TECHNICAL NOTE

Secugrid® - Secant stiffness

TN-SG 3

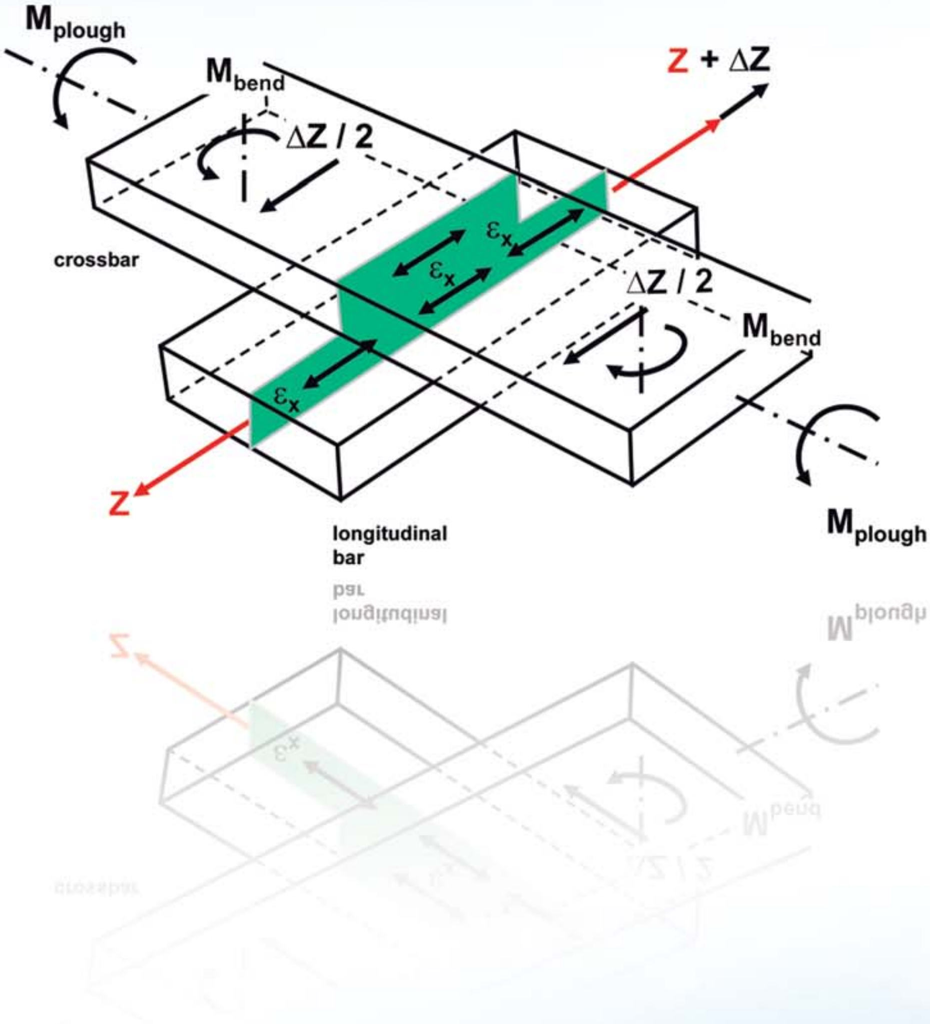
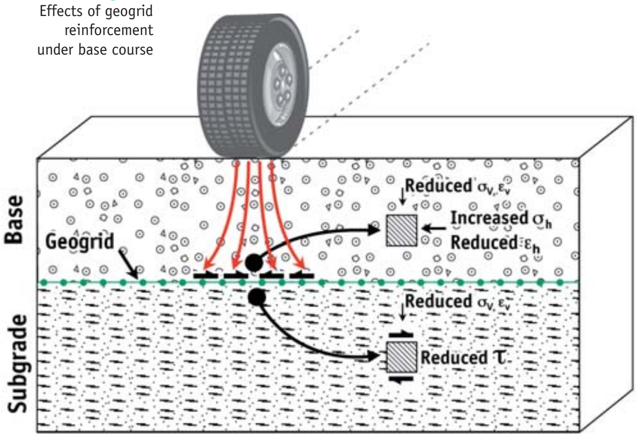


Figure 1
Effects of geogrid reinforcement under base course



Geogrid reinforcement mechanisms in unpaved roads

The benefit of geosynthetic reinforcement used in unbound aggregate base courses is attributed to the ability of the reinforcement to prevent or reduce the loss of mechanical properties of the base course aggregate, which governs the load carrying capacity. In the following the mechanisms and effects of the two main reinforcement functions, which are known as "lateral base course restraint" and the "tensioned membrane" effect, will be described.

