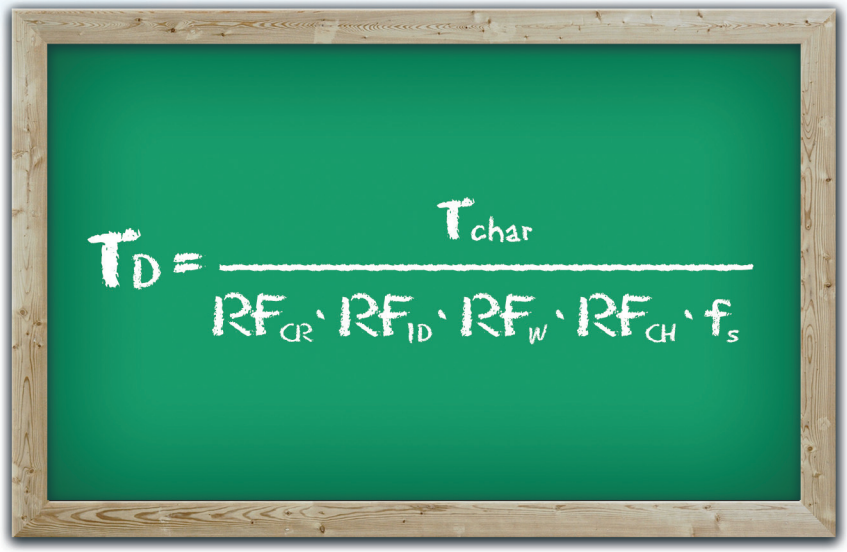
Secugrid® - Long-term Design Strength of Secugrid® PET Geogrids

In accordance to BBA Certificate No 14/H218 and BS 8006-1:2010

TN-SG 6

TECHNICAL NOTE



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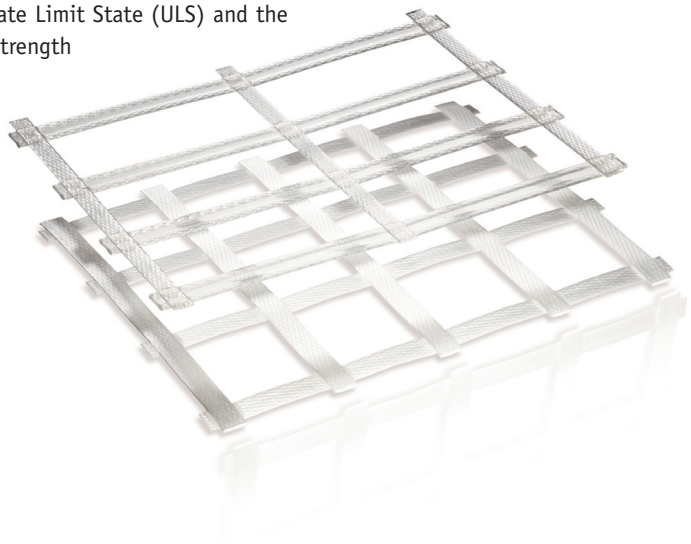
Secugrid® PET Geogrids are laid geogrids made of extruded and drawn, monolithic polyester flat or profiled bars with welded junctions. These soil reinforcing products are used in many fields of civil engineering including landfill engineering, road construction and hydraulic engineering.

According to British Standard (BS 8006-1:2010), limit state principles are applied to the design of reinforced soil walls, slopes and embankment foundations.

The two limit states considered in the design are the Ultimate Limit State (ULS) and the Serviceability Limit State (SLS). For ULS designs long-term strength is defined in terms of rupture and in the case of SLS designs long-term strength is defined in terms of limited creep strain. The long-term design strength of geosynthetic reinforcement has to be calculated in accordance to BS 8006-1:2010 and ISO/TR 20432:2007 as follows:



For Ultimate Limit State (ULS): $T_D = \frac{T_{CR}}{f_m}$

For Serviceability Limit State (SLS): $T_D = \frac{T_{CS}}{f_m}$

where:

