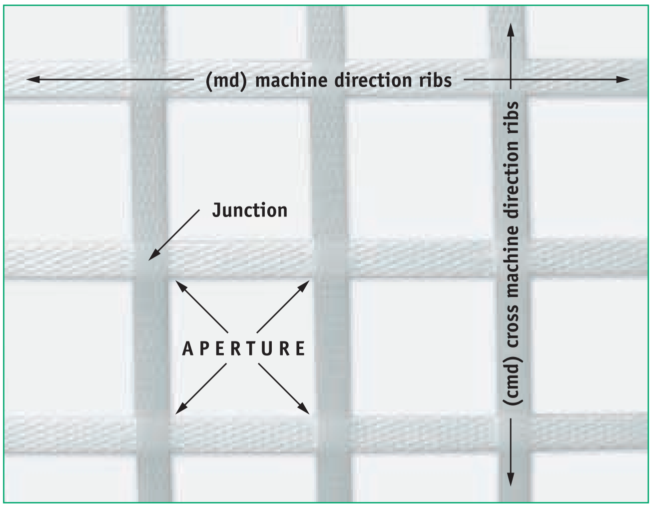
Secugrid®

geogrid introduction

1 What are geogrids and how are they made?

Geogrids are polymeric products formed by joining intersecting ribs. They have large open spaces also known as "apertures". The directions of the ribs are referred to as machine direction (md), orientated in the direction of the manufacturing process or cross machine direction (cmd) perpendicular to the machine direction ribs. Geogrids are mainly made from polymeric materials, typically polypropylene (PP), high density polyethylene (HDPE) and polyester (PET).

Fig. 1
Geogrid definitions



Geogrids are manufactured as either biaxial or uniaxial. Biaxial geogrids are those that exhibit the same strength in both the machine and cross machine directions while uniaxial geogrids exhibit the primary strength in the machine direction with minimal strength, enough to maintain the aperture structure, in the cross machine direction.

Presently geogrids are manufactured in three manners.

The first is a manufacturing method consisting of extruding a flat sheet of plastic, either high density polyethylene or polypropylene, punching a controlled pattern of holes (the apertures), and stretching the sheet in both directions, orienting the polymers, developing tensile strength. However, there is a little orientation in the junction.

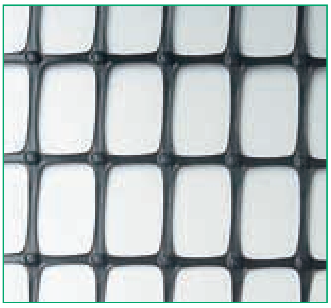


Fig. 2
Extruded geogrid

The second method is to take high tenacity polyester or polypropylene yarns that are typically twisted together. The single yarns are then weaved or knitted forming flexible junctions. Typically these products are additionally coated, depending on the manufacturer, with polyvinyl chloride (PVC), a bituminous material or latex.

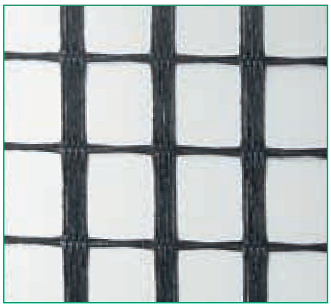


Fig. 3
Knitted/woven geogrid

The third method which produces **Secugrid**® is to extrude flat polyester or polypropylene ribs (also known as straps or bars) that are passed over rollers, running at different speeds that stretch the ribs and orientate the polymers into high tenacity flat bars (figure 4). These ribs are fed into the welding equipment where cross machine direction ribs are introduced and are welded together (figure 5) forming dimensioned apertures (figure 6).

