

# MIRAFI® PET

Properties	Unit	PET 200-50	PET 300-50	PET 400-50	PET 600-50	PET 800-50	PET 1000-50	PET 1200-50	PET 1400-50	PET 1600-50	PET 2000-50
<b>Initial Mechanical Properties</b>											
Characteristic initial strength <sup>1</sup> , T <sub>u</sub> (ISO 10319)	MD <sup>2</sup> kN/m	200	300	400	600	800	1000	1200	1400	1600	2000
Characteristic initial strength <sup>1</sup> (ISO 10319)	CD <sup>3</sup> kN/m	50	50	50	50	50	50	50	50	50	50
Characteristic initial strength <sup>1</sup> at 5% strain (ISO 10319)	MD <sup>2</sup> kN/m	100	150	200	300	400	500	600	700	800	1000
Strain at initial strength	MD <sup>2</sup> %	8	8	8	8	8	8	8	8	8	8
<b>Material reduction factor creep-rupture, f<sub>cr</sub></b>											
at 10 years design life		1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
at 50 years design life		1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
at 100 years design life		1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
<b>Creep limited strength based on creep-rupture, T<sub>cr</sub></b>											
at 10 years design life	kN/m	146	219	292	438	584	730	876	1022	1168	1460
at 50 years design life	kN/m	143	214	286	429	571	714	857	1000	1143	1429
at 100 years design life	kN/m	140	210	280	420	559	699	839	979	1119	1399
<b>Material reduction factor - installation damage, f<sub>id</sub></b>											
in clay, silt or sand		1.10	1.10	1.10	1.05	1.05	1.05	1.05	1.05	1.05	1.05
in aggregate (50mm max size)		1.20	1.20	1.20	1.20	1.20	1.15	1.15	1.15	1.15	1.15
<b>Material reduction factor - environmental effects (4 &lt; pH &lt; 9), f<sub>en</sub></b>											
at 10 years design life		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
at 50 years design life		1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
at 100 years design life		1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05

TenCate Geosynthetics Asia Sdn. Bhd. – A Solmax company

199301009495 (264232-U)  
 14, Jalan Sementa 27/91, Seksyen 27,  
 40400 Shah Alam, Selangor Darul Ehsan, Malaysia  
 Tel: +60 3 5192 8568 | Fax: +60 3 5192 8575

infoasia@solmax.com



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<b>Long term design strengths in clay, silt or sand, T<sub>D</sub></b>											
at 10 years design life	kN/m	133	199	265	417	556	695	834	973	1112	1390
at 50 years design life	kN/m	126	189	252	396	528	660	793	925	1057	1321
at 100 years design life	kN/m	121	182	242	381	507	634	761	888	1015	1269
<b>Long term design strengths in aggregate (50mm max size), T<sub>D</sub></b>											
at 10 years design life	kN/m	122	182	243	365	487	635	762	889	1016	1269
at 50 years design life	kN/m	116	173	231	347	462	603	724	844	965	1206
at 100 years design life	kN/m	111	167	222	333	444	579	695	811	927	1158
<b>Roll sizes <sup>4</sup></b>											
Nominal roll width	m	5	5	5	5	5	5	5	5	5	5
Nominal roll length	m	100	100	100	100	100	100	100	100	100	50
Estimated roll weight <sup>5</sup>	kg	230	320	420	509	770	980	1180	1460	1640	980

**NOTES:**

- <sup>(1)</sup> Tensile strength in terms of characteristics (95<sup>th</sup> percentile) values, which are statistically safe values
- <sup>(2)</sup> MD = Machine Direction
- <sup>(3)</sup> CD = Cross Machine Direction
- <sup>(4)</sup> Other forms of supply adjusted to the requirement of specific projects, are available on request
- <sup>(5)</sup> Estimated roll weight is a guidance for logistic purpose only

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# Design strengths and strains for MIRAFI PET geotextiles

## MIRAFI PET geotextiles design strengths and strains

MIRAFI PET high strength geotextiles are engineered materials suitable for short and long term soil reinforcement applications. They are composed of high modulus polyester yarns, assembled to form a directionally structured and stable geotextile that enables maximum load carrying efficiency.

MIRAFI PET high strength geotextiles are manufactured in a wide range of tensile strengths to suit different soil reinforcement conditions. Standard assessment procedures exist to determine the long term design strengths of MIRAFI PET high strength geotextiles. These rely on the application of material reduction factors to the initial tensile strength of the geosynthetic reinforcement in order to determine the appropriate long term design strength. For example, such procedures are standard practice in US Federal Highway Administration documentation and well-recognized Codes of Practice such as British Standard BS8006-1:2010.

