Tensile testing method and material variability effects in the tensile behavior of PET geogrids

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ABSTRACT: Geogrids are geosynthetic material with apertures that allow the interaction between two consecutive compacted soil layers. They are commonly used as soil reinforcement elements. As a result, their tensile behavior needs to be defined by means of standardized methods, which differ mainly in one aspect: the size of the specimen to be tested. Thus, single rib and wide-width tests are usually used to describe tensile behavior of geogrids. The objective of this research is to evaluate tensile behavior of five PVC-coated PET geogrids by means of both single rib and wide-width tensile tests. Additionally, material variability was assessed by comparing results from fifteen different lots of the same geogrid submitted to both tensile test methods. Single rib tensile tests resulted in higher values of both ultimate tensile strength and geogrid strain at break. However, the curves obtained from both methods have similar shapes. The tensile tests conducted with fifteen lots of the same geogrid showed that the number of lots tested does not influence the repeatability of the tests. Further information is necessary to clarify this issue concerning different geogrids.

1 INTRODUCTION

Geogrids are geosynthetic materials consisting of connected parallel set of tensile ribs with apertures of sufficient size to allow the interaction between both layers of compacted surrounding materials (e.g. soils and rocks) (Koerner, 2005). They are commonly used in geosynthetic reinforced soil (GRS) structures and may be manufactured from several different polymers, such as high density polyethylene (HDPE), polypropylene (PP), polyester (PET), polyvinyl chloride (PVC) and fiberglass. Moreover, geogrids strength fall between conventional geotextiles and those geotextiles specifically made for high-strength applications (Koerner, 2005). Thus, they may present high strength (20 – 1,000 kN/m) and low strain at break compared to non-woven geotextiles.

The key feature of geogrids is the presence of the large apertures, which vary from 10 to 100 mm. As mentioned above, geogrid apertures permit either the soil or rock to strike-through from one side of the geogrid to the other. Hence, due to geogrids matrix-like structure, there are two mechanisms of soil-geogrid interaction, friction along the ribs parallel to loading direction and passive strength in transverse ribs. As a result, both rib tensile and junction strengths need to be defined by means of standardized tests. However, since the soil within the apertures bears against the transverse ribs, which transmit the load to the longitudinal ribs via the junctions, the characterization of tensile strength of ribs parallel to load direction is highly important.

Currently, there are different methods to evaluate tensile strength of geogrids. Basically, they differ in the size of the specimen. Some methods prescribe specimen with only one rib being loaded; on the other hand, others standardize the specimen as a set of ribs. They are commonly referred as single rib and wide-width test methods, respectively. Obviously, there is a wide range in geogrid tensile response depending on the polymer, thickness, spacing of the ribs and so on. ASTM D 6637 standardized both methods for geogrid tensile testing.

Wide-width tensile tests are frequently used to define geogrid tensile behavior, since they are more reliable on representing geogrid field behavior. Nonetheless, due to geogrids high strength, such tests may require special equipments, e.g. special clamps and powerful testing machines. Additionally, Vertematti (2004) stated that both tensile test methods provide similar results. Hence, single rib tests are an alternative to wide-width tests, mainly when the analysis concerns a high-strength geogrid.

On the other hand, Hsieh and Lin (2004) concluded that wide-width tensile tests may result in different tensile behavior from those obtained by single rib tensile tests. Thus, which test method is more adequate to assess tensile strength of geogrid is still a concern for engineers.

Besides, it is also necessary to evaluate the influence of the material on geogrid tensile behavior. Accordingly, test results should be repeatable enough in order to allow reliable analyses.

Therefore, the objective of this paper is to present tensile testing data obtained from both tensile tests methods with five different PVC coated PET geogrids. In addition, the specimen variability of one geogrid is evaluated by means of tensile tests performed with fifteen different lots of this material.

2 MATERIALS AND METHODS

This paper focuses on a comparison of the difference in tensile behavior of geogrids due to the size of the specimen (single rib and wide-with specimens). Five different PVC-coated PET geogrids provided by two manufactures were submitted to tensile tests, according to ASTM D 6637. The tests were conducted at a strain rate of 10%/min of the gage length. The nominal ultimate tensile strengths and the number of ribs in both machine (MD) and cross-machine direction (XMD) for the whole set of geogrids are presented in Table 1. Despite only geogrid A is biaxial; geogrids A, D and E were tested in both machine and cross-machine directions. Moreover, fifteen lots of geogrid D were also submitted to single rib and wide-width tensile tests in order to evaluate material variability.

