

Safety factors to be applied to calculate the Long Term Design Strength (LTDS) properties of MACGRID™ WG

The **MACGRID™ WG** are made from synthetic polymers, therefore, the creep behaviour, ultraviolet, microbes, temperature and chemical aggressions can significantly effect the long term strength of materials and it is critical issue for the reinforced structure design. Reduction factors for geogrids are obtained from tests, which are described in ISO TR 20432. The Long Term Design Strength is derived as the follows:

$T_{LTDS} = T_{UTS} / RF$

$RF = RF_{CR} \times RF_{ID} \times RF_W \times RF_{CH} \times f_s$

T_{LTDS} = Long Term Design Strength
 T_{UTS} = Ultimate Tensile Strength
 RF = Overall reduction factor

RF_{CR} = Creep factor
 RF_{ID} = Factor due to the installation damages
 RF_W = Factor due to weathering effects
 RF_{CH} = Factor due to the environmental degradation (chemical biological) at the service temperature
 f_s = factor related to the mass of info available and to the production quality management

Ultimate Tensile Strength (UTS, T_{UTS}) : the UTS of **MACGRID™ WG** uses a constant rate of extension testing machine to pull a specific width geogrid to failure, ad described in ASTM D6637 and EN ISO 10319. Make reference to the product data sheet to determine the T_{ch} (MARV) for the different grades of **MACGRID™ WG**.

Reduction Factor for Creep (RF_{CR}) : the strength the material under a constant load gradually decays due to the changes of the molecular structure. Relevant tests should be conducted to understand the creep behaviour of geogrids to extrapolate the reduction factors for different service lives. The following values can be assumed at a standard 20°C temperature equal to: (*Reference test 215786/21-IV by SKZ-D*)

Design Life	5y	50y	60y	75y	100y
% uf UTS	≥68%	≥65.7%	>65.3%	≥65.3%	≥64.9%
RF creep	1.46	1.52	1.53	1.53	1.54

For seismic analyses, the computation of the polymeric reinforcements strength must be evaluated considering a RF_{CR} equal to 1.00, as indicated in several main international guidelines (BS 8006:2016, NF P94-270, FHWA-NHI-10-024, Japanese Railway Code).

Reduction Factor for Installation Damage (RF_{ID}) : during installation of geogrid, backfill placement may cause geogrid damage according to the different type of fillings and to the compacting energy. Results data obtained from laboratory tests are used to calculate and elaborate the values reported in the attached table.

Reference test 218788/21 I-X by SKZ/Germany

MacGrid WG grade	≥3 ; <5	≥5 ; <8	≥8 ; ≤12	>12 ; <18	≥18
D ₉₀ ≤ 1.2 mm - Sand	1.06	1.06	1.04	1.04	1.02
D ₉₀ ≤ 7.2 mm - Sandy Gravel	1.06	1.06	1.04	1.04	1.02
D ₉₀ ≤ 27 mm - Coarse Gravel	1.06	1.06	1.04	1.04	1.02
D ₉₀ ≤ 52 mm - Mixed crush	1.23	1.17	1.17	1.15	1.15

Reduction Factor for Durability (RF_W and RF_{CH}) : The reduction factors for PET durability aging vary depending on grade and design life including for microbiological, chemical resistance, hydrolysis and weathering effects. These factors are incorporated in the overall safety factors shown in the table below referring to a 5-100 years design life (temporary/permanent structures) at standard temperature (20°C) in normal soil conditions (4≤pH≤9) having assumed that the reinforcement material is promptly covered (for long term exposure timing please contact the competent Maccaferri office). *Reference test 10/24206B; 10/21105E/RM Supplement; 10/23787H; 10/23787J by BTTG/UK.*

Reduction Factor for statistical data and uncertainties (F_s) : this safety factor takes into account those cause whose effects cannot be quantified, the quality of the data provided, together with the statistical variation in the reduction factors calculated. For **MACGRID™ WG** range such value is assumed equal to 1.0. Some National Standards impose a constant value independently from any certificate evidence; in such cases the values reported in the data sheet should be factorized of the requested value imposed by the referenced normative.

The table below summarises the overall safety factor for the mentioned geogrid grades, as well as the defined pH and temperature range, taking into account all of the reduction factors reported above (RF_{CR} , RF_{ID} , RF_W , RF_{CH} and F_s).