The generic relationship for assessing the long term design strengths of geosynthetic reinforcements is shown below.

$$T_D = \frac{T_u}{f_{cr} f_{id} f_{en}} \quad (1)$$

where,

- $T_D$  is the long term design strength of the reinforcement;
- $T_u$  is the initial tensile strength of the reinforcement;
- $f_{cr}$  is the material reduction factor relating to creep effects over the required life of the reinforcement;
- $f_{id}$  is the material reduction factor relating to installation damage of the reinforcement;
- $f_{en}$  is the material reduction factor relating to environmental effects over the required life of the reinforcement.

The magnitudes of the material reduction factors  $f_{cr}$  and  $f_{en}$  are not only affected by time (the design life of the reinforcement) but also by temperature (the average in-ground temperature). In this datasheet a standard in-ground temperature of 20°C is used as the basis for measurement. This also agrees with in-ground conditions in many parts of the world and can also be considered to be conservative for colder climates.

## Initial strengths and strains

All geosynthetic reinforcement materials should be described in terms of their characteristic initial strengths and not their mean initial strengths. This ensures the representation of initial tensile strength is statistically safe. The initial tensile strengths of MIRAFI PET high strength geotextiles shown at the front of this datasheet are expressed in terms of characteristic (95<sup>th</sup> percentile) values, which are statistically safe values.

The initial tensile loads and strains of MIRAFI PET high strength geotextiles can be represented by a single master curve covering all grades. This master curve is shown in Figure 1. Here the ordinate value is expressed as a percentage of the initial characteristic tensile strength. Because of the use of special high modulus PET yarns MIRAFI PET high strength geotextiles exhibit tensile loads of 50% of the initial tensile strength at only 5% strain which makes these materials very efficient in carrying tensile loads at relatively low strains.

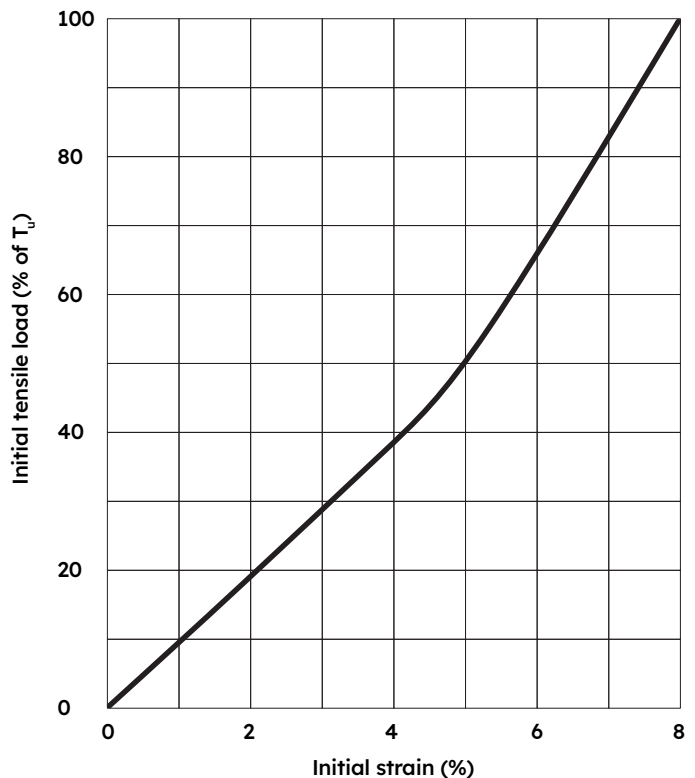


Figure 1: Initial tensile load – strain master curve for MIRAFI PET high strength geotextiles

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In prescribing suitable reinforcement strain limits to soil reinforcement applications reference is normally made to well-recognised Codes of Practice, e.g. BS8006-1:2010. Normally, for most soil reinforcement applications, reinforcement strains are limited to 5% or less over the design life of the reinforcement. Thus, the lower part of the tensile load – strain curve shown in Figure 1 (less than 5% strain) is the most important part of the curve when assessing allowable reinforcement strain levels.

**Material reduction factor for creep effects,  $f_{cr}$**

Creep effects can influence the behaviour of geosynthetic reinforcements in two ways – by decreasing the rupture load over time and by increasing the strain over time. Creep-rupture effects are associated with ultimate limit states (i.e. collapse modes) and are considered a critical case where basal reinforced embankments constructed on soft foundations are concerned. Creep-strain effects are associated with serviceability limit states (i.e. deformation modes) and may be critical where maximum reinforcement strains need to be limited and controlled.

