TECHNICAL REPORT

Non-reinforcing hexagonal geogrid for the stabilization of unbound granular layers by way of interlock with the aggregate

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Foreword

EOTA Technical Reports were developed as supporting reference documents to European Technical Approval Guidelines (ETAG) and were applicable to a Common Understanding of Approval Procedures (Art 9 (2) Directive (EEC) No 89/106 – referred to as CPD), an EOTA Comprehension Document or an European Technical Approval issued under the Construction Products Directive 89/106/EEC (CPD), as far as reference was made therein. They are also developed under Regulation (EU) 305/2011.

EOTA Technical Reports go into detail in some aspects and express the common understanding of existing knowledge and experience of the Technical Assessment Bodies in EOTA at a particular point in time.

Where knowledge and experience is developing, especially through assessment work, such reports can be amended and supplemented. Amendments of EOTA Technical Reports supersedes the previous one.

When this happens, the effect of the changes upon the relevant European Assessment Documents such as "ETAG used as EAD" or "EAD" will be laid down in Comprehension documents, if appropriate, unless the assessment documents are revised as such.

This EOTA Technical Report has been elaborated by the EOTA WG "08 Geotextiles, Geomembranes and related products" convened by KIWA (www.kiwa.nl) to define testing procedures in support of the EAD 080002-00-0102 - **Non-reinforcing hexagonal geogrid for the stabilization of unbound granular layers by way of interlock with the aggregate.** Technical Reports are adopted by the EOTA Technical Board.

A Function of stabilization - description and definitions

A.1 Introduction

Paved and/or unpaved roads, railways and hard-standings consist of multiple layers of bound and unbound materials such as concrete, asphalt and granular materials.

The granular layers are at rest and experience only the relatively insignificant load from the weight of the layers on top. It is only when construction or in-service traffic passes (vehicles, trains, etc.), that these layers are under transient increased pressure and the associated strain that forms part of the instantaneous response.

During the short period of time associated with the passing of the transient load, granular layers undergo stress with both vertical and horizontal components, where the associated horizontal strains have a radial distribution, (see Figure A1, showing the distribution of the traffic load in all directions of the granular layer). The horizontal components of stress will cause the particles in the layer to move laterally and after the wheel has passed they will not recover completely to the condition before the load was applied. It is this cumulative lateral movement that will cause deformation and will eventually result in a condition beyond serviceability of the layers.

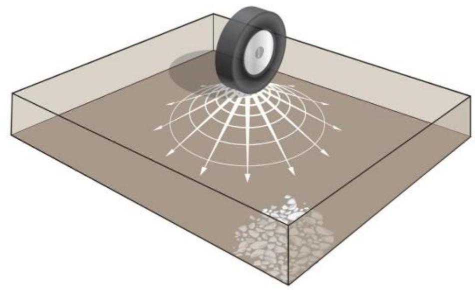

Figure A1
Radial distribution of traffic load

The stabilization function addresses this lateral movement and inhibits the accumulation of strain, hence affecting the design life of the granular layer beneficially.

A.2 Definitions

All definitions are to be read in the context of this technical report and associated ETA.

A.2.1 Interlock

Interlock is defined as the mechanism by which the geogrid and the aggregate interact under applied load. (During the placement and compaction of a granular layer over a geogrid, the aggregate particles partially penetrate into the apertures and abut against the ribs of the geogrid.)

A.2.2 Confinement

Confinement is defined as the effect of the mechanism of Interlock by which the structure of the geogrid restrains the aggregate particles.

A.2.3 Stabilization

Stabilization is defined as the beneficial consequence on the serviceability of an unbound granular layer via the inhibition of the movement of the particles of that layer under applied load. This is the result of the mechanical effect of Confinement on an aggregate layer, resulting from the mechanism of Interlock provided by a stiff geogrid structure.

A.3 The function of stabilization provided by the geogrid

The function of stabilization is provided by the interlocking of the aggregate with the geogrid and subsequent confinement of the particles and addresses the issues described in A.1 above.

An additional effect of stabilization and the aggregate confinement is the increase in modulus of the granular layer and its associated enhanced resilience, trafficking performance and load bearing capacity.

B. 1 Determination of radial secant stiffness through wide width tensile testing

B. 1.1 Principle

The method described in this paragraph has been developed on the basis of EN ISO 10319 to determine the secant stiffness at low strain values and describes only the differences to this standard.
This testing procedure determines the tensile properties in defined radial directions of the plane of the geogrid. EN ISO 10319 is written predominantly for orthogonal geogrids where the major tensile properties are only determined in the machine direction and the cross machine direction.

B.1.2 Apparatus

B.1.2.1 Tensile Testing Machine

In addition to EN ISO 10319 clause 5.1 the following requirements for clamps/jaws are prescribed.

Jaws shall be a variation of the 'compressive block jaw' type, with the clamping effort supplied by hydraulic pressure. The actual hydraulic pressure used will be dependent on the cumulative effective area of the clamping cylinders, but it shall be sufficient that no slippage occurs, without the pressure being set so high that the geogrid is damaged resulting in premature failure. See the example in figure 1. Jaw clamping faces are nominally of size 300mm x 75mm.

Figure 1- Hydraulic jaw design suitable for wide-width testing polymer geogrids

B.1.2.2 Extensometer

In deviation to the standard EN ISO 10319, clause 5.2, the use of an extensometer is not necessary, due to the rigid nature of structured polymer geogrid. To measure strain crosshead displacement / travel can be used.

B.1.3 Test Specimens

B.1.3.1 Number of test specimens

In deviation to EN ISO 10319, clause 6.1 the properties cannot be accurately represented by testing purely in the machine direction (0˚) and cross machine direction (90˚).
For this geogrid, the two principle testing directions are ‘mid rib’ direction and ‘rib’ direction. Testing is therefore required in four directions, namely the two ‘mid rib’ directions (0˚ and 60˚) and the two ‘rib’ directions (30˚ and 90˚). See figure 2.