T_D	=	long-term design strength	
T_{CR}	=	tensile strength based on creep rupture	→ T_{char}/RF_{CR}
T_{CS}	=	tensile strength based on creep strain	→ T_{char}/RF_{CS}
f_m	=	partial material factor	→ $RF_{ID} \times RF_W \times RF_{CH} \times f_s$

where:

T_{char}	=	Characteristic short-term strength [kN/m]
RF_{CR}	=	Reduction factor for creep rupture
RF_{CS}	=	Reduction factor for creep strain
RF_{ID}	=	Reduction factor for installation damage
RF_W	=	Reduction factor for weathering
RF_{CH}	=	Reduction factor for chemical/environmental effects
f_s	=	Factor of safety for the extrapolation of test data

resulting in:

For Ultimate Limit State (ULS): $T_D = \frac{T_{char}}{RF_{CR} \cdot RF_{ID} \cdot RF_W \cdot RF_{CH} \cdot f_s}$

For Serviceability Limit State (SLS): $T_D = \frac{T_{char}}{RF_{CS} \cdot RF_{ID} \cdot RF_W \cdot RF_{CH} \cdot f_s}$

For Ultimate Limit State (ULS) the creep rupture strength for Secugrid® PET geogrids is determined on the basis of laboratory tests following the requirements of EN ISO 13431:1999. From the product-specific creep rupture curve the acceptable tensile forces can be determined for a given design life that is considered with 120 years in the following overview in table 1. The individual reduction factors are taken from the Secugrid® PET product-specific BBA Certificate No 14/H218.

Table 1: Overview of partial reduction factors for Secugrid® PET Geogrids and resulting T_D for design life 120 years (ULS)

120 Years														
GEOGRID TYPE	Polymer	Ultimate Tensile Strength	Partial Partial Safety Factors											Long-Term Design Strength
			(RF_{CR}) Creep	(RF_{ID}) Installation Damage			(RF_W) Wheathering ①	(RF_{CH}) Environmental Effects					(f_s) Factor of safety for extrapolation of data	e.g. in coarse gravel; pH=4.1-9.0
		kN/m (md)	(120 years / 20°C)	Sand ≤ 2 mm	Sandy Gravel ≤ 8 mm	Coarse Gravel ≤ 35 mm	Coverage of geogrid within 4 weeks	pH 2.0-4.0	pH 4.1-9.0	pH 9.1-10.0	pH 10.1-11.0	pH 11.1-12.5	(120 years)	kN/m (md)
30/30 Q6	PET	**30**	**1,40**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**18,50**
40/40 Q6	PET	**40**	**1,40**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**24,67**
40/20 R6	PET	**40**	**1,40**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**24,67**
60/60 Q6	PET	**60**	**1,40**	1,02	1,05	**1,08**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**37,35**
60/20 R6	PET	**60**	**1,40**	1,02	1,05	**1,08**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**37,35**
80/80 Q6	PET	**80**	**1,40**	1,01	1,03	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**51,22**
80/20 R6	PET	**80**	**1,40**	1,01	1,03	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**51,22**
120/40 R6	PET	**120**	**1,40**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**76,84**
150/40 R6	PET	**150**	**1,40**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**96,05**
200/40 R6	PET	**200**	**1,40**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**128,06**
400/40 R6	PET	**400**	**1,40**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**256,12**

① EN12224:2000: Geotextiles and geotextile-related products. Determination of the resistance to weathering

*md - machine direction (of geogrid product)

For the Serviceability Limit State (SLS) BS 8006-1:2010 requires a limited creep strain which is determined according to EN ISO 13431:1999. In general product specific isochronous curves are used to determine the residual tensile load in the reinforcement at the end of the selected design life. According to BS 8006-1:2010 the following creep strain limits are defined:

- 0.5% over the period between end of construction and end of selected design life for bridge abutments and retaining walls with permanent structural loading
- 1.0% over the period between end of construction and end of selected design life for retaining walls with no applied structural loading (i.e. transient live loadings only)

The corresponding reduction factors for the above limited creep strains RF_{CS} and resulting long-term design strengths are documented in the tables 2 and 3. For the construction time, a period of 1 month and a selected design life of 120 years have been considered. Shorter design lives will increase the residual strength in the reinforcement and, by consequence increase the available design strength as the considered design life of 120 years has to be seen as worst case scenario.

