GEOSYNTHETIC REINFORCEMENT PRODUCTS– NOT ROCKET SCIENCE- Martin Smith

ABSTRACT:

Geosynthetic products (polymeric products used in a soil or geo environment) are rapidly gaining a much wider acceptance in the civil engineering community.

Over the last 25 years there has been increasing acceptance of geotextiles in applications of filtration and separation works. More recently there has been tremendous growth throughout Australia in the use of geosynthetics for applications of reinforcement (high strength geotextiles, geogrids and composite geotextiles/geogrids).

Typically reinforcement applications include the use of geosynthetics for slope reinforcement, wall reinforcement, basal reinforcement and pavement reinforcement.

The polymer type and the environment in which the geosynthetic is used will have a major effect on the working strength of the product and the efficiency of use of the product.

Whilst there is good overseas guidance in the use of these products in applications of reinforcement, there is little formal Australian guidance both from a design and specification perspective.

Key Words: creep, strain, geosynthetic, installation damage, temperature. reinforcement, geogrid, geotextile

INTRODUCTION:

Geosynthetics is a term used to describe a wide variety of synthetic materials (polymeric and natural) used in a soil (geo) environment to improve some fundamental property of the soil or the soil environment.

Geosynthetics are used to describe a vast range of "geo" products and includes within this family such products as geotextiles, geogrids, geomembranes, geocells, geodrains, geosynthetic clay liners, geotubes, geobags and similarly described product types.

The function of a geosynthetic will be one of separation, filtration, containment, protection, reinforcement or stabilisation or may be some combination of the above functions.

It is the writer's belief that the use of geosynthetic products in the specific application of soil reinforcement for civil engineering works is not well understood by the majority of specifiers and users. The benefits in the use of these products are not realised to their maximum extent and may result in poor product selection, uneconomical engineering solutions or inappropriate engineering solutions.

Geosynthetics are well suited to reinforce soils. Geosynthetics can be manufactured in a wide variety of strengths, polymer types and configurations to fulfil some engineering requirement.

This paper looks at geotextiles and geogrids and a variety of polymer types and material manufacturing methods to provide some guidance on choice and selection of a specific geotextile type or geogrid type for a reinforcement application.

GEOTEXTILES

Broadly speaking for the geotextile family these are separated into two distinct family types and are described as woven geotextiles or non -woven geotextiles.

The major simplistic differences between these products are that woven geotextiles exhibit clearly defined strengths in two specific directions (warp and weft) whilst non-wovens are generally more uniform in strength regardless of direction in the fabric. Woven geotextiles are capable of being manufactured to very high tensile strengths whilst non-woven geotextiles are of much lower strength capability. Woven geotextiles develop strength at much lower strains than those of the non-woven type. It is widely accepted that for applications of soil reinforcement the woven geotextiles perform the best. Both geotextiles may be manufactured from a variety of polymers.

Geotextile Construction	Tensile Strength kN/m	Maximum Extension %
NONWOVENS		
Melt-bonded	3-25	20-60
Needle-punched	7-90	50-80
Resin-bonded	5-30	25-50
WOVENS		
Monofilament	20-80	9-35
Multifilament	40-800	9-30
Tape	8-90	10-20

GEOGRIDS

An additional family of geosynthetic products are marketed under the generic term of geogrids. Geogrids are manufactured by the bonding of strips, by the punching and drawing of polymer sheet, or by the weaving or knitting of yarns to form quite open mesh like structures. Geogrids may be manufactured from a variety of polymer types. Dependant upon the polymer type and manufacturing process geogrids can be manufactured to a reasonably wide range of strengths and strains. Geogrids have a defined strength in the roll and cross roll direction. Geogrids that have equal strength in both directions are called biaxial geogrids. Geogrids that have a dominant strength in one direction are called uniaxial geogrids. All geogrids are ideal for soil reinforcement applications but some types may be better suited in terms of performance and price than other types for specific applications.

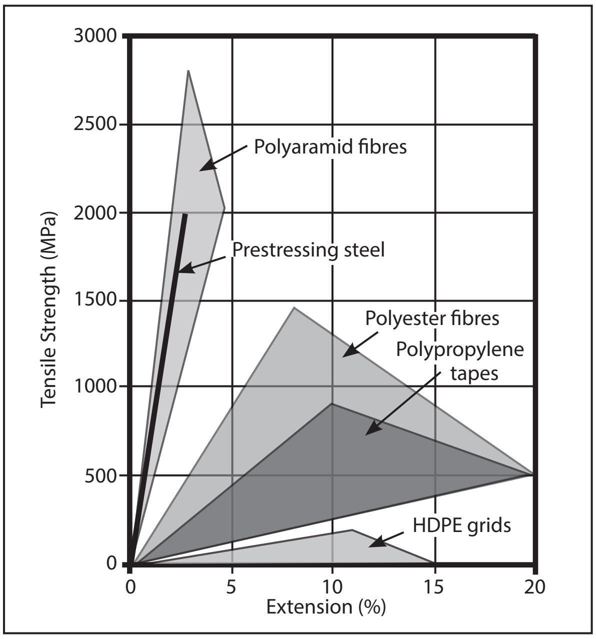
Geogrid Construction	Tensile Strength kN/m	Maximum Extension %
GEOGRIDS		
Textile Based	25-300	3-20
Polymeric Sheets	10-160	11-