In each direction, a minimum of 3 specimens should be cut, giving a minimum total of twelve test specimen for a single sample of the geogrid.

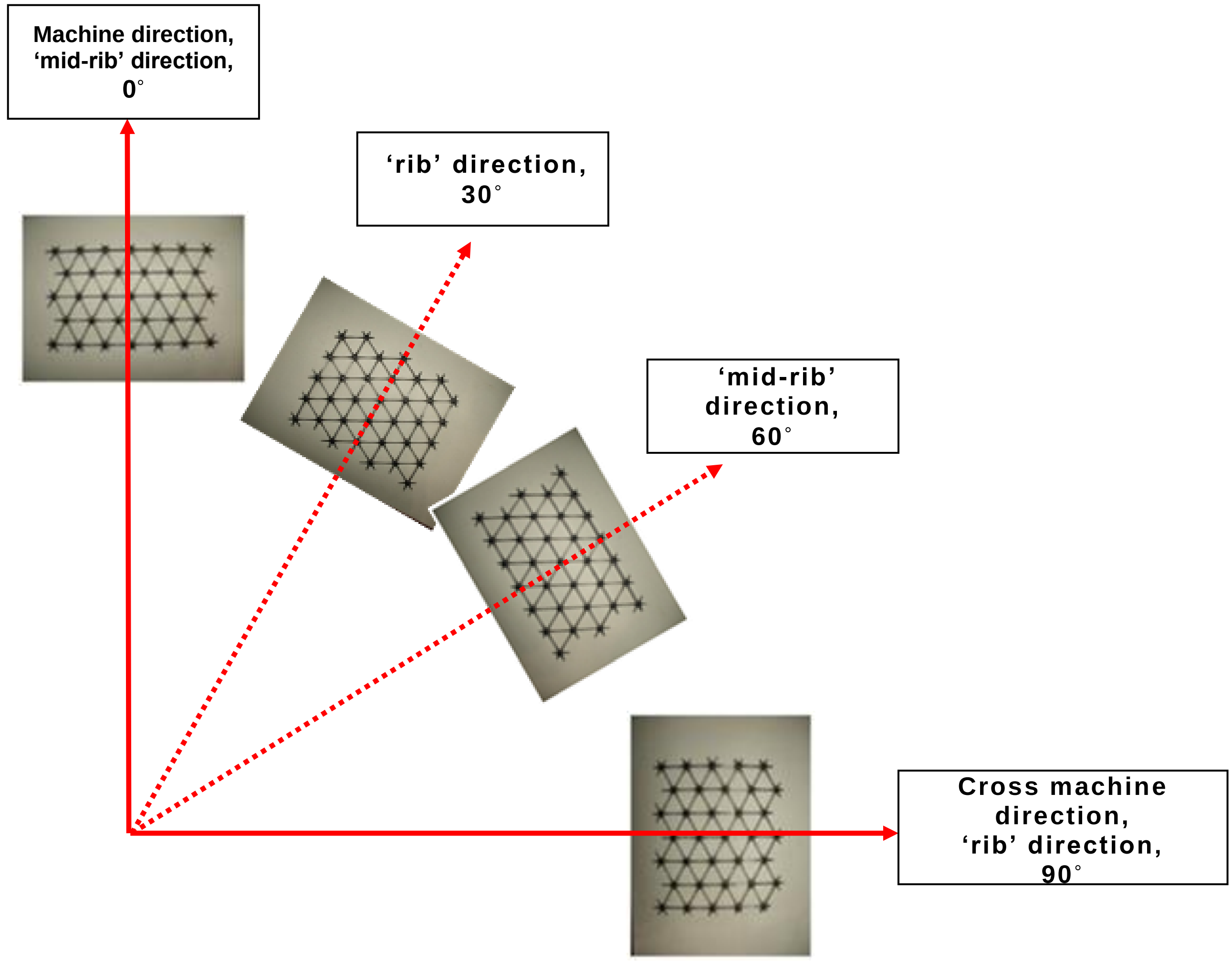

Figure 2- Schematic of testing directions

B.1.3.2 Dimensions

There are several 'Product Series' of isotropic non-reinforcing hexagonal geogrid, each series having different aperture sizes. This requires different specimen sizes. All the test specimen widths comply with the EN ISO 10319, clause 6.3.3 requirement that for geogrids the specimen width shall be a minimum width of 200mm.

The specimen sizes have been determined to maintain symmetry about the centre point and balance in the tensile forces during testing.

For the three different product series certified the nominal dimensions of the 'mid-rib' and 'rib' direction specimens are included in the figures 3 below.

NOTE: the nominal effective width chosen for each series of products (66mm A/F, 80mm A/F, 120mm A/F repeating hexagon) is judged to be the best approximation of the activated tensile elements in the specimen sizes chosen. For each series the specimen sizes and dimensions shall match those shown in Fig. 3.1, 3.2 and 3.3, in terms of repeating geometrical elements as those sizes and dimensions form the basis for the performance declared by the manufacturer.

