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A description of comparative test results designed to illustrate differences between laboratory and in-soil field conditions for geotextiles

F. De MEERLEER, N.V. TEXION, Consultants to LYS FABRICS S.A., Belgium.

ABSTRACT: Standard test procedures such as ISO EN and ASTM describe in detail how the properties of geosynthetics should be measured. Once values are obtained, they are used in equations for design purposes. The author considers the problem of how realistically do those tested values relate to the performance of the same geosynthetics when placed in real structures. This paper illustrates and compares some results of standard test procedures with results from non-standard tests aimed at simulating site conditions. The author provides guidelines intended to allow designers to anticipate the difference between laboratory test values and those that may be expected to apply under real conditions. Thus, designers may apply better judgment to the insertion of design parameters into design equations for real structures that are to be built on site.

1 INTRODUCTION

The author has become increasingly concerned at the clear discrepancy between laboratory testing conditions and the conditions to which geosynthetics are actually subject in the field during construction processes.

In the laboratory, perfectly clean, regular, temperature and humidity-controlled conditions apply quite rightly in the pursuit of homogeneous world-wide testing conditions. Without such standards, uniformity of results and comparison of test output would not be possible. Many eminent engineers give much valuable time to sitting on committees whose purpose is to rationalise and standardise in this way.

Having said that such standards are eminently desirable, the author believes that engineers may fall into the trap of failing to make the connection with - or better still, the extrapolation from laboratory conditions to those in the field.

It is difficult to know how to make such an extrapolation without considerable experience. The author tries, in this paper, to assist less experienced engineers to consider some of the relevant possibilities.

2 GENERAL LOGICAL CONSIDERATIONS

There are some logical conclusions that one can draw from the 'situational transfer' between clean laboratory and rough, dirty site conditions.

Firstly, it would be difficult to refute the proposal that the chemical conditions on site are certain to be more aggressive in virtually all cases, than the clean laboratory conditions in which tests are conducted. Consequently, one has to make allowance for deterioration of fabrics with time. The same applies to microbial and general biological deterioration. Such common-sense expectations are catered for in current limit-state design by the appropriate partial factor, as specified prescriptively in the imminent Eurocode 7 and as presently prescribed, for example in the British Standard BS8006 for the design of strengthened soils. It is not really practical to comment further on this logical consideration, since the chemical and biological deterioration of a geosynthetic is very site specific. However, as a first warning for consideration, it is highly unlikely that such phenomena develop in isolation; it is much more likely (from both the points of view of intuition and experience) that such deterioration will act in concert with and in relation to other factors such as site damage. In simple terms, this is the first consideration of the problems associated with laboratory testing. Such testing is invariably carried on in isolation. Therefore, no matter how good such tests might be, if they are not simultaneously simulating other relevant site conditions, then their results will be of doubtful meaning. Having assessed that this statement is true, one can logically follow on to the conclusion that whatever test results are produced, the actual field performance will not be as good.

For example, if a certain test were to be undertaken to assess long term biological degradation, but the product being tested was not partially damaged, or kept in a state of permanent stress during the test, then the outcome result might not be near the real in-situ field value experienced by the product.

Alternatively, consider the converse situation, where a damage test is being conducted. These are now frequently undertaken in clean laboratory conditions using statistically rough metal template sheets, or with such clean granular material as steel screw-threaded nuts. Such test conditions will clearly not reflect real site conditions and can thus only represent what has come to be called 'index' testing for relative comparisons and on-site quality checking. However, even if damage tests are undertaken in the field, it is all too easy for the engineer to forget the 'symbiotic' nature of the relationships between all on-going processes in the ground. In particular, the author has noted that engineers will commonly use the same partial safety factor against damage for both short and long term equations. Upon reflection, bearing in mind the author's comments above, the engineer may properly draw the conclusion that this is not correct. Indeed, since it is almost inevitable that chemical and biological deterioration will preferentially attack any damaged components rather than those undamaged parts of a geosynthetic, it is logical to deduce that a worse partial factor should be inserted into equations for damage in the long term, than that inserted for the short term.

The first lesson from these observations is that the engineer is not only fully entitled, but highly advised to take a pessimistic view of laboratory test results in principle. The well derived, standard test values given in literature should be viewed with caution in the light of the above observations. Long term partial factors should clearly be reduced in comparison with the short term ones to allow for the catalytic effect of one process upon another.

3 SOME LABORATORY OBSERVATIONS

In order to focus the point, the author has given consideration to two examples of tests with their hidden assumptions and their potential over-optimism.