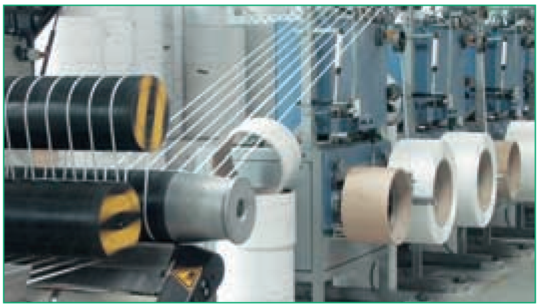


Fig. 4
Stretching process of Secugrid® ribs

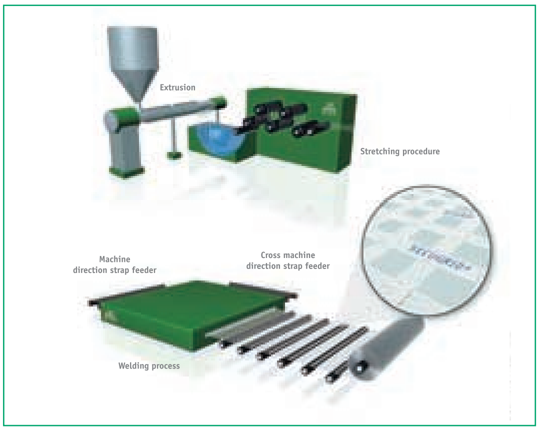


Fig. 5
Secugrid® manufacturing process

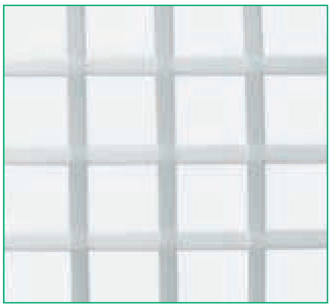


Fig. 6
Welded Secugrid® geogrid

2 Where are geogrids used?

There are several major markets for geogrids. These are base reinforcement, earth retaining wall construction including veneer stabilisation, the segmental retaining wall market, embankment reinforcement and pile cap platforms. Biaxial geogrids are primarily used in base reinforcement applications, while the uniaxial geogrids are often used in the other markets. **This document will only be concentrating on base reinforcement and biaxial geogrids.**

Fig. 7
Installed Secugrid® as a base course reinforcement

Fig. 8
Base course reinforcement on a very soft subsoil with Combigrid® (bottom) and Secugrid®

The base reinforcement market is just what the name implies. These are applications where an engineer is trying to improve the performance of a gravel base over poor soils, trying to minimise the amount of gravel in the base course design, or increasing the life of the surface cover, concrete or asphalt. Geogrids are used under parking lots, airport runways, gravel construction roads, highways, dam levees and railroad tracks.

3 How do geogrids work?

Geogrids work by interlocking with the granular or soil material placed over them. The apertures allow for strike-through of the cover soil material which then interlocks with the ribs (flat straps/bars) providing confinement of the overlaying granular/soil material due to the stiffness and strength of the ribs (figure 9 and 10).

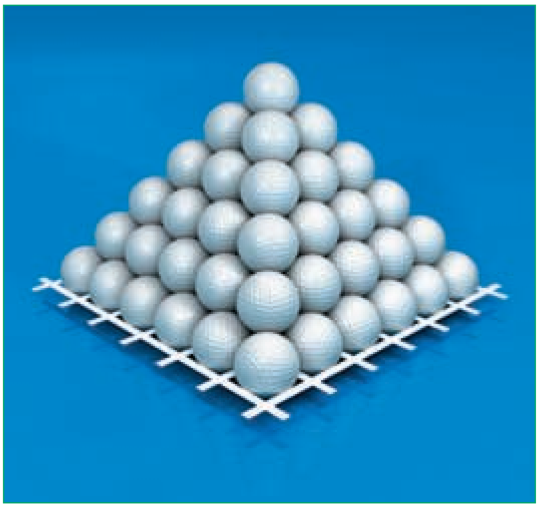


Fig. 9
Secugrid® works because of an interlocking with the soil aggregate (here schematic demonstrated with golf balls)

Fig. 10
Demonstration of the interlock effect with a car standing on a Secugrid® reinforced gravel column

4 What are geogrid physical properties?

Geogrid physical properties are the characteristics of the geogrid that provide it with its strength and ability to act as soil reinforcement. The following properties are those that the majority of the geogrids can be tested for and will provide a means to compare the various geogrids against each other. The test methods to determine these properties are nearly all standardised by ISO, CEN, ASTM, Geosynthetic Research Institute (GRI) or national standards. The properties typically listed are as follows:

1. **Tensile strength @ ultimate**
2. **Elongation @ ultimate**
3. **Tensile or true tensile strength @ 1%, 2% and 5%**
4. **Elongation**
5. **Initial or true initial modulus**
6. **Aperture size or dimensions**
7. **Junction strength**
8. **Junction efficiency**
9. **Flexural rigidity or stiffness**
10. **Aperture stability**
11. **UV Resistance**
12. **Rib thickness and width**
13. **Resistance to installation damage**
14. **Resistance to long term degradation**
15. **Creep behaviour**

For a more detailed explanation of physical properties with a simple explanation of the test method, please contact a NAUE representative.