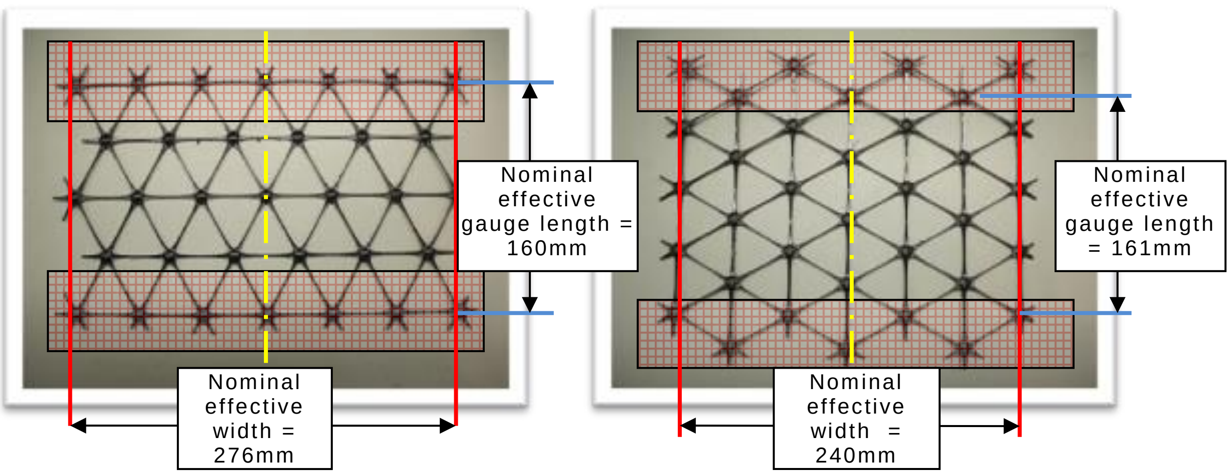

Figure 3,1 – example series nominal 80mm A/F repeating hexagon

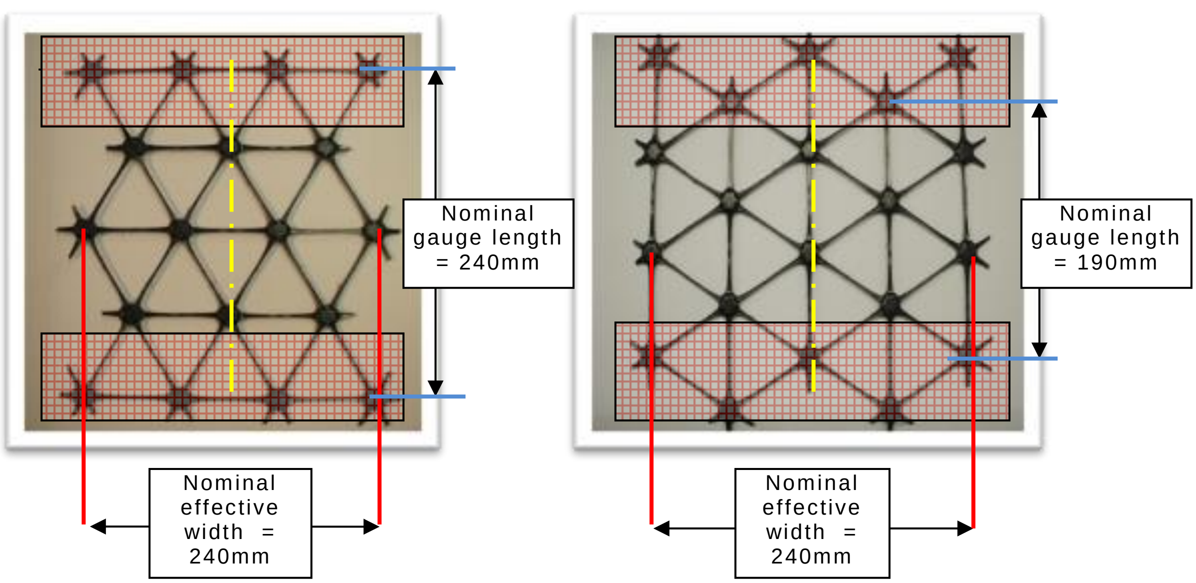

Figure 3.2 – example series nominal 120mm A/F repeating hexagon

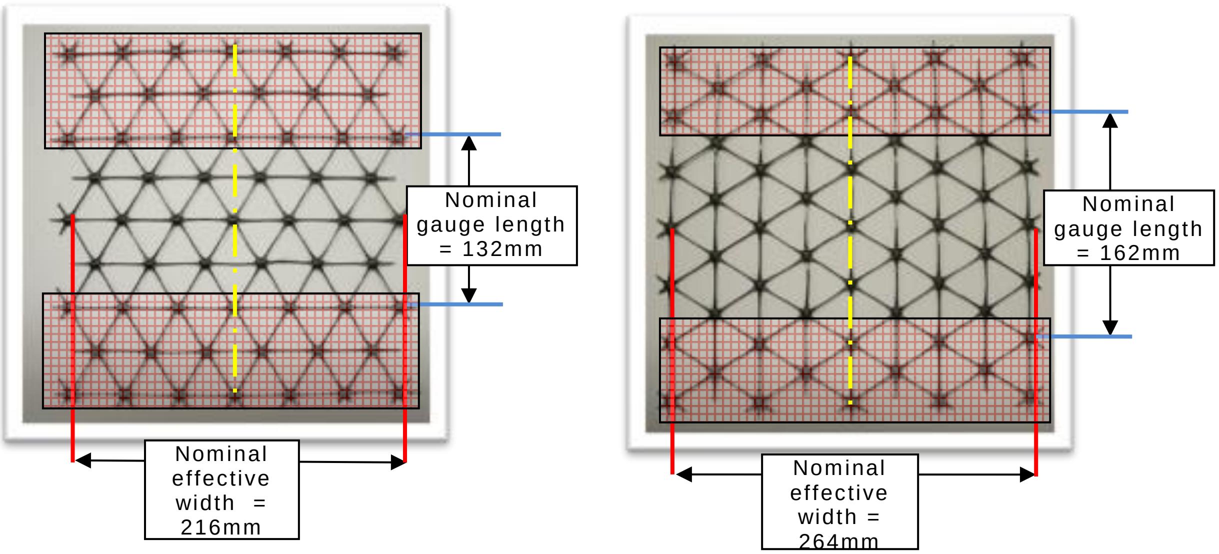

Figure 3.3 – example series nominal 66mm A/F repeating hexagon

B.1.4 Calculations

B.1.4.1 Radial Secant Stiffness

As detailed in EN ISO 10319, clause 9.3, the secant stiffness, j, expressed in kilonewtons per metre (kN/m) in each direction per test specimen at a defined strain shall be calculated using the equation

$$\boldsymbol{j} = \frac{\boldsymbol{F} \times (\mathbf{1}/\boldsymbol{B}) \times \mathbf{100}}{\boldsymbol{\varepsilon}}$$