Lateral base course restraint

The reinforcement mechanism of "lateral base course restraint" is developed by the ability of the base aggregate to interlock with the geogrid. The interlocking effect restrains the aggregate laterally (see Figure 1) and transmits tensile forces from the aggregate to the geogrid. The lateral restraint mechanism has also been referred to as shear resisting interface, as suggested in Perkins et al. (1998).

Figure 2
Lateral restraint of base course aggregate with Secugrid® geogrids

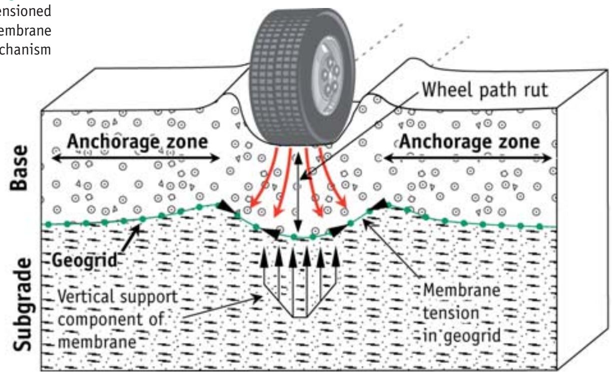
Figure 2 shows the shear interaction (interlocking) between base aggregate and Secugrid® geogrids which leads to a lateral restraint of the used crushed stone.

Figure 2
Lateral restraint of base course aggregate with Secugrid® geogrids

The mechanism of "lateral restraint" has the following effects:

- Increased stiffness σ_h of base course ⇒ Reduced horizontal strain ε_h in base course
- Reduced vertical stress σ_v and strain ε_v in base course (Improved load distribution)
- Reduced vertical stress σ_v and strain ε_v in subgrade
- Reduced shear stress τ in the subgrad

Figure 3
Tensioned membrane mechanism



Tensioned Membrane

If heavy traffic loads are applied to the base course surface and/or the subgrade is extremely soft, significant deformations on the base course surface as well on the subgrade surface occurs. The configuration of the geogrid in such cases can be assumed as shown in Figure 3. As the geogrid is anchored beyond the developed rut bowl in the transition zone subgrade/base course, the geogrid reinforcement is stressed and acts as a tensioned membrane.

Figure 4
rut development on unbound base course

The support of the applied traffic loads by the tensioned geogrid reinforcement reduces the stresses applied to the subgrade, which finally leads to reduced rutting at the base course surface.

Figure 4 and 5 show the rut development on top of an unbound base course after severe trafficking and the shape of the geogrid on top of the soft subgrade after removal of the base course aggregate.

Figure 5
Secugrid® geogrid reinforced base course showing tensioned membrane effect

The described effects of the lateral base course restraint and the tensioned membrane effect result in less vertical deformations at the surface of the unbound base course (reduced rut depth) as well as reduced vertical deformations on the subgrade due to an improved load distribution behaviour of the geogrid reinforced base course.

The documented positive effects of geogrid reinforced base courses can economically and ecologically be utilised to reduce reinforced aggregate thicknesses in comparison to un-reinforced aggregate layers or to increase the service life and maintenance interval of the reinforced base courses at comparable base course thicknesses. With increasing building material costs or aggregate taxes, possible reductions of aggregate fill material can have a major savings potential in the overall costs of construction projects.

Relevant deformations in geogrids used in unbound base courses

Large scale field tests as well as laboratory tests have shown that depending on which of the above described reinforcement mechanisms (lateral restraint or tensioned membrane) will be the guiding one, typical strains in the area of 0.5% to 2% are achieved in the geogrid reinforcement, which is installed between the base course aggregate and the weak subgrade.