Table 1 – Nominal tensile properties of the geogrids used in the tests

Geogrid	Nominal tensile strength (kN/m)		Number of ribs of the wide-width specimen	
	MD	XMD	MD	XMD
A	29	29	5	6
B	100	20	7	6
C	120	30	6	3
D	200	30	6	3
E	370	25	7	5

Note: MD = machine direction; XMD = cross-machine direction.

Roller clamps were used to grip 1 m long specimens, which reduced geogrid damage during the tests. Consequently, two different external extensometers systems were used to determine displacements, which allow the calculation of geogrids strains. In part of the tests, displacements were measured by means of a laser system developed in the Laboratory of Geosynthetics of University of São Paulo, at São Carlos. The laser system follows two marks on the geogrid surface and provides their displacements. Thus, readings from both lasers are computed and the geogrid strain is registered during the whole test. Displacement readings of the second part of the tests were taken by means of a video extensometer, which immediately calculates geogrid strain. Both single rib and wide-width tensile test with each material were conducted with the same extensometer system.

The whole set of tensile tests were evaluated concerning its mean values and coefficient of variation (CV), which is defined as the mean value of a group of numbers divided by its standard deviation.

3 RESULTS AND DISCUSSION

Based upon the results obtained from both single rib and wide-width test programs, three different analyses were conducted. Firstly, the material variability was assessed by the tests performed with fifteen different lots of geogrid D. Then, the results from single rib and wide-width tests are compared concerning each geogrid. Finally, the whole set of materials were compared together in order to provide data for other types of PVC-coated PET geogrids. The whole set of results is presented in terms of load per rib. It helps the comparison between values obtained from both tensile test methods.

3.1 *Single rib and Wide-width tensile tests*

Single rib and wide-width tensile tests on five different geogrids were conducted in this research. The main results are presented in Table 2.

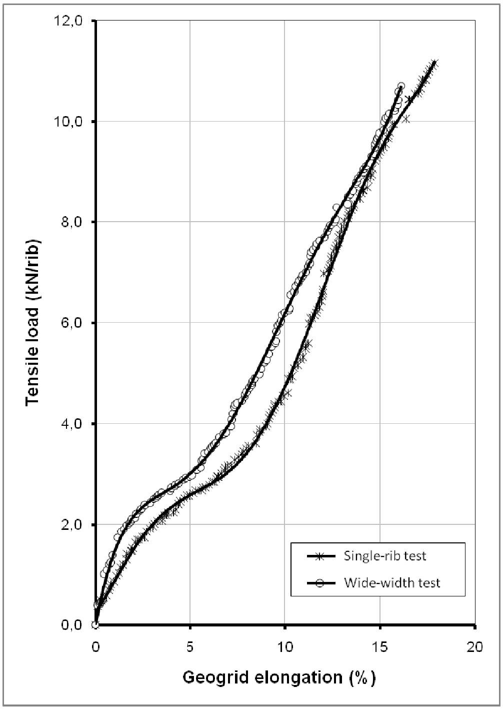
Table 2 – Single rib and wide-width tensile tests conducted on five different geogrids.

GG	Single rib tests				Wide-width tests			
	MD		XMD		MD		XMD	
	UTS	ε_b	UTS	ε_b	UTS	ε_b	UTS	ε_b
A	1,08	11,1	0,82	14,7	1,05	10,9	0,79	12,9
B	3,18	14,0	---	---	2,98	12,8	---	---
C	4,18	9,8	---	---	4,00	9,6	---	---
D	6,22	12,7	1,97	12,6	5,67	12,1	1,86	12,7
E	9,81	19,2	1,85	17,7	9,42	14,4	1,03	17,1

Note: GG = geogrid identification; MD = machine direction; XMD = cross-machine direction; UTS = ultimate tensile strength, kN/rib; ε_b = geogrid strain at break, %; Mean = mean value; Max. = maximum value; Min. = minimum value; SD = standard deviation; CV = coefficient of variation, %.