Where

$\boldsymbol{F}$ is the determined load at strain, ε, in kilonewtons (kN)

$\boldsymbol{B}$ is the actual effective width of the specimen, in metres

$\boldsymbol{\varepsilon}$ is the specified strain, in percent

Note: Although a specified strain level of 0.5% is shown in the following examples of the calculations, these calculations can also be performed at a specified strain level of 2% if the secant stiffness is being checked for the purpose of identifying the product during installation in a construction works

In addition to EN ISO 10319, clause 9.3, the mean radial secant stiffness at a defined strain for a sample shall be calculated as the arithmetic mean of the secant stiffness in the four test directions, using the equation

$$\sum\left(j_{0^\circ@0.5\%}, j_{30^\circ@0.5\%}, j_{60^\circ@0.5\%}, j_{90^\circ@0.5\%}\right)/4 = Mean\ radial\ secant\ stiffness\ (\bar{x}RSS)$$

$j_{n^\circ@0.5\%}$ is the mean secant stiffness of the three test specimens in each defined direction of test at the specified strain level Ɛ (in %).

In addition to EN ISO 10319, clause 9.3, the radial secant stiffness ratio at 0.5% strain for a sample shall be calculated as the quotient of the minimum and maximum stiffness's at 0.5% strain of the four test directions, using the equation

$$min\left(j_{0^\circ@0.5\%}, j_{30^\circ@0.5\%}, j_{60^\circ@0.5\%}, j_{90^\circ@0.5\%}\right) \Big/ \max\left(j_{0^\circ@0.5\%}, j_{30^\circ@0.5\%}, j_{60^\circ@0.5\%}, j_{90^\circ@0.5\%}\right) = Radial\ Secant\ Stiffness\ ratio\ (:RSS)$$

$j_{n^\circ@0.5\%}$ is the mean secant stiffness of the three test specimens in each defined direction of test at 0.5% strain.

Figure 2 above and figure 4 below, give clear indication of the various directions of test.

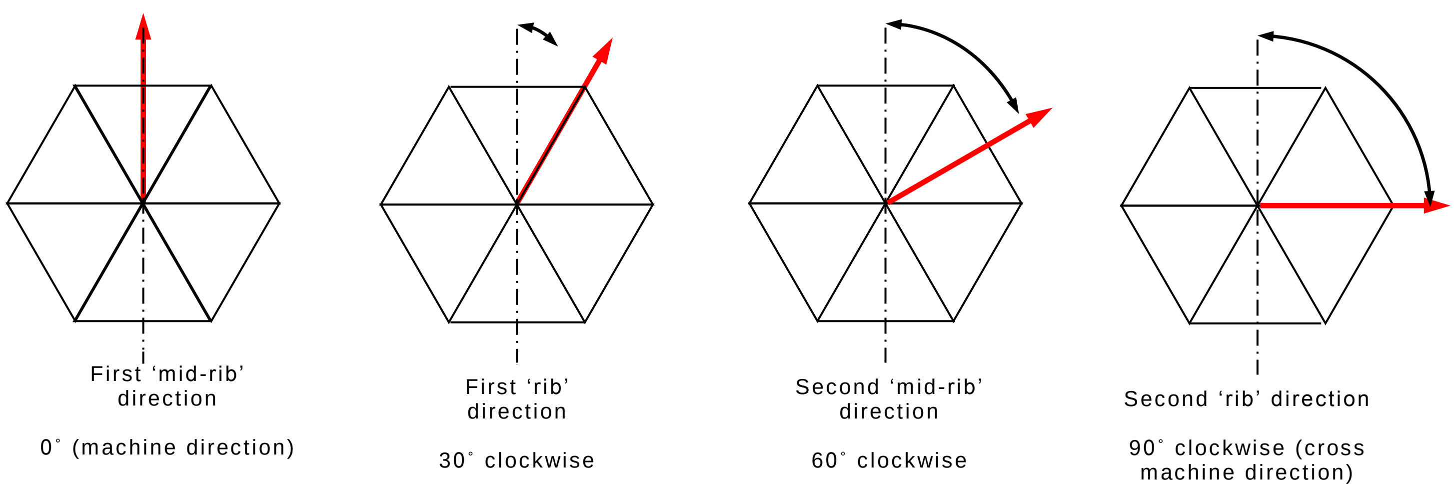

Figure 4 – Four directions of test (2x 'mid-rib' and 2x 'rib' directions)

B.1.5 Test Report

In deviation to EN ISO 10319, clause 10 the test report shall include as a minimum the following information.

1. Reference to this test procedure

2. All relevant data for complete identification of the test specimen
3. The radial secant stiffness at 0.5% strain in each test direction
4. The mean radial secant stiffness at 0.5% strain
5. The radial secant stiffness ratio (at 0.5% strain)
6. The mean radial secant stiffness at 2% strain

1.6 Normative References

EN ISO 10319:2008 – Geosynthetics Wide-width Tensile Test

B.2 Determination of junction efficiency

B.2.1 Principle

This test method describes the determination of the junction efficiency of the geogrid.

To calculate the load transfer efficiency of the geogrid, both the ultimate load of a single rib and a single junction are determined. The junction efficiency is the ratio of the ultimate load sustained by the junction to the single rib ultimate load and is expressed as a percentage. Both the average ‘single rib strength’ and the average ‘junction strength’ of the geogrid are determined.