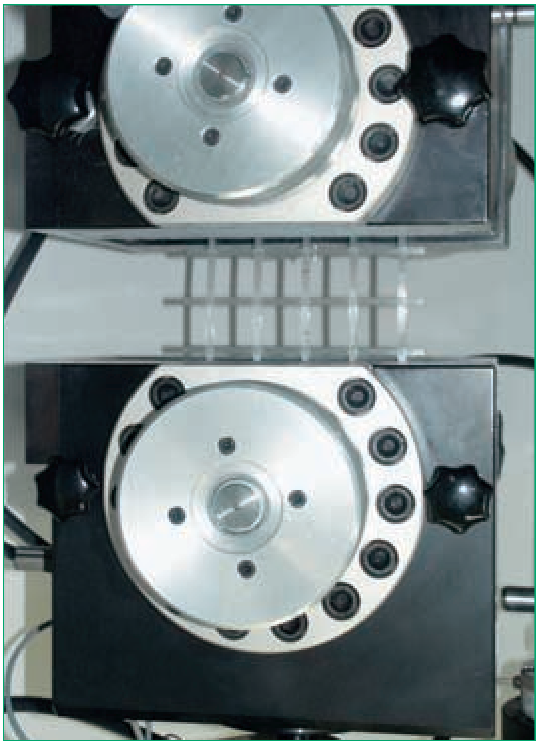


Fig. 12
Tensile strength testing of Secugrid®

Most of these properties will impact the level of performance of the geogrid as a base reinforcement material. Table 1 identifies the property, the geogrid characteristic and the generally accepted belief this property has on the performance of the geogrid to reinforce the base material.

Fig. 11
Geogrid properties affecting base reinforcement

GEOGRID ITEM	PROPERTY	GENERAL BELIEF	+
Rib	Stiffness	Stiffer is better. Need good test to measure stiffness (property # 5, 9 and 10)	✓
Rib	Aperture shape	Square or rectangular is better then curved or rounded	✓
Size	Aperture size	Related to base aggregate size. Optimum size not determined but should be minimum of 25mm to 40mm (1.0 in to 1.5 in)	✓
Aperture	Rigidity	Stiffer is better (Property # 9 and 10)	✓
Junction	Strength	Need some minimum strength. Need to look at strength @ $\leq$ 2% strains	✓
Junction	Aperture stability	High value shows good potential for improved traffic performance relationship (Property # 9)	✓
Rib	Initial modulus	The higher the better (Property # 5)	✓

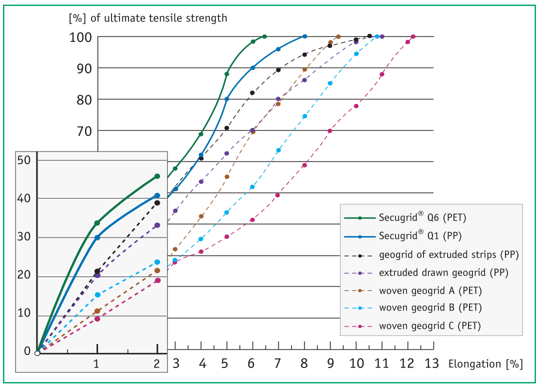
+ fulfilled by Secugrid®

5 Advantages of Secugrid®

There are several features of Secugrid® that make it the choice to use for base stabilisation applications. Some Secugrid® advantages are:

- True biaxial geogrid with equal strengths in both the machine and cross machine direction which allow stress transfer in all directions, e.g. in road curves.
- **Strength** - Higher strengths than most other geogrids @ 1%, 2% and 5% strains.
- **Modulus** - Very high modulus which means this product will pick up the stresses quickly with little or no movement in the overlying base materials.