The main feature that can be noticed in Table 2 is that single ribs tensile tests resulted in greater values of both UTS and geogrid strain at break. Figure 1 presents two typical curves obtained from these tests. This behavior was observed in the whole set of tensile tests and agrees with the results presented by Hsieh and Lin (2004).

Figure 1 – Typical curves obtained from both single rib and wide-width tensile tests on geogrid E.



Geogrid A presented the closest results, where the differences between single rib and wide-width tensile tests in machine and cross-machine directions were 2.8% and 3.7%, respectively. Concerning all five geogrids, UTS from single rib tensile tests in machine direction were 5.1% greater than those from wide-width tensile tests, varying from 2.8% to 8.8%. In cross-machine direction, geogrid E presented UTS values 44.3% greater in single rib tests. Nevertheless it is not of concern since it is a uniaxial geogrid.

Similar behavior was noticed concerning geogrid strains at break. Although geogrid D presented higher values of strain at break in wide-width tests, in most cases single rib tensile tests resulted in greater values of strains at break.

Those greater values of UTS and geogrid strain at break from single rib tests are due to load concentration that may occur during the test. In wide-width tensile tests, one rib of the specimen may be overloaded while others are not close to their UTS values. After the break of one rib, there may be a redistribution of tension, which may evolve to the failure of the whole specimen. Therefore, wide-width tensile tests are more dependent on the test operator.

3.2 *Material variability*

Tensile tests performed with fifteen different lots of geogrid D are summarized in Table 3. As mentioned above, the coefficient of variation was used to evaluate how repeatable the results were. From Table 3, one can observe that both single rib and wide-width tensile tests provided reliable results concerning ultimate tensile strength (UTS), since CV values were up to 6.5%. On the other hand, it can be noticed that geogrid strains were not as repeatable as UTS. The coefficient of variation values of geogrid strains were up to 14.1%.

Table 3 – Tensile tests results performed with fifteen different lots of geogrid D.

Value	Single rib tests				Wide-width tests			
	MD		XMD		MD		XMD	
	UTS	ε_b	UTS	ε_b	UTS	ε_b	UTS	ε_b
Mean	6,22	12,7	1,97	12,6	5,67	12,1	1,86	12,7
Max.	6,71	15,2	2,08	15,1	6,70	15,1	1,98	14,7
Min.	5,70	8,8	1,66	10,5	5,07	9,7	1,59	11,0
SD	0,25	1,7	0,11	1,43	0,37	1,70	0,10	1,18
CV	4,0	13,8	5,6	11,3	6,5	14,1	5,4	9,3

Note: MD = machine direction; XMD = cross-machine direction; UTS = ultimate tensile strength (kN/rib); ε_b = geogrid strain at break (%); Mean = mean value of the whole set of tests; Max. = maximum value of the whole set of tests; Min. minimum value; SD = standard deviation; CV = coefficient of variation (%).

In addition to the fact that geogrid D lots showed such low variability, it is important to mention that the values of coefficient of variation of both UTS and geogrid strain at break obtained from the tests conducted with each lot are either higher or lower than the one for the whole set of fifteen tensile tests, considered as one single test. It means that, as expected, the increase in the number of lots is not directly related to the increase of the results variability.

4 CONCLUSION

This paper presented geogrid tensile test results conducted with two different methods: single rib and wide-width tests. These tests were performed in order to evaluate tensile behavior differences of five PVC-coated PET geogrids, provided by two different manufactures. Besides, material variability of geogrid D was assessed by means of tensile tests in fifteen different lots of this geogrid. The following conclusions are drawn from the present study:

- Single rib tensile tests provided UTS values about 5% greater than those obtained from wide-width tensile tests.
- Geogrid strains at break were also greater in single rib tensile tests.

- Both tensile test methods presented curves with similar shapes.
- The tensile tests performed with fifteen different lots of geogrid D were not influenced by the number of samples. It means that the number of lots is not directly related with the variability of both UTS and geogrid strain at break.
- Further studies are necessary to clarify this issue when a new geogrid is about to be commercialized.

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