For the determination of the ´single rib strength´ the test specimen is clamped on two nodes. For the ‘junction strength’ the ribs on each side of a junction are clamped and load is applied to the free rib coming from that junction. In both cases the test is executed until failure. Refer to Figure 6 below for clarity.

B.2.2 Definitions

B.2.2.1 Junction (or node)

A junction or node is the interconnection of 6 ribs. Reference figure 8

B.2.2.2 Rib

A rib is the tensile element that connects two nodes or junctions. Reference figure 8

B.2.2.3 Junction efficiency

Junction efficiency indicates the ability of the geogrid to transfer loads from one rib to the other ribs connected to that junction in a different direction.

B.2.3 Apparatus

B.2.3.1 Tensile Testing Machine

B.2.3.1.1 Tensile test machine - The tensile testing machine should comply with ISO7500-1, Class 2 or higher and shall be capable of operating under a constant rate of extension and shall be capable of measuring tensile force using a load cell of adequate load capacity and resolution.

B.2.3.1.2 Test clamps – Shall be capable of gripping the specimen with appropriate clamping force to prevent slippage and/or crushing.

A typical set of hydraulic clamps for a ‘single rib strength’ test are shown in Figure 5 below. Jaw clamping faces are nominally of size 50mm x 50mm.

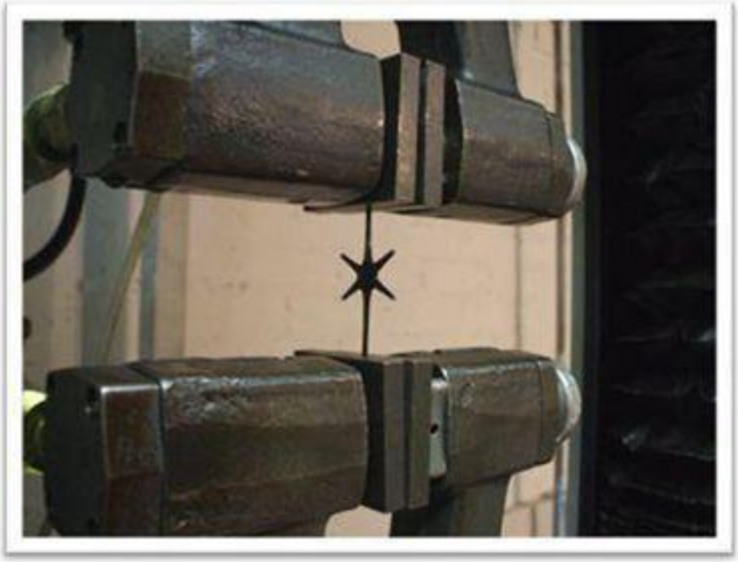

Figure 5- typical example of ‘Single rib strength’ test hydraulic clamps

The jaws associated with the ‘junction strength’ test are shown in figure 6 below.

The upper junction clamp (Figure 6a & 6b) shall be able to clamp the ribs on either side of the junction transversely without influencing the junction itself. The two movable restraining clamps shall be capable of adjustment so that the ribs can be clamped sufficiently without touching the junction of the geogrid. The clamp shall be capable of providing appropriate clamping force whilst preventing slippage during the test.

Figure 6- typical example of ‘Junction strength’ test clamps (6a & 6b show the upper junction clamp in open and closed positions; 6c shows the lower node/junction clamp)

The lower junction clamp (Figure 6c) is the same type as that used for the ‘single rib strength’ test.

B.2.3.2 Extensometer

The use of an extensometer is not necessary, due to the rigid nature of non-reinforcing hexagonal polymer geogrid. To measure strain crosshead displacement / travel can be used.

B.2.4 Test Specimens

B.2.4.1 Number of test specimens

To establish junction efficiency, samples shall be taken in the directions 30˚/210˚, 90˚/270˚, 150˚/315˚.

In each direction, a minimum of 4 specimens shall be cut, giving a minimum total of twelve tests for a single set of specimens. Two complete sets of twelve specimens shall be cut, one set for the 'single rib' strength test, and one set for the 'junction strength' tests. The three directions in which the specimens shall be cut are shown in figure 7 below.

NOTE: It is advisable to prepare additional test specimens in each direction for the case that during testing a slippage occurs and the test result has to be discarded.

Each specimen shall contain three junctions, or nodes and two complete ribs. See figure 8 below.

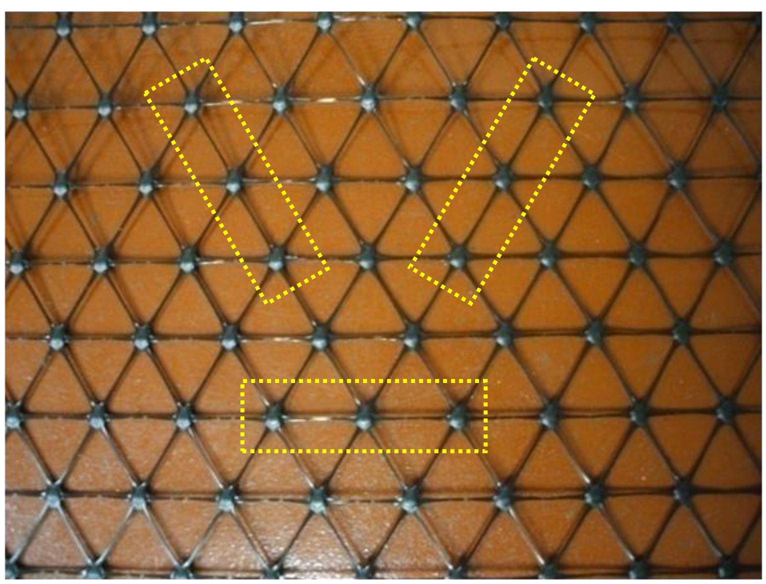

Figure 7 – Typical test specimen directions, four specimens required in each direction

