MIRAGRID® GX-Series

Properties	Unit	GX 40/40	GX 60/30	GX 80/30	GX 100/30	GX 130/30	GX 160/50	GX 200/50	GX 400/50
Initial Mechanical Properties									
Characteristic initial strength [1], T_u (ISO 10319)	MD [2] kN/m	40	60	80	100	130	160	200	400
Characteristic initial strength [1] (ISO 10319)	CD [3] kN/m	40	30	30	30	30	50	50	50
Characteristic initial strength [1] at 5% strain (ISO 10319)	MD [2] kN/m	22	33	44	55	72	88	110	220
Strain at initial strength	MD [2] %	8	8	8	8	8	8	8	8
Material reduction factor creep-rupture, f_{cr}									
at 50 years design life		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
Creep limited strength based on creep-rupture, T_{cr}									
at 50 years design life	kN/m	28.6	42.9	57.1	71.4	92.9	114.3	142.9	285.7
at 100 years design life	kN/m	28.0	42.0	55.9	69.9	90.9	111.9	139.9	279.7
Material reduction factor - installation damage, f_{id}									
in clay, silt or sand		1.10	1.05	1.05	1.05	1.05	1.05	1.05	1.05
in gravel (125mm max size)		1.15	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Material reduction factor - environmental effects ($4 < pH < 9$), f_{en}									
at 50 years design life		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
Long term design strengths, T_D									
at 50 years design life									
in clay, silt or sand	kN/m	25.2	39.6	52.8	66.0	85.9	105.7	132.1	264.2
in gravel (125mm max size)	kN/m	24.1	37.8	50.4	63.0	82.0	100.9	126.1	252.2
at 100 years design life									
in clay, silt or sand	kN/m	24.2	38.1	50.7	63.4	82.5	101.5	126.9	253.7
in gravel (125mm max size)	kN/m	23.2	36.3	48.4	60.5	78.7	96.9	121.1	242.2
Roll sizes [4]									
Nominal roll width	m	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Nominal roll length	m	100	100	100	100	100	100	100	100
Estimated roll weight [5]	kg	155	155	170	189	244	310	374	660

NOTES:

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

Solmax Geosynthetics Asia Sdn. Bhd. (formerly known as TenCate Geosynthetics Asia Sdn Bhd)
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

STANDARDS MALAYSIA ACCREDITED SAMM 207
QUALITY SYSTEM SIRIM CERTIFIED TO ISO 9001:2015 CERT NO.: QMS 03940
GAI-LAP Accreditation #: GAI-LAP-45-02

SOLMAX

Design strengths and strains for MIRAGRID GX-Series

MIRAGRID® GX geogrid design strengths and strains

MIRAGRID GX geogrids 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 geogrid that enables maximum load carrying efficiency.

MIRAGRID GX geogrids 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 **MIRAGRID** GX geogrids. 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.

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

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 **MIRAGRID** GX geogrids shown at the front of this datasheet are expressed in terms of characteristic (95th percentile) values, which are statistically safe values.

The initial tensile loads and strains of **MIRAGRID** GX geogrids 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 **MIRAGRID** GX geogrids exhibit tensile loads of 55% of the initial tensile strength at only 5% strain which makes these materials very efficient in carrying tensile loads at relatively low strains.

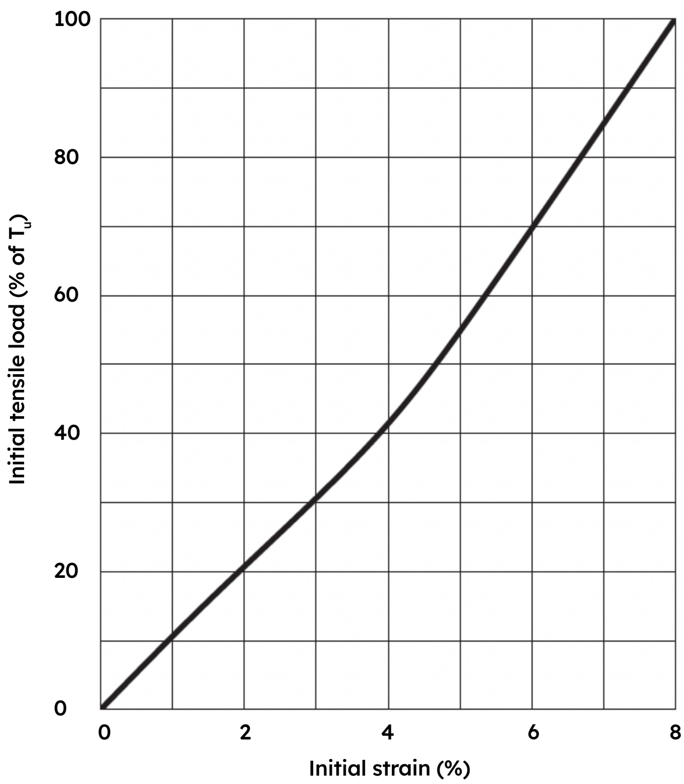

Figure 1: Initial tensile load - strain master curve for MIRAGRID GX geogrids

In prescribing suitable reinforcement strain limits to soil reinforcement applications reference is normally made to well-recognized 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 reinforced soil walls, reinforced soil slopes and 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 factor 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 **MIRAGRID** GX geogrids is shown in Figure 2. This curve 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 below lists the creep-rupture material reduction factors for **MIRAGRID** GX geogrids 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.