3.1 *Variation in laboratory test results*

For the experimental work described in this paper, the author made use of a number of different laboratories in order to be able to comment upon the variability of outcome from them. This is another aspect that the engineer should bear in mind. Given the identical test on the same fabric, the author has found, in common with others, that test results can vary widely. It is well known, for example, that in soil mechanics, the Atterberg limit tests are particularly prone to variation depending upon the individual conducting them. It is also true of every test where individual hand placing of specimens into machines takes place. Also, where pre-tensioning and hand preparation are involved. In this work, the author found that there were variations in output from laboratory to laboratory. The details are not published here since this paper is not intended to be a laboratory critique, but nonetheless, the engineer can bear in mind that any laboratory test result might just - by chance laboratory choice - be a low one. Many organisations will use the same testing laboratory continuously without thinking about conducting comparative tests. The author therefore recommends any reader whose organisation continually uses the same test laboratory, to conduct a blind test comparison with at least three other similarly recognised laboratories, to ensure that they are not being consistently fed with a lower-than-average output on any particular test. The outcome of such a comparative test would not necessarily mean that the laboratory concerned should be abandoned, but again, judgment can be used by the designer if such variations are recognised.

3.2 *Tensile Strength and Elongation*

In the laboratory, perfectly aligned clamps are used to test perfectly flat, undamaged geosynthetics under near-perfect conditions. On site, conditions are substantially different from this idealised perfect situation. Geosynthetics are, in reality, installed on soil layers which are never perfectly flat, but contain undulations and stones. The gripping friction between geosynthetics and soil cannot be compared with the efficiency of laboratory clamps.

Test standards clearly describe the size of the samples to be tested both in length and width. This is a first consideration. It has been well tested and well recognised that sample size affects the outcome of tensile test results.

Myles and Carswell (1986), for example showed (Fig.1) from tensile tests on geotextiles up to 1 m wide - that a 200 mm wide woven sample underestimated a nonwoven sample by 20 % and overestimated the true tensile strength by 10 %.

This test output was most useful, although it again allowed itself the luxury of using the outcome concept as the 'true value'. Such wording can deceive the reader who is not critical. The true outcome was, in fact, that the Myles experiments showed clearly (and valuably) that the size and aspect ratio of an in-air tensile test sample - tested under the particular strain rate conditions of the test and with that particular test apparatus and clamps, etcetera, etcetera - influenced the outcome test result. The test result graphs can be seen to converge and this is an interesting feature, but it is not necessarily true that the converged position is the universally 'true' value of the tensile test of the products concerned. Only for that test.

In order to provide another perspective on the outcome of standard laboratory tests, the author undertook some tensile tests under standard conditions and with non-standard comparisons. Tests were conducted on the same woven and nonwoven geotextiles and were executed with different testing devices and clamps.

For comparison, an Instron 10 kN (capstan clamps) and a Zwick 250 kN (rectangular flat clamps) tensile machine were used to conduct a series of tests. Even given standard testing, it was interesting to note that the results of tensile strength and elongation changed not just with the size of the samples, but with the type of machine used.

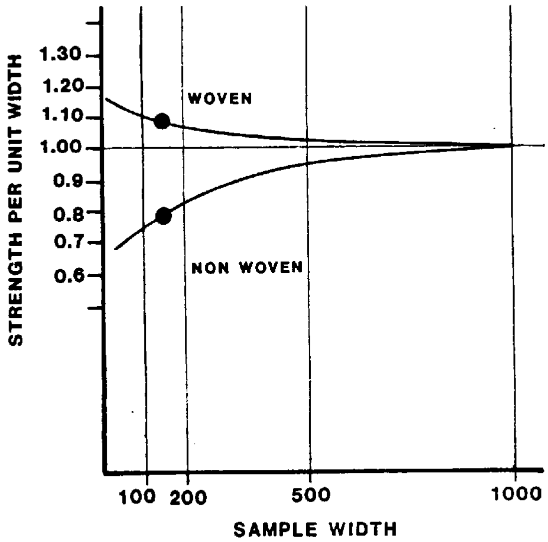

Figure 1. Comparative ultimate tensile strengths of woven and nonwoven geotextiles at different widths (Myles and Carswell 1986)

Before moving on to consider non-standard laboratory testing, it is important to assess what the implications of the above test results are. Myles, the author and others have all recognised that the size, shape and now, even the machine type have a marked influence on the in-air laboratory test result. It is necessary to think about this. Generally, it may be assessed that the effective size of the sample in the field will be very large and that across such a sample, stress conditions will necessarily vary. Thus the perfectly uniform laboratory conditions will not apply to in-situ stress conditions in the field.

Site conditions are situations of both variable and non-effective clamping of the geosynthetic. To make an approximate, very simple simulation of this, two strips (40 mm wide x 100 mm high) of nonwoven geotextile (40 kN/m and 600 g.s.m.) at distance of 40 mm were clamped. The equal pressure of the standard clamps now became an unequal pressure. Tests on woven and nonwoven geotextiles were executed and the measurements in average tensile strength and elongation were compared with the results from standard EN ISO test procedures. Fig. 2 shows the results from these tests. It is surprising to recognise that variability of up to +40% to -50% was experienced between the tests. Note in particular that it was not just one type of fabric that produced variable results. This kind of variability is something to be borne in mind when engineers are considering how these textiles might behave in the ground under stress.