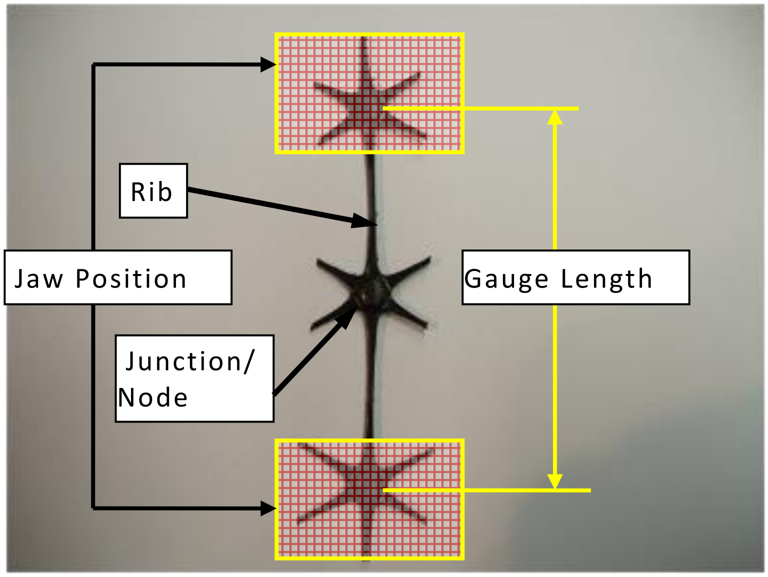

Figure 8- Typical single rib specimen

B.2.5 Test Procedure

B.2.5.1‘ Single rib strength’

B.2.5.1.1 The specimen shall be mounted centrally in the clamps and then a clamping force shall be applied to prevent slippage whilst avoiding damage to the specimen. An example of a correctly clamped specimen is shown in Figure 5.

B.2.5.1.2 Set the constant rate of extension of the crosshead movement to 10% strain per minute (based on the actual specimen gauge length).

B.2.5.1.3 Start the machine and let the test continue until rupture. Record the maximum load.

B.2.5.1.4 Repeat the same for all twelve specimens.
If a specimen shows signs of slippage within the jaws or gives results significantly below the average of the specimens discard the result and test another specimen.

B.2.5.2‘ Junction strength’

B.2.5.2.1 Adjust the clamping surfaces of the top clamp assembly so that the four angular part ribs are clamped without touching or influencing the node leaving the specimen mounted centrally in the clamp. See Figure 6a

B.2.5.2.2 Tighten the clamps sufficiently to prevent slipping or crushing.

B.2.5.2.3 Mount the lower part of the specimen centrally in the bottom clamp and tighten sufficiently. Avoid bending or torsion so that the specimen is uniaxially tensioned. See Figure 6b

B.2.5.2.4 Set the constant rate of extension of the crosshead movement to 10% strain per minute (based on the actual specimen gauge length).

B.2.5.2.5 Balance the test machine and start test failure. Record the maximum load.

B.2.5.2.6 Repeat the same for all twelve specimens.
If a specimen shows signs of slippage within the jaw or gives results significantly below the average of the specimens discard the result and test another specimen.

B.2.6 Calculations

B.2.6.1 Mean Single Rib Strength

The mean strength of a single rib is calculated;

$$\boldsymbol{T_{rib}} = \sum_{i=1}^{n} \boldsymbol{T_r}/n$$

Where: $\boldsymbol{T_{rib}}$ = mean breaking load in kN
$\boldsymbol{T_r}$ = breaking load for each individual rib specimen in kN
n = total number of test specimens (minimum of 12, 4 specimens in each of the 3 test directions)

B.2.6.2 Mean Junction Strength

The mean ´junction strength´ is calculated;

$$\boldsymbol{T_{Jun}} = \sum_{i=1}^{n} \boldsymbol{T_J}/n$$

Where: $\boldsymbol{T_{Jun}}$= mean junction strength per rib in kN
$\boldsymbol{T_J}$ = test strength for each individual junction specimen in kN
n = total number of test specimens (minimum of 12, 4 specimens in each of the 3 test directions)

B.2.6.3 Junction Efficiency

The ´junction efficiency´ of the geogrid is calculated by

$$\boldsymbol{E_{junction}} = \boldsymbol{T_{Jun}}/\boldsymbol{T_{rib}}\ x\ 100$$

Where: $\boldsymbol{E_{junction}}$ = Junction Efficiency in percent
$\boldsymbol{T_{Jun}}$ = mean junction strength per rib in kN
$\boldsymbol{T_{rib}}$ = mean rib tensile strength in kN

B.2.7 Test Report

The test report shall include the following information.

1. Reference to this test procedure
2. All relevant data for complete identification of the test specimen

3. The mean ´single rib strength´
4. The mean ´junction strength´
5. The junction efficiency

B.2.8 Normative references

ISO7500-1:2004 and ISO 7500-1/C1 2008 Metallic materials -- Verification of static uniaxial testing machines -- Part 1: Tension/compression testing machines -- Verification and calibration of the force-measuring system

B.3 Determination of mass per unit Area

B.3.1 Principle

This method is prepared to determine the mass per unit area of the geogrid.

B.3.2 Apparatus

A calibrated set of weigh scales with a resolution of 0.001 kilogram (1 gram)

A 5m tape measure with a resolution of 0.001 metre (1mm)

B.3.3 Test Specimens

A single specimen of the geogrid, measuring approximately 4m wide by 1m long shall be weighed, and its surface area shall be calculated from accurate width and length dimension measurements. The width is dependent on the variant being sampled: 4m, 3.8m, etc.

B.3.4 Test Procedure

Place the test specimen on the weigh scale and ensure that no part of the specimen is under any external influence to the weighing process. Record the mass of the specimen in kilograms to an accuracy of 0.001kg.

Lay the specimen out on a flat surface and measure both the width and length of the specimen on the four sides. Record both the mean length and mean width to a resolution of 0.001m.