Fig. 13
Stress/strain curves of Secugrid® and selected geogrids



- **Flexural rigidity** - ***Secugrid***® is a very stiff geogrid. It is generally accepted that a stiff geogrid will perform better for base reinforcement, as the geogrid will hold its shape, maintaining a horizontal plane versus flexible geogrids when installed. As a result, there is no movement when the loading from the overlaying gravel is transferred to the geogrid, whereas the flexible geogrids have to move to lie in a horizontal plane and be placed in tension. The stiffer geogrids pick up the transferred loading quicker with little or no deformation in the overlaying gravel.
- **Aperture stability** - Based on the Kinney test method, **Secugrid**® has very high test values. According to test trials carried out by WES and Kinney, a geogrid with a high aperture stability (also referred to as torsional stability) will allow more traffic passes than products with lower aperture stability. Therefore, they have a higher Traffic Benefit Ratio (Relationship between number of truck passes over an area with geogrid compared to an area without geogrid).
- **Wide rolls** will translate into less overlaps. In a large flat area this will result in less material required and save overall costs.
- **Resistance to installation damage** - Installation damage testing is performed on geogrids to see what, if any, damage occurs to the geogrid during installation. In this test the geogrid is installed and covered with, typically, three types of cover material, exhumed and wide width tensile (wide width strength) testing is performed on the exhumed material. These test results are compared to "control" tests performed on the same material not buried and the percentage of retained strength is calculated. A reduction factor can then be calculated and taken into account by an engineer when designing with geogrids. Current **Secugrid**® installation damage results are listed in the table below and are compared to published competitors values in the same test (e.g. SPRAGUE et al., Geosynthetics Conference 1999). The results show that **Secugrid**® is as durable if not better than other geogrids.

Fig. 14
Installation damage tests

	Extruded geogrids	Secugrid® 20/20 Q1	Secugrid® 30/30 Q1	Coated PET geogrids
Sand	83%	98.6%	98%	89% average
Sandy gravel	90%*	98.6%	91%	84% average
Coarse gravel	70%	91.3%	90%	82% average

* Clayey sand

- **Soil pull-out testing** - For soil reinforcement with geogrids, the comparison of the stress-strain behaviour of the soil and the geogrid is very important. To determine the strength of a geogrid in a soil that will also indicate the ability of the aperture to interlock with the soil, pull-out tests are typically carried out. Recent research publications of soil pull-out test with **Secugrid**® have shown that **Secugrid**® is again, as good if not better than comparable geogrids.

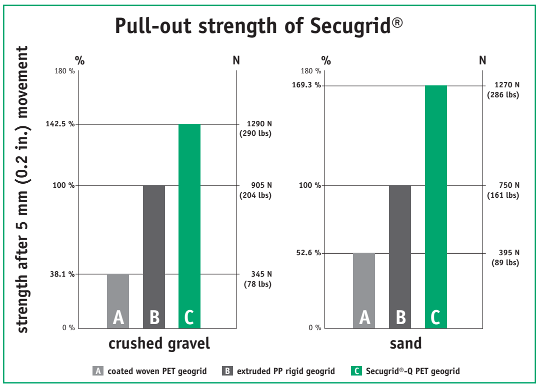


Fig. 15
Soil pull-out results with 3 geogrids

6 References

Secugrid® base course reinforcement over loess loam

The growing amount of traffic on roads increases stress conditions to the road structure resulting in the necessity to improve the strength of the structures. The long-term stability of the pavement depends primarily on the structure of the base course.

Fig. 16
Truck tire creating rutting on weak subsoil

Typically the base course under roadways is made of crushed gravel that must ensure efficient load distribution of the stresses transferred from traffic. In all cases it is important that the shear strength of the subsoil is exceeded, which in general can be very low, by the base course material. Plate load tests, such as described in DIN 18134 (similar to AASHTO T 222 and ASTM D 1196) allow a means for determining the bearing capacity of the subsoil and the compacted base course which can then be correlated to a CBR (California Bearing ratio) value.

In Germany and many other parts of the world there are subsoils very similar to loess loam, requiring additional measures for base course construction if roads are built over this type of soil. Often the thickness of the base course is simply increased. This requires more excavation of subsoil and additional material in the thicker base course resulting in increased labor, equipment and material costs. An alternative and cost effective method to achieve a long term safe solution for low strength subsoils is to use polymeric geosynthetic geogrids, such as Secugrid®, between the subsoil and the overlaying base course. The additional benefit of this solution is the overall reduction of the base course thickness because the Secugrid® geogrid reinforces the base course allowing for uniform stress distribution across the base course.

A test trial was made on an access road to a landfill where various cross sections of base courses were constructed over a loess loam (E_{V2} = 27.6 MN/m², approximately CBR = 6 %). These various sections were

Fig. 17
Placement of base course gravel over the Secugrid® section

then tested using a plate load test to determine the resulting bearing capacity of the subsoil. Control sections were also built where the thickness of the base course, without geogrid reinforcement, were 300 mm and 400 mm thick. Three different geogrids were incorporated in the study and were installed in the geogrid reinforced base course sections as follows.