This demonstrates that the resistance of the geogrid reinforcement in the deformation range up to 2% strain is more important than the ultimate tensile strength. To be able to quantify the resistance (tensile strength) of a geogrid reinforcement product at a desired strain rate, the so called "secant stiffness" value can be used. The secant stiffness of a geogrid is determined on the basis of a wide-width tensile test according to EN ISO 10319/ASTM D 6637 (see Figure 6) and the resulting stress-strain curve (see Figure 7).

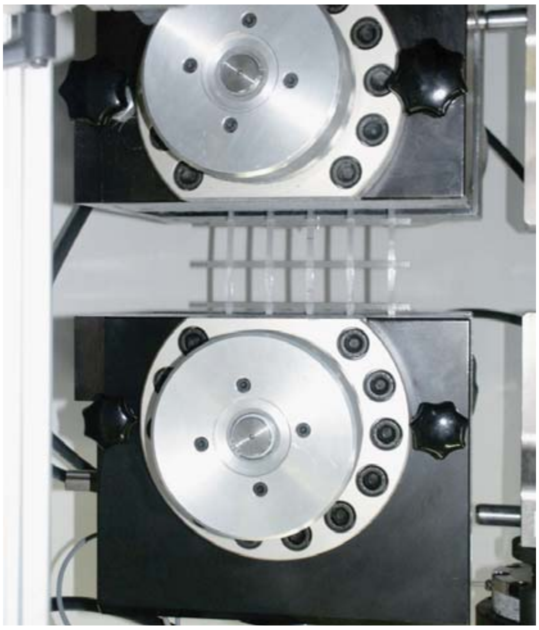


Figure 6
Wide-width tensile test (EN ISO 10319 /ASTM D 6637)

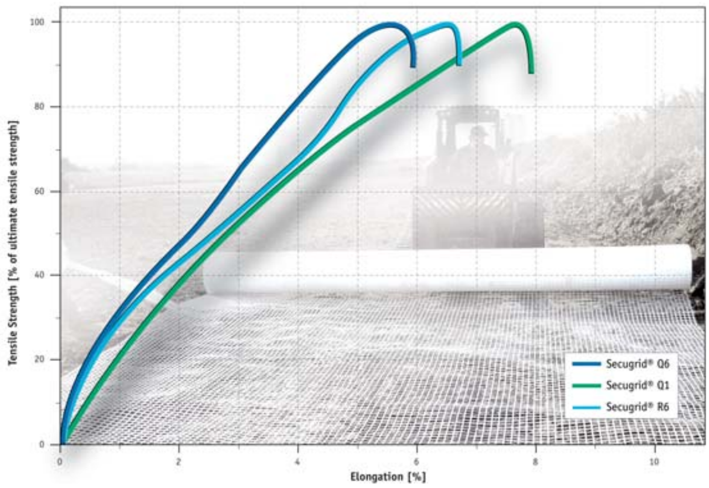


Figure 7
Stress-strain curve of Secugrid® PET

Using the data of the wide-width tensile test, the secant stiffness J is then calculated as follows:

$$J_{a-b} = \frac{F_a - F_b}{\varepsilon_a - \varepsilon_b}$$

Where:

J_{a-b} = Characteristic short-term secant stiffness at strain rate between ε_a and ε_b [kN/m]

F = Tensile strength at given strain ε [kN/m]

ε = Given strain [%]

In Figure 8 typical stress-strain curves of geogrid reinforcement products used in base course reinforcement applications are shown.

The stress-strain curves are shown in the relevant strain range up to 2%. The nominal tensile strength of the products shown in Figure 2 varies between 20kN/m and 40kN/m.

