetic can ultimately rupture at loads significantly less than the breaking strength recorded during a wide width tensile strength test.
There is no direct relationship between the long term characteristic strength of the polymer reinforcement and its short term strength. Thus the long term design strength shall be determined by the mean of a creep test in which a set of constant loads are applied at constant temperatures (usually 20°C, 30°C and 40°C) for a minimum period of 10,000 hours. A typical test arrangement is shown in Fig. 2. While the load and the temperature are maintained constant, the creep strain is recorded and plotted against the log of the elapsed time. Typical results are shown in Fig. 3.

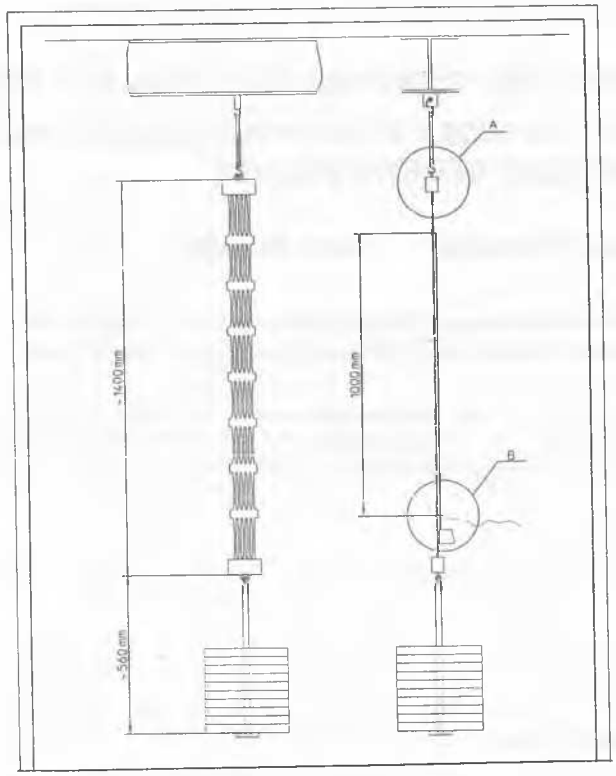

Fig. 2 Scheme of the tensile crep test. Details are shown in fig. 5 and fig. 6.

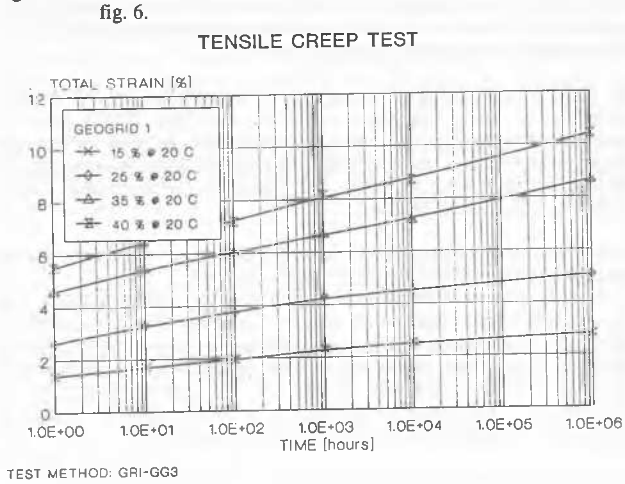

Fig. 3 Elongation-longtime curves for a geogrid.

The long term design strength may be obtained from a family of curves, by the mean of time-temperature shifting techniques or by extrapolating of maximum one order of magnitude. Fig. 4 shows the time-temperature superposition.
When testing a geosynthetic for creep properties, it is important that a proper specimen is selected. In fact, it has been shown, by many Authors, that testing the single fibers or single tensile elements that constitute a geotextile or a geogrid will give erroneous results with woven products, in particular, the creep behavior shall be determined on a specimen representing the overall structure because the results of testing single filaments will not consider any fibers rearrangement, any slack inside the products and any crimp usually experienced when a tensile load is applied to a woven structure.

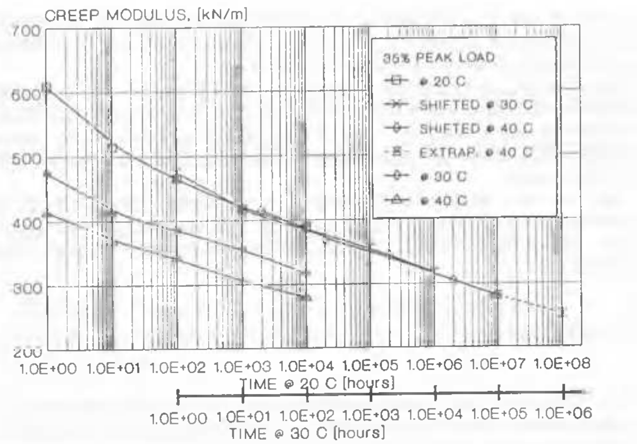

Fig. 4 Creep modulus versus time for geogrid at 20°C, 30°C and 40°C; and time-temperature superposition curve.