Overall safety factor (RF) for temperature ≤ 20°C; 4 < ph < 9 for soil reinforcement; long term applications

MacGrid grade	≥ WG3 ; < WG 5	≥ WG5 ; < WG 8	≥ WG8 ; ≤ WG 12	> WG12 ; < WG 18	≥ WG18
5 yrs, 20°C, 4≤pH≤9					
D ₉₀ ≤ 1.2 mm - Sand	1.60	1.60	1.57	1.57	1.54
D ₉₀ ≤ 7.2 mm - Sandy gravel	1.60	1.60	1.57	1.57	1.54
D ₉₀ ≤ 27 mm - Coarse gravel	1.60	1.60	1.57	1.57	1.54
D ₉₀ ≤ 52 mm - Mixed crush	1.85	1.76	1.76	1.73	1.73
50 yrs, 20°C, 4≤pH≤9					
D ₉₀ ≤ 1.2 mm - Sand	1.75	1.75	1.71	1.71	1.68
D ₉₀ ≤ 7.2 mm - Sandy gravel	1.75	1.75	1.71	1.71	1.68
D ₉₀ ≤ 27 mm - Coarse gravel	1.75	1.75	1.71	1.71	1.68
D ₉₀ ≤ 52 mm - Mixed crush	2.03	1.93	1.93	1.90	1.90
100 yrs, 20°C, 4≤pH≤9					
D ₉₀ ≤ 1.2 mm - Sand	1.86	1.86	1.82	1.82	1.79
D ₉₀ ≤ 7.2 mm - Sandy gravel	1.86	1.86	1.82	1.82	1.79
D ₉₀ ≤ 27 mm - Coarse gravel	1.86	1.86	1.82	1.82	1.79
D ₉₀ ≤ 52 mm - Mixed crush	2.15	2.05	2.05	2.01	2.01

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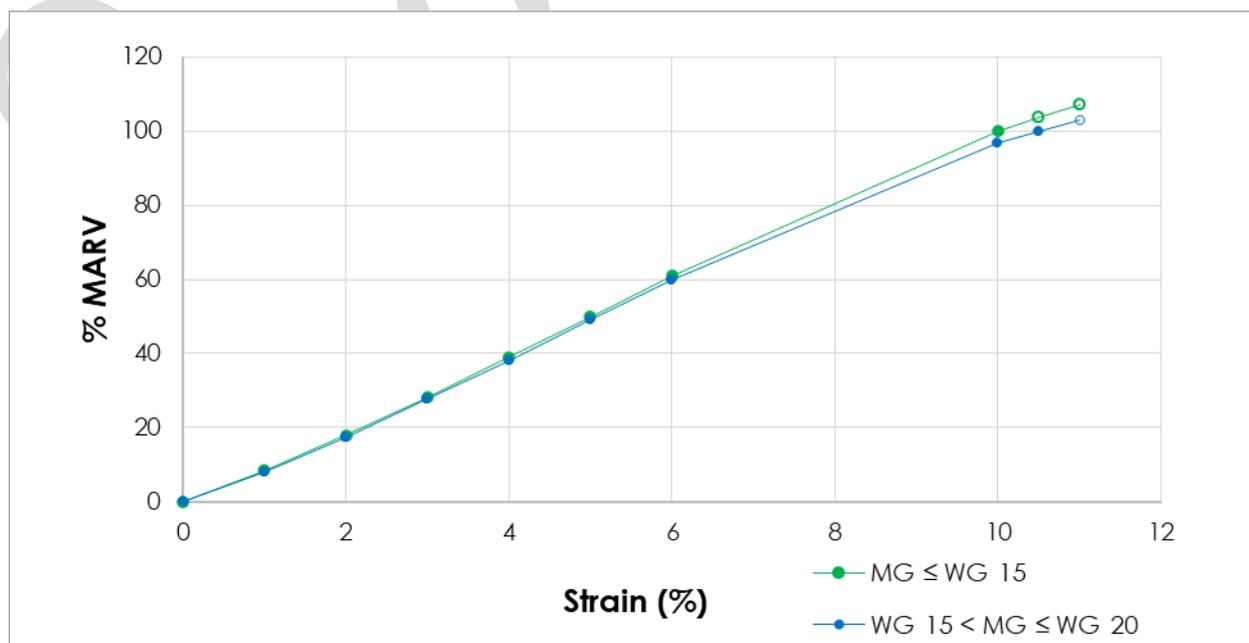
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Stress - strain curves of MacGrid™ WG range

The table below shows typical values of tensile strength of the MacGrid WG range from 20 to 200 kN/m/ in the longitudinal direction at a fixed strain. These data have been collected from existing stress-strain curve throughout the range from internal and external tests from production campaigns and even if are not to be considered granted values they are accurate and represents our current knowledge; these data does not take into account the safety factors to be applied to the reinforcement due to potential environmental, chemical aggression and mechanical damages occurring during the installation and compaction phases. In the table below the tensile strength available at a certain strain level is expressed as a rounded percentage of the Characteristic Tensile strength (MARV) of the geogrid. The technical data sheet of the product shows the mean value of ultimate strength obtained by short-term tests (as per EN ISO 10319:2015) and the tolerance values that correspond to the required level of confidence to establish the Characteristic Short-term Tensile Strength in accordance with European and American standards .

MacGrid WG		
Strain (%)	MG ≤ WG 15	WG 15 < MG ≤ WG 20
1	8.5%	8.2%
2	18 %	17.5%
3	28.2%	27.6%
4	39 %	38.2%
5	50 %	49 %
6	61 %	59.8%
10	100 %	96.7%
10.5		100 %
Strain@ MARV	10%	10.50%



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