B.3.5 Calculations

The mass per unit area of the specimen is calculated as follows

$$\boldsymbol{\rho_a = m/(w \times l)}$$

Where

$\boldsymbol{\rho_a}$ is the mass per unit area, in kilograms per square metre (kg/m2)
w is the width of the specimen, in metres (m)
l is the length of the specimen, in metres (m)

B.3.6 Test Report

The test report shall include the following information.

1. Reference to this test procedure
2. All relevant data for complete identification of the test specimen
3. The mean length, the mean width and the weight of the specimen
4. The mass per unit area

B.4 Determination of Hexagon Pitch

B.4.1 Principle

The test method has been prepared to determine the hexagon pitch of the geogrid.

B.4.2 Definition

The hexagon pitch is the distance measured between two parallel ribs on the hexagon formed by two opposing triangular apertures.

B.4.3 Apparatus

A 300 mm steel ruler, with a resolution of 0.001 metre (1mm)

B.4.4 Test Specimen

A single sample with a minimum surface area of 3.5 m2 shall be taken.

Measurements shall be taken at three positions across the width of the geogrid roll, namely 500 mm in from either edge and from the centre. An example of typical locations of the three measurement positions are shown in Figure 9 below.

At each of the three positions, measurements shall be taken in each of the three principle directions of the repeating hexagon, 0˚/180˚, 60˚/240˚, 120˚/300˚., as shown in Figure 10 below.

For each product series, a different number of repeating hexagons shall be measured. An example is outlined in Table 1 below.

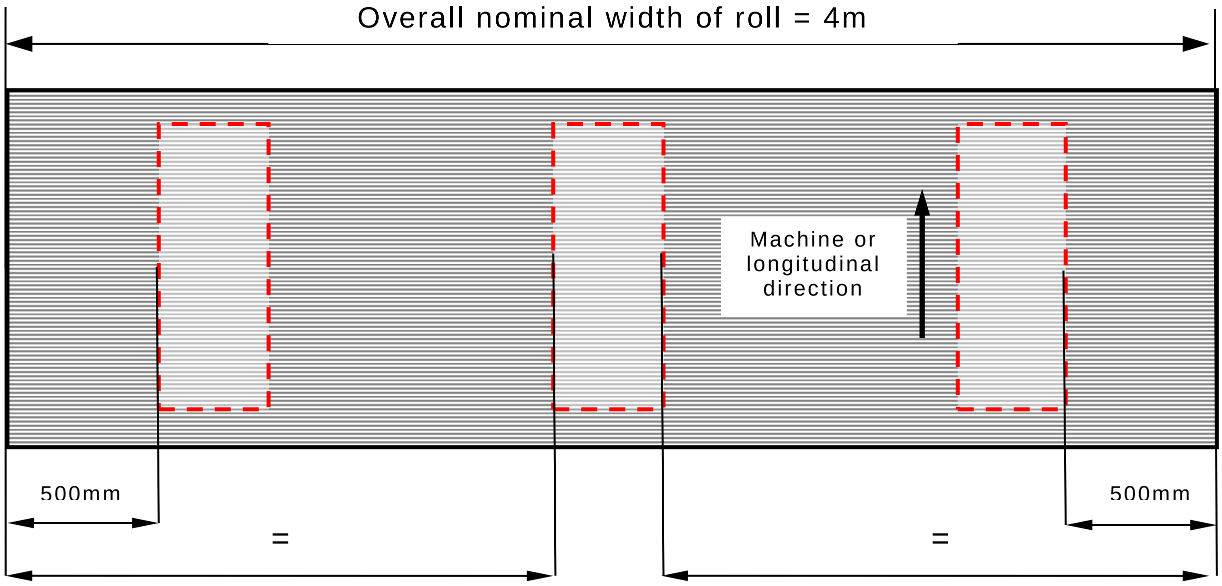

Figure 9- Measurement positions for hexagon pitch across the width of the role

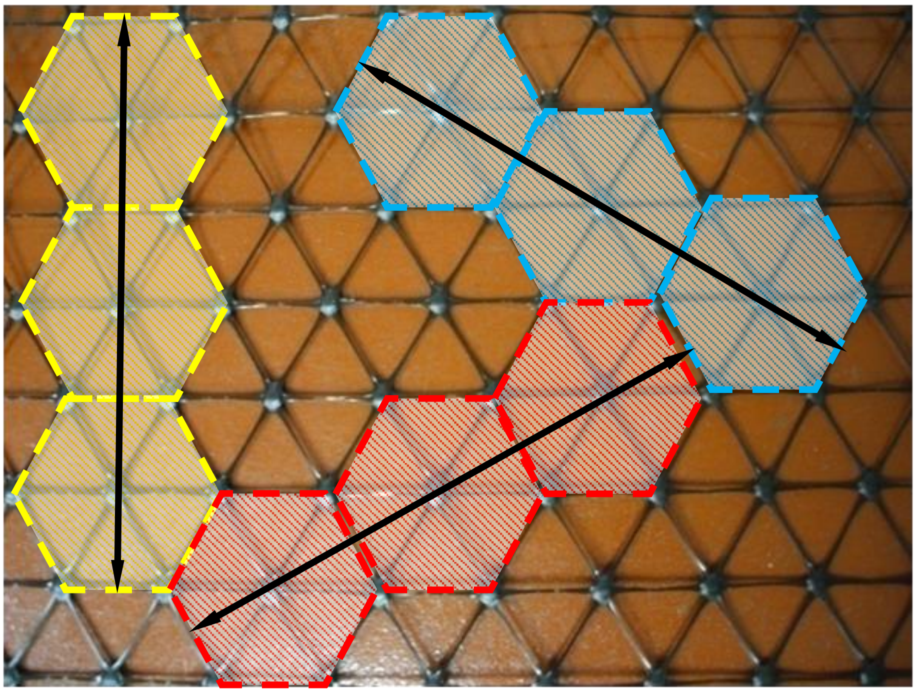

Figure 10- Three directions of measurement for hexagon pitch,

B.4.5 Test Procedure

The hexagon pitch is determined by measuring the distance over a defined number of complete pitches divided by the number of pitches measured.