- F35 - A PVC coated polyester geogrid with a biaxial ultimate tensile strength of 35 kN/m (2400 lbs/ft) in both machine (md) and cross machine direction (cmd)
- T30 - A stretched polypropylene geogrid with a biaxial ultimate tensile strength of 30 kN/m (2055 lbs/ft) in both md and cmd
- Secugrid® 30/30 Q1 - manufactured of extruded, stretched, monolithic, structured flat bars with welded junctions and a biaxial ultimate tensile strength of 30 kN/m (2055 lbs/ft) in both md and cmd

It was assumed that the bearing capacity of the unreinforced control section would exceed a value of 45 MN/m² (CBR 12.5 %).

In figure 18 the bearing capacity values are summarised by cross section and after compaction. Using only a 300 mm thick crushed gravel base course resulted in a bearing capacity improvement to the subsoil. In addition the cross sections using the three geogrids all showed an additional improvement in the bearing capacity of the subsoil. However the test plot reinforced with Secugrid® 30/30 Q1 achieved the highest improvement in bearing capacity values. The bearing

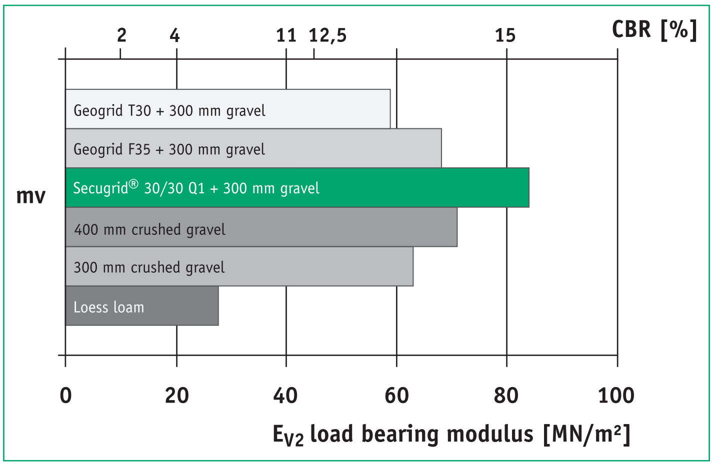


Fig. 18
Performance of Secugrid® compared to other geogrid reinforced sections as base course stabilisation

capacity results (E_{V2}) with Secugrid®, averaged at 95.2 MN/m² (CBR: 14.5 - 19 %), ranging approximately 18.9 to 29.8 % higher than the other geogrid sections.

Soil reinforcement with Secugrid®/Combigrid®

In the community of Neuenkoop-Koeterende, Germany several farm access roads required improvement because the roads could not withstand the stresses developed from current traffic levels. The roads were several decades old and had only very thin bearing layers (approx. 30 cm). In addition these roads were built over very soft peat with a CBR value of approximately 1 %.

The local design engineer used test results from an investigation in 2001 of the nearby wind mill Neuhuntorfer Moor project, which had similar subsoil conditions, as the basis for re-designing the farm access roads. The new design increased the base course bearing layer and incorporated geogrids for additional strength. The designer recommended new cross sections to the existing road which included the installation, depending on the soil CBR values, either Secugrid® or Combigrid® geogrids with tensile strengths of 30 kN/m (for higher soil strength CBR values), 40 kN/m or 60 kN/m (for the weakest soil strength CBR values). To achieve the recommended CBR value of the bearing layer, without allowing any long term rutting, the designer recommended two different bearing layer thicknesses using available recycled materials to keep the overall project costs low:

- 200 mm crushed tile material, 300 mm crushed recycling concrete
- 300 mm crushed tile material under 100 mm B2 recycling concrete

The Secutex® needle-punched nonwoven geotextile, an integral part of Combigrid® geogrids, ensured adequate

Fig. 19
Crushed base course material over Secugrid® for base stabilisation in access roads

filter and separation performance between the bearing layer of recycled materials and the subsoil.
The load bearing tests performed after placement of the geogrid and the base course showed that the CBR results had variation, due to the very different subsoil conditions which was expected. While the newly installed base course did not achieve the expected CBR value of 50 % in all cases the results from areas not meeting 50 % were very close and determined to be adequate. Based on the performance of the new base course from construction traffic as well as a few weeks of farming traffic it was concluded that the proposed solution fulfilled the expectations of the design. The design engineer, as well as the owners, concluded that a huge improvement was achieved using the Secugrid® and Combigrid® in the design and expectations are that the road would perform successfully for a long time.

Loading of Secugrid®

Secugrid® storage

Quick and simple installing

Railroad slope stabilisation

Slope reinforcement of a noise barrier with Secugrid®

Veneer slope reinforcement

Two layers of Secugrid® as a road dam reinforcement

Compaction

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