Table 2: Overview of partial reduction factors for Secugrid® PET Geogrids for a limited creep strain of 0.5% and resulting T_D for design life 120 years (SLS)

120 Years														
GEOGRID TYPE	Polymer	Ultimate Tensile Strength	Partial Partial Safety Factors											Long-Term Design Strength
			(RF_{CR}) Creep	(RF_{ID}) Installation Damage			(RF_W) Wheathering ①	(RF_{CH}) Environmental Effects					(f_s) Factor of safety for extrapolation of data	e.g. in coarse gravel; pH=4.1-9.0
		kN/m (md)	(120 years / 20°C)	Sand ≤ 2 mm	Sandy Gravel ≤ 8 mm	Coarse Gravel ≤ 35 mm	Coverage of geogrid within 4 weeks	pH 2.0-4.0	pH 4.1-9.0	pH 9.1-10.0	pH 10.1-11.0	pH 11.1-12.5	(120 years)	kN/m (md)
30/30 Q6	PET	**30**	**1,53**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**16,96**
40/40 Q6	PET	**40**	**1,53**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**22,62**
40/20 R6	PET	**40**	**1,53**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**22,62**
60/60 Q6	PET	**60**	**1,53**	1,02	1,05	**1,08**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**34,24**
60/20 R6	PET	**60**	**1,53**	1,02	1,05	**1,08**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**34,24**
80/80 Q6	PET	**80**	**1,53**	1,01	1,03	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**46,96**
80/20 R6	PET	**80**	**1,53**	1,01	1,03	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**46,96**
120/40 R6	PET	**120**	**1,53**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**70,44**
150/40 R6	PET	**150**	**1,53**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**88,04**
200/40 R6	PET	**200**	**1,53**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**117,39**
400/40 R6	PET	**400**	**1,53**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**234,78**

① EN12224:2000: Geotextiles and geotextile-related products. Determination of the resistance to weathering

*md - machine direction (of geogrid product)

Table 3: Overview of partial reduction factors for Secugrid® PET Geogrids for a limited creep strain of 1.0 % and resulting T_D for design life 120 years (SLS)

120 Years														
GEOGRID TYPE	Polymer	Ultimate Tensile Strength	Partial Partial Safety Factors											Long-Term Design Strength
			(RF_{CR}) Creep	(RF_{ID}) Installation Damage			(RF_W) Wheathering ①	(RF_{CH}) Environmental Effects					(f_s) Factor of safety for extrapolation of data	e.g. in coarse gravel; pH=4.1-9.0
		kN/m (md)	(120 years / 20°C)	Sand ≤ 2 mm	Sandy Gravel ≤ 8 mm	Coarse Gravel ≤ 35 mm	Coverage of geogrid within 4 weeks	pH 2.0-4.0	pH 4.1-9.0	pH 9.1-10.0	pH 10.1-11.0	pH 11.1-12.5	(120 years)	kN/m (md)
30/30 Q6	PET	**30**	**1,67**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**15,54**
40/40 Q6	PET	**40**	**1,67**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**20,72**
40/20 R6	PET	**40**	**1,67**	1,06	1,08	**1,09**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**20,72**
60/60 Q6	PET	**60**	**1,67**	1,02	1,05	**1,08**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**31,37**
60/20 R6	PET	**60**	**1,67**	1,02	1,05	**1,08**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**31,37**
80/80 Q6	PET	**80**	**1,67**	1,01	1,03	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**43,02**
80/20 R6	PET	**80**	**1,67**	1,01	1,03	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**43,02**
120/40 R6	PET	**120**	**1,67**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**64,53**
150/40 R6	PET	**150**	**1,67**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**80,66**
200/40 R6	PET	**200**	**1,67**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**107,55**
400/40 R6	PET	**400**	**1,67**	1,00	1,02	**1,05**	**1,00**	1,10	**1,01**	1,02	1,06	1,21	**1,05**	**215,10**

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*md - machine direction (of geogrid product)

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