Lay the specimen out on a flat surface and either cut samples for measurement or mark the three basic measurement positions as shown in Figure 9.

Record the 'across rib' dimension of the specimen in each of its three principle directions to a accuracy of 1mm, at each measurement position.

Table 1 below outlines an example of the nominal dimensions and number of repeating hexagons to be measured for each product Series. For clarity, Figure 10 shows a sample of a B series geogrid with 3 hexagons in each of the three principle directions defined.

Product Series	Nominal Hexagon AF Dimension, mm	Number of repeating hexagons	Nominal measured dimension across hexagons, mm
A	66	4	264
B	80	3	240
C	120	2	240

Table 1- Example nominal dimensions for hexagon pitch determination for three product series (A, B and C)

Measurement shall be taken from the inside of the first rib to the outside of the last rib. See Figure 11.

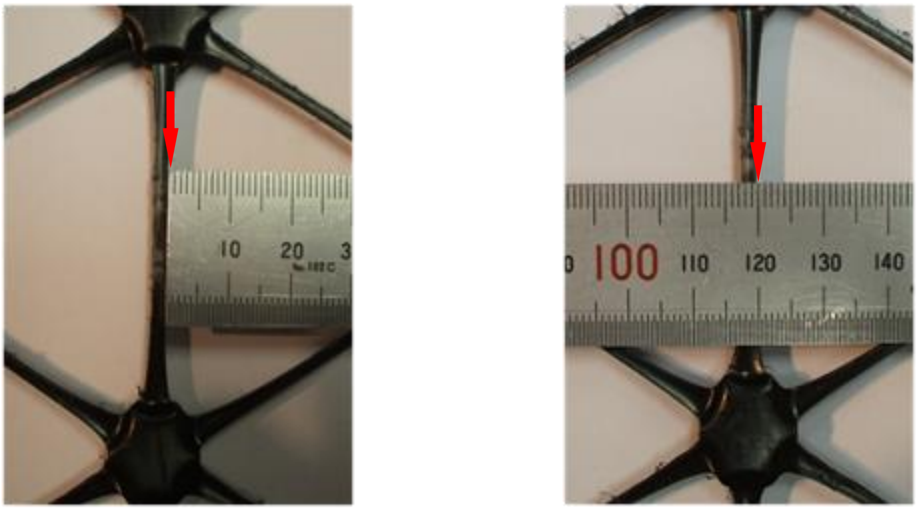

Figure 11 – Alignment of ruler during measurement

B.4.6 Calculation

B.4.6.1 Mean hexagon pitch in the 0° direction

The mean hexagon pitch of the specimen in the 0° direction is calculated as follows

$$HP_{0^\circ} = \sum (HP_{0^\circ L}, HP_{0^\circ C}, HP_{0^\circ R})/(3)$$

Where

HP_{0° is the mean hexagon pitch in the 0° direction, in millimetres (mm)

$HP_{0^\circ L}$ is the hexagon pitch in the 0° direction on the left, in millimetres (mm)

$HP_{0^\circ C}$ is the hexagon pitch in the 0° direction in the centre, in millimetres (mm)

$HP_{0^\circ R}$ is the hexagon pitch in the 0° direction on the right, in millimetres (mm)

B.4.6.2 Mean hexagon pitch in the 60° direction

The mean hexagon pitch of the specimen in the 60° direction is calculated as follows

$$HP_{60^\circ} = \sum (HP_{60^\circ L}, HP_{60^\circ C}, HP_{60^\circ R}) / (3)$$

Where

HP_{60° is the mean hexagon pitch in the 60° direction, in millimetres (mm)

$HP_{60^\circ L}$ is the hexagon pitch in the 60° direction on the left, in millimetres (mm)

$HP_{60^\circ C}$ is the hexagon pitch in the 60° direction in the centre, in millimetres (mm)

$HP_{60^\circ R}$ is the hexagon pitch in the 60° direction on the right, in millimetres (mm)

B.4.6.3 Mean hexagon pitch in the 120° direction

The mean hexagon pitch of the specimen in the 120° direction is calculated as follows

$$HP_{120^\circ} = \sum (HP_{120^\circ L}, HP_{120^\circ C}, HP_{120^\circ R}) / (3)$$

Where

HP_{120° is the mean hexagon pitch in the 120° direction, in millimetres (mm)

$HP_{120^\circ L}$ is the hexagon pitch in the 120° direction on the left, in millimetres (mm)

$HP_{120^\circ C}$ is the hexagon pitch in the 120° direction in the centre, in millimetres (mm)

$HP_{120^\circ R}$ is the hexagon pitch in the 120° direction on the right, in millimetres (mm)

B.4.6.4 Overall mean hexagon pitch

The overall mean hexagon pitch of the specimen is calculated as follows

$$\boldsymbol{HP_{nom}} = \sum(\boldsymbol{HP_{0^\circ}}, \boldsymbol{HP_{60^\circ}}, \boldsymbol{HP_{120^\circ}})/(\mathbf{3})$$

Where

HP_{nom}	is the overall mean hexagon pitch, in millimetres (mm)
HP_{0°	is the mean hexagon pitch in the 0˚ direction, in millimetres (mm)
HP_{60°	is the mean hexagon pitch in the 60˚ direction, in millimetres (mm)
HP_{120°	is the mean hexagon pitch in the 120˚ direction, in millimetres (mm)

B.4.7 Test Report

The test report shall include the following information.

1. Reference to this test procedure
2. All relevant data for complete identification of the test specimen
3. The mean hexagon pitch in the 0°, 60° and 120° directions
4. The overall mean hexagon pitch