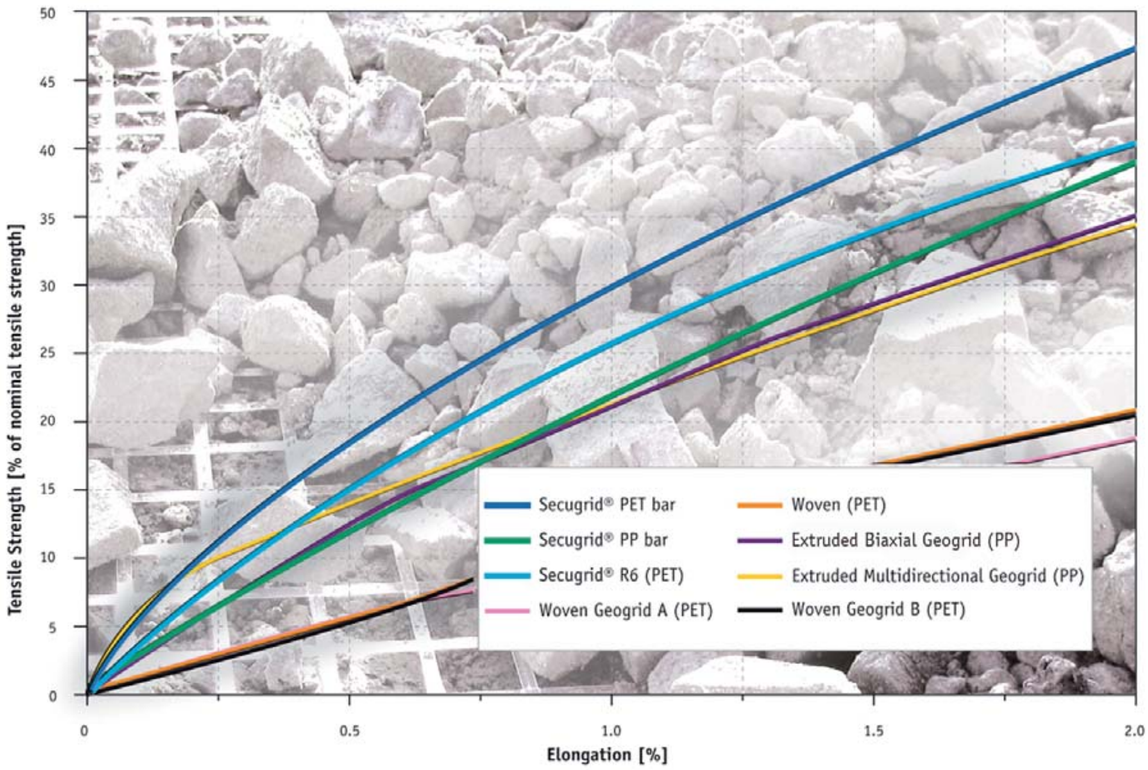


Figure 8
Stress-strain curves of typical base reinforcement geogrids

Using the above equation, the secant stiffness J at 2% strain for the geogrids shown in Figure 8 are determined and summarized in Table 1:

Table 1
Secant stiffness values of different geogrids

Geogrid	Secant Stiffness J_2% [kN/m]	
	tBU Tests	Data Sheet
Secugrid® 40/40 Q1 (PP)	> 1110	800
Secugrid® 30/30 Q6 (PET)	> 1010	675
Secugrid® 30/30 Q1 (PP)	> 796	600
Knitted multifilament geogrid (PP)	> 722	600
Woven multifilament geogrid (PET)	> 452	400
Extruded multidirectional geogrid (PP) - Type 160	> 383	-
Extruded biaxial geogrid (PP)	> 756	745

* test results according to tBU test reports ** according to manufacturer's product information

The documented secant stiffness values J_2% in Table 1 show very high resistance values for Secugrid® geogrids at a strain rate up to 2%. The calculated secant stiffness values J_2% indicate that the resistance of Secugrid® geogrids against the lateral deformation behaviour of base course aggregates, caused by typical traffic loads on top of the base course, is better than other reinforcement materials.

Higher secant stiffness values J_2% correspond to lower deformations inside the base course aggregate, which will have a positive effect on the load carrying capacity, as the loss of base course stiffness is reduced. This finally leads to lower rut deformation on the surface of the base course aggregate, less maintenance and a longer service life of the road.

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