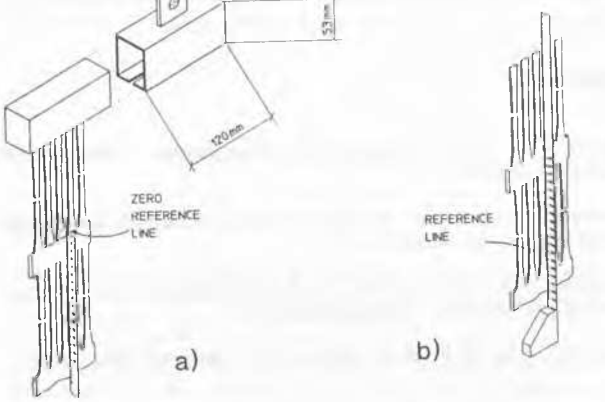

Fig. 5 a) Details for clamp for integral geogrids.
b) Elongation measurement system.

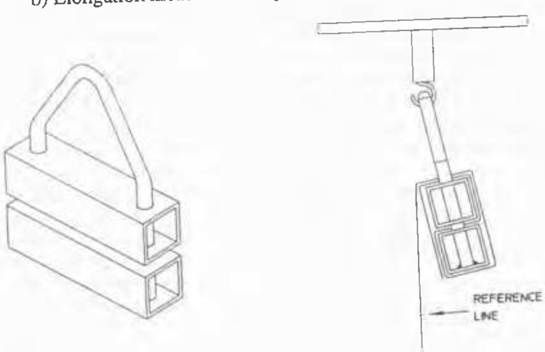

Fig. 6 Typical clamps for woven geogrid and geotextiles.

INSTALLATION SURVIVABILITY

Once the tensile properties of the materials have been determined in air, the effect of placing and compacting fill soil onto these products need to be assessed.
The effect of different types of fill (particularly the effects of different grading and angularity) needs to be assessed so that any damage caused by the normal construction process is taken into account in the assessment of the design strength to be used.
Typical damage situations are:

- heavy stones dropping over the geosynthetics causing localized heavy damages;
- angular stones pushed over the geosynthetic surface causing distributed fiber damages and abrasion;
- fill soil mechanically or dynamically compacted over the geostynthetic causing tearing, tensile stresses, and distributed damages.

The European committee for normalization (CEN) has developed three index tests to determine such damages.
The dynamic puncture test (cone drop test) consists of dropping an heavy cone (0.5 kg) over a tensioned geosynthetic (maximum opening size 10 mm) to determine its resistance to puncture by assessing the degree of cone penetration.
The static puncture test (CBR test) determines the force required to puncture a geosynthetic (maximum opening size 10 mm) by a flat ended plunger pushed through at constant speed.
The installation damage test simulates the effect of compaction by applying a series of repeated loading to a geosynthetic placed between two layers of angular soil. The scheme of this test is shown in Fig. 7.
The tensile properties of the damaged specimen are compared to the undamaged product characteristics to determine a construction damage factor to be used to reduce the strength while designing.

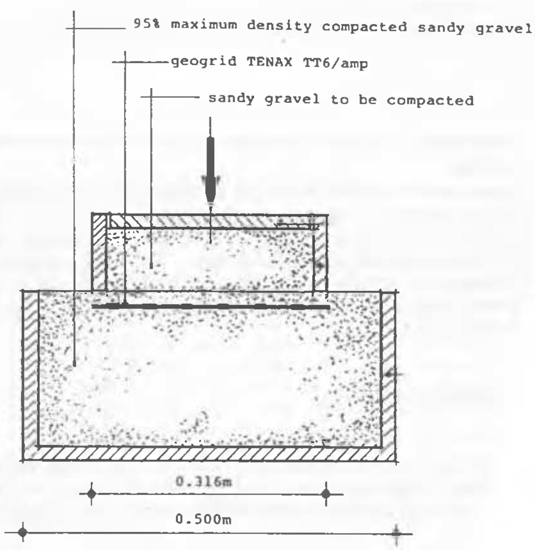

Fig. 7 Cross section of testing apparatus.