**Material reduction factors for creep-rupture effects,  $f_{cr1}$**

The material reduction factor for creep-rupture  $f_{cr1}$  is derived from the creep-rupture curve of the geosynthetic reinforcement. The creep-rupture curve for **MIRAFI** PET high strength geotextiles is shown in Figure 2. This has been generated from a combination of long term (in accordance with ISO 13431) and accelerated creep testing (in accordance with ASTM D6992). For example, from Figure 2, the material reduction factor for creep-rupture at 100 yrs is  $f_{cr1} = 100\%/70\% = 1.43$ . Table 1 lists the creep-rupture material reduction factors for **MIRAFI** PET high strength geotextiles at 10 yrs, 50 yrs and 100 yrs design lives. Interpretation of the creep-rupture curve in Figure 2 can provide appropriate creep-rupture reduction factors for other reinforcement design lives.

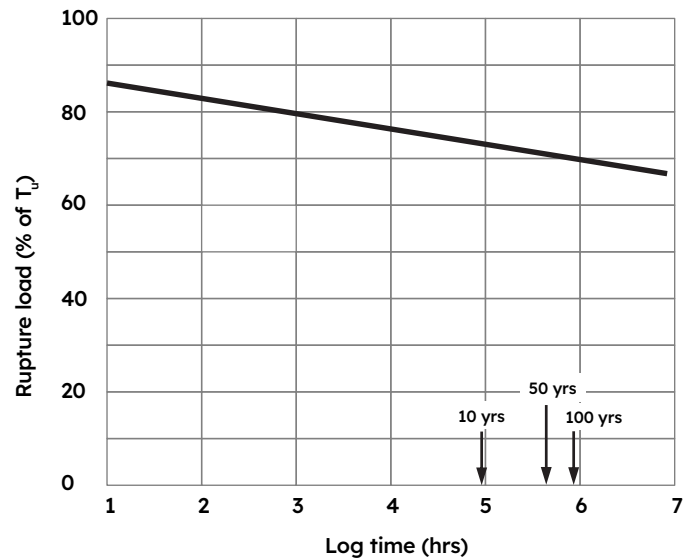


Figure 2: Creep-rupture curve at 20°C for MIRAFI PET high strength geotextiles

$f_{cr}$	at 10 yrs	at 50 yrs	at 100 yrs
	1.37	1.40	1.43

Table 1: Material reduction factors based on creep-rupture at 20°C for MIRAFI PET high strength geotextiles at three different reinforcement design lives

**Material reduction factor for creep-strain effect,  $f_{cr2}$**

The material reduction factor for creep-strain  $f_{cr2}$  is derived from the isochronous creep curves of the geosynthetic reinforcement. These curves show the change in strain of the reinforcement over time at different load levels. The isochronous creep-strain curves for **MIRAFI** PET high strength geotextiles are shown in Figure 3. The isochronous curves show that Mirafi® PET high strength geotextiles exhibit low creep strains over long design lives.

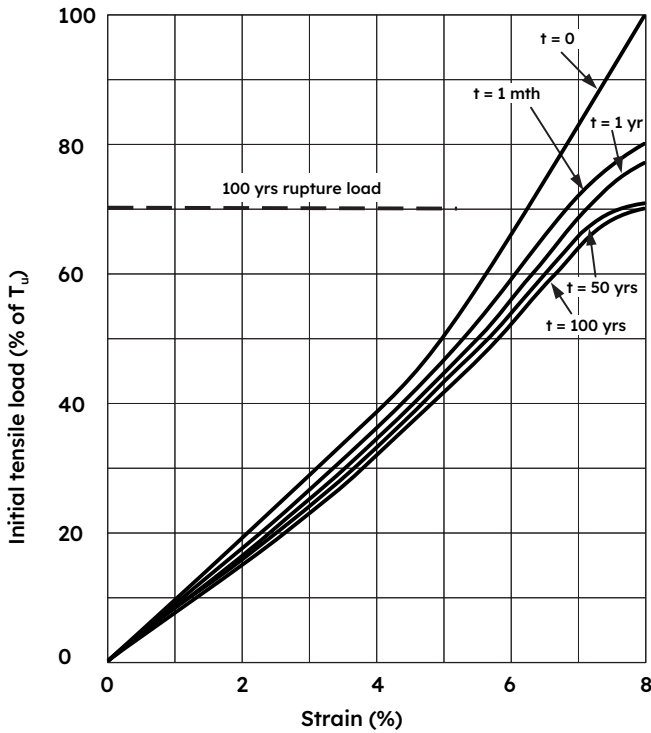


Figure 3. Isochronous creep-strain curves at 20°C for MIRAFI PET high strength geotextiles.

For example, if a design requires the total reinforcement strain to be limited to a maximum of 5% strain over a 100 year design life, then from Figure 3 a load level of 42% over 100 years will meet this requirement for MIRAFI PET high strength geotextiles. Thus,  $f_{cr2} = 100\%/42\% = 2.38$ .

In some cases, it may be required to limit the post-construction strain in the reinforcement to, say, 1% in order to prevent long term deformations in a reinforced soil structure. In this case the  $t = 1$  mth curve shown in Figure 3 can be used as a good approximation of the time it takes to construct the structure, and if the design life is 100 years and the maximum creep-strain has to be limited to 1%, then a maximum load level of around 65% can be sustained. Thus, here  $f_{cr2} = 100\%/65\% = 1.54$ .

**When to use  $f_{cr1}$  or  $f_{cr2}$  for the value  $f_{cr}$  in Equation 1**

Whether to use  $f_{cr1}$  or  $f_{cr2}$  for the value  $f_{cr}$  in Equation 1 depends on the design method being used as well as the type of analysis being undertaken.

Where a design method based on a global factor of safety approach is being used then values of  $f_{cr1}$  based on reinforcement creep-rupture should be used as the value of  $f_{cr}$  in Equation 1.

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Where a design method based on a limit state approach is being used then both  $f_{cr1}$  and  $f_{cr2}$  should be used as the value of  $f_{cr}$  in Equation 1 depending on whether an ultimate limit state analysis or a serviceability limit state analysis is being performed. In an ultimate limit state analysis  $f_{cr1}$  should be used as the value for  $f_{cr}$ , whereas in a serviceability limit state analysis  $f_{cr2}$  should be used as the value for  $f_{cr}$  in Equation 1.

**Material reduction factor for installation damage effects,  $f_{id}$**

MIRAFI PET high strength geotextiles are mostly used as basal reinforcement for embankment on clay, silt or sand subgrade when the reinforcement is installed and fill is compacted against it on such subgrade, some loss in initial strength can be accounted for by use of a material reduction factor,  $f_{id}$ . The magnitude of the material reduction factor for installation damage effects depends on the reinforcement structure and the type of fill being compacted against the reinforcement. Normally, installation damage tests are carried out on sites, in accordance with established methods such as ASTM D5818 or BS8006-1:2010 Annex D, using different fill types.

MIRAFI PET high strength geotextiles exhibit material reduction factors for installation damage on clay, silt or sand subgrade, the magnitude of which depends on the grade of product and the type of fill used.

**Material reduction factor for environmental effects,  $f_{en}$**

The chemical inertness of the high modulus PET yarns used in MIRAFI PET high strength geotextiles makes them highly durable when installed in a wide range of soil environments. For PET reinforcement to be used for long term design lives (100 years) the US Federal Highway Administration recommends that the PET molecular weight  $\geq 25,000$  g/mol and Carboxyl End Group count  $\leq 30$  mmol/kg. MIRAFI PET high strength geotextiles surpass these requirements.

Long term environmental testing in pH conditions ranging from  $4 < \text{pH} < 9$  at 20°C yield the material reduction factors listed in Table 2 for MIRAFI PET high strength geotextiles.

$f_{en}$	at 10 yrs	at 50 yrs	at 100 yrs
	1.00	1.03	1.05

Table 2: Material reduction factors based on environmental effects at 20°C for MIRAFI PET high strength geotextiles at three different reinforcement design lives



**Bond Resistance - direct sliding and pull-out**

For geosynthetic reinforced soil structures the reinforcement must behave in a composite manner with the adjacent soil. To accomplish this there must be a good bond resistance developed between the reinforcement and the adjacent soil. Two different forms of bond resistance can arise – bond resistance due to direct sliding and bond resistance due to pull-out. Direct sliding occurs when a potential failure plane coincides with the surface of the reinforcement layer. Pull-out occurs when a potential failure plane intersects reinforcement layers at an inclined angle.

The effectiveness of the reinforcement bond resistance is governed by the magnitude of the interaction coefficient between the reinforcement and the adjacent soil and its bond length. Table 3 lists interaction coefficients for **MIRAFI** PET high strength geotextiles with three different soil types.

Interaction Coefficient	Silt or clay	Sand	Gravel (< 50mm)
Direct shear, $\alpha_{ds}$	0.7	0.8	0.9
Pull-out, $\alpha_{po}$	0.7	0.8	0.9

**Table 3: Interaction coefficients for direct sliding and pull-out resistance for different adjacent fill types.**

**REFERENCES:**

ASTM D5818: Standard practice for exposure and retrieval of samples to evaluate installation damage of geosynthetics.

ASTM D6992: Standard test method for accelerated tensile creep and creep rupture of geosynthetic materials based on time-temperature superposition using the stepped isothermal method.

BS8006-1:2010 Code of practice for strengthened/reinforced soils and other fills, British Standards Institution.

ISO 13431: Geotextiles and geotextile-related products-Determination of tensile creep and creep rupture behaviour.

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