		Terralys LF 16/16 01 PP Woven	Terralys LF 25/25 11 PP Woven	Terralys LF 80/80 01 PP Woven	Texipsun NW 15 PP Non-woven	Texispun NW 25 PP Non-woven	Texispun NW 40 PP Non-woven
Tensile strength MD (EN ISO 10319)	kN/m	16.74	31.59	80.34	17.68	32.50	43.61
Tensile strength CMD (EN ISO 10319)	kN/m	17.28	25.45	75.88	20.51	31.59	53.50
Elongation MD (EN ISO 10319)	%	24.76	14.98	19.25	81.17	69.95	73.76
Elongation CMD (EN ISO 10319)	%	26.00	15.73	13.63	74.55	77.52	67.09
Tensile strength MD irregular surface clamp	kN/m	12.80	21.09	57.88	15.50	28.94	38.84
Tensile strength CMD irregular surface clamp	kN/m	8.80	15.62	46.49	16.67	26.18	50.25
Elongation MD irregular surface clamp	%	25.08	14.41	17.13	79.02	98.91	80.89
Elongation CMD irregular surface clamp	%	24.14	15.29	13.02	73.95	81.72	72.88
Results tests simulated site conditions / Results tests under ISO EN conditions in %							
Tensile strength MD	kN/m	76.46	66.76	72.04	87.67	89.05	89.06
Tensile strength CMD	kN/m	50.93	61.38	61.27	81.28	82.87	93.93
Elongation MD	%	101.29	96.19	88.99	97.35	141.40	109.67
Elongation CMD	%	92.85	97.20	95.52	99.20	105.42	108.63
Difference in % between simulated site conditions and results tests under ISO EN							
Tensile strength MD	kN/m	-23.54	-33.24	-27.96	-12.33	-10.95	-10.94
Tensile strength CMD	kN/m	-49.07	-38.62	-38.73	-18.72	-17.13	-6.07
Elongation MD	%	1.29	-3.81	-11.01	-2.65	41.40	9.67
Elongation CMD	%	-7.15	-2.80	-4.48	-0.80	5.42	8.63

Figure 2. Test results for tensile properties between standard and non-standard tests and between wovens and nonwovens.

3.3 *Cross-plane permeability*

The author conducted a similar set of tests under comparative conditions, but for permeability. He found similar variability of results.

Under load, the stress/strain responses of geosynthetics follow a deformation curve which are similar to one another, but which are, in fact, unique for each product. As the deformation of a geosynthetic changes, so some of its properties will necessarily change. For example, when a geotextile is deformed, as in the case of being spread over stones and then covered in saturated sand, how do its permeability properties change? This needs investigation fundamentally, but for simple comparison purposes, the author conducted some tests with results shown below.

Woven and nonwoven geotextiles where submitted to a uniaxial stress equal to 25 % of their ultimate strength. When used in marine structures, for example, where the textile must perform a filtration function, this level of stress may often be generated. After this stress had generated its consequent deformation, the water permeability was measured. The comparison between the values measured without deformation and the values measured with deformation show significant differences.

Again, as in the case of the tensile test comparisons, it can be seen that the non-standard test procedure (intended to simulate more realistically, the on site conditions), produces different results from the standard test. Variations are of the order of +/-25%.

Also, under site conditions, a vertical load is commonly found, reducing the thickness of geosynthetics. The density of the yarns or fibres becomes higher thus reducing the water permeability and the pore size.

		Terralys LF 16/16 01 PP Woven	Terralys LF 25/25 11 PP Woven	Terralys LF 80/80 01 PP Woven	Texipsun NW 15 PP Nonwoven	Texispun NW 25 PP Nonwoven	Texispun NW 40 PP Nonwoven
Water permeability (EN ISO 11058)	m/sec	0.0261	0.0359	0.0082	0.0804	0.0496	0.0258
Water permeability deformation @ load 25 % of ultimate strength in MD	m/sec	0.0198	0.0352	0.0056	0.0693	0.0584	0.0279
Water permeability deformation @ load 25 % of ultimate strength in CMD	m/sec	0.0196	0.0377	0.0092	0.0771	0.0491	0.0297
Results tests simulated site conditions / Results tests under ISO EN conditions in %							
Water permeability deformation @ load 25 % of ultimate strength in MD	m/sec	75.86	98.05	68.29	86.19	117.74	108.14
Water permeability deformation @ load 25 % of ultimate strength in CMD	m/sec	75.10	105.01	112.20	95.90	98.99	115.12
Difference in % between simulated site conditions and results tests under ISO EN conditions							
Water permeability deformation @ load 25 % of ultimate strength in MD	m/sec	-24.14	-1.95	-31.71	-13.81	17.74	8.14
Water permeability deformation @ load 25 % of ultimate strength in CMD	m/sec	-24.90	5.01	12.20	-4.10	-1.01	15.12

Figure 3.. Test results for permeability properties between standard and non-standard tests and between wovens and nonwovens.

4 CONCLUSIONS

Tests to simulate more realistic on-site conditions have been undertaken. These were in-air tests looking at particular aspects. They gave results that are substantially different from those produced by standard laboratory tests. Further research is needed. Engineers should use this experience to increase partial safety factors as recommended in this paper - between 1.1 - 1.5. Test results indicate that stronger textiles are less susceptible to these variations than the weaker end of the range.

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