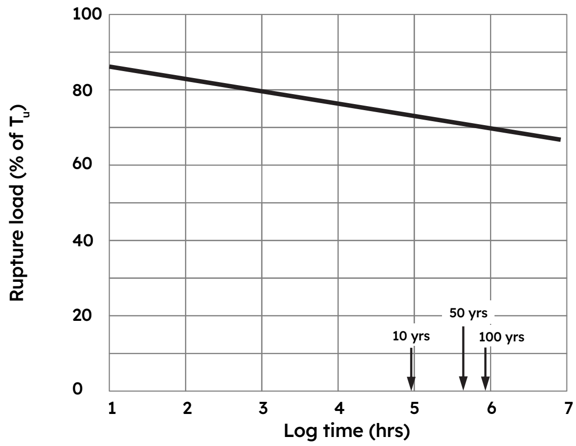

Figure 2: Creep-rupture curve at 20°C for MIRAGRID GX geogrids

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 MIRAGRID GX geogrids at three different reinforcement design lives

Material reduction factor for creep-strain effects, 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 **MIRAGRID** GX geogrids are shown in Figure 3. The isochronous curves show that **MIRAGRID** GX geogrids exhibit low creep strains over long design lives.

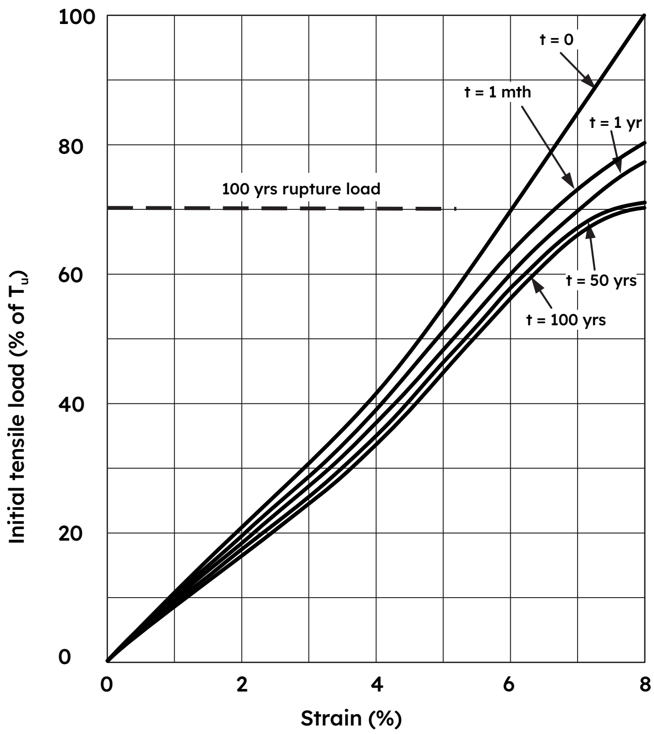

Figure 3. Isochronous creep-strain curves at 20°C for MIRAGRID GX geogrids.

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 45% over 100 years will meet this requirement for **MIRAGRID** GX geogrids. Thus, f_{cr2} = 100%/45% = 2.22.

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 fcr 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.

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}

When the reinforcement is installed and fill is compacted against it, some loss in initial strength can be experienced by the reinforcement. This loss in strength due to installation damage is 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.

MIRAGRID GX geogrids exhibit material reduction factors for installation damage, the magnitude of which depends on the grade of product and the type of fill used. For example, when clay, silt or sand fill is compacted against **MIRAGRID** GX geogrids a value of f_{id} = 1.10 is a conservative upper limit to be used for ultimate limit state design (rupture), and for coarser fills the material reduction factor will be greater. As for serviceability limit state design (strain), f_{id} = 1.05 can be adopted for all types of fill including clay, silt, sand, or gravel.

Material reduction factor for environmental effects, f_{en}

The chemical inertness of the high modulus PET yarns used in **MIRAGRID** GX geogrids 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 ≥ 25,000 g/mol and Carboxyl End Group count ≤ 30 mmol/kg. **MIRAGRID** GX geogrids surpass these requirements.

Long term environmental testing in pH conditions ranging from $4 < pH < 9$ at 20°C yield the material reduction factors listed in Table 2 for **MIRAGRID** GX geogrids.

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 MIRAGRID GX geogrids 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. **MIRAGRID** GX geogrids exhibit high bond resistance with a variety of soil types. This is demonstrated by the high interaction coefficients shown in Table 3 for a range of soil types.

Interaction Coefficient	silt or clay	sand	Gravel (≤ 50mm)
For direct sliding, α_{ds}	0.7	0.9	0.95
For pull out, α_{po}	0.7	0.9	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.