SOIL GEOSYNTHETIC INTERACTION

The essential difference between soil reinforcement inclusions and the dead-man-anchors-type inclusions lays in the location and the distribution of stress transfer: continuously along the inclusion for reinforcement, at the end of the inclusion for anchorage by passive pressure against the dead-man. While reinforcement improves the behavior of the soil and consequently the structure, anchorage improves the structure without improving the soil itself. Thus the ability of a product to receive and transfer stresses to the soil shall be investigated by the mean of an appropriate test. Stresses are transferred between soil and reinforcement by two mechanisms: friction and passive resistance.
Friction develops at location where there is a relative shear displacement and corresponding shear stress between soil and reinforcement surfaces. Passive resistance occurs through the development of bearing stresses on the transverse reinforcement bars.
The coefficient of friction is determined by a direct shear test method similar to the one used for testing of soils. This test is intended to produce even design data when the products are tested with the on-site soil and field conditions. The peak shear stress recorded is plotted against normal compressive stress for at least 3 different points. The slope of the

interpolating line is the coefficient of friction of the interface tested while the intercept is called adhesion.
The test equipment (see Fig. 8) is composed of a square or rectangular box having a minimum width and length of 300 mm and depth of 50 mm. The soil is placed in both containers and compacted as per project requirement. The traveling box is sheared at a constant rate and the shear force is recorded against displacement, while a normal compressive stress is applied to the overlying fixed container.
For retaining walls and reinforced slopes, it is worth to determine the pull-out resistance of the geosynthetic layer. Usually in a reinforced wall the active wedge will tension the geosynthetic layers that will prevent the block failure by anchoring into the passive block soil.

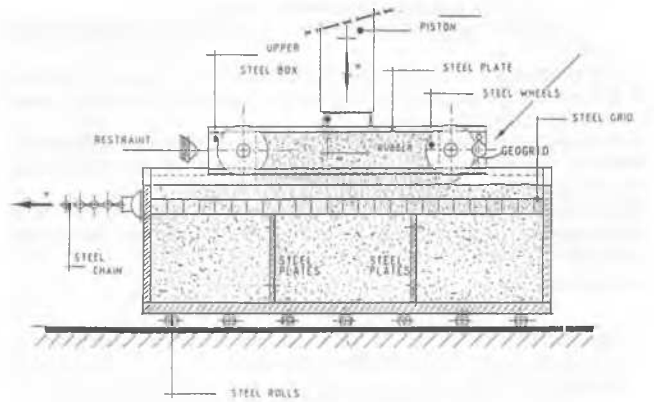

Fig. 8 Direct shear and pullout test apparatus prepared for direct shear testing.

The length of the pull-out resisting layers can be determined by the pull-out test. The soil/geosynthetic relative movement required to mobilize the design tensile force depends mainly upon the load transfer mechanism, the extensibility of the reinforcement and the soil type. The pull-out resistance of the reinforcement is defined by the ultimate tensile load required to generate outward sliding through the reinforced soil. A typical testing scheme is shown in Fig. 8.

GEOSYNTHETIC DURABILITY

The durability of a geosythetic exposed to the effects of a given environment shall be determined through appropriate testing. When the primary function is reinforcement the main degradation processes that shall be investigated are listed in table 2.

Table 2 Principal potential degradation processes are the following:

- hydrolysis may be a concern for polyester (PET) and polyamide (PA) geosynthetics exposed to high conditions of acidity and alkalinity;
- chemical degradation may be a concern for geosynthetics exposed to high concentrated chemicals liquids or organic solvents;
- micro-organisms attack may be a concern for polymer containing additives such as plasticizers, lubricants and to initiate possible deteriorative reactions;
- weathering exposure is a concern when the geosynthetic is permanently exposed during construction or during the structure service life;
- oxidation is a concern when the geosynthetic is permanently exposed to oxygenated environment leading to oxidation chain reaction.

The principal result of the degradation is loss of mechanical strength and elongation. Other changes may include loss of weight, loss of thickness, dimensional changes such as swelling or contraction.
The design engineer has to know the environment were the reinforced structure will be built and he shall consider the likelihood of the different degradation mechanisms. Generally it will be necessary to know the nature of the soil, the PH, the presence of calcium and metal ions, the temperature, the particle size distribution and particle angularity, the U.V. irradiation which the geosynthetic will have to withstand.
The durability properties are investigated by performing accelerated aging exposure tests that will predict the behavior of the material in actual use. Numerous accelerating test have been proposed and many will become testing standards as soon as their correlation with the in service conditions will be shown.
Test may be accelerated by increasing the testing temperature or by increasing the concentration of a chemical substance or, as in the case of U.V. exposure, by utilizing U.V. lamps irradiating an higher volume of ultra violet rays.

CONCLUSIONS

It is obvious that the failure mode considered in a particular test has to be characteristic of the material examined so that the results can be used for the prediction of the material's service life. It should always be borne in mind that a correlation established for a particular physical or mechanical property does not necessarily imply a valid correlation for another characteristic of the material or for all of them. The validity of the test method shall be considered from the experimental as well as from the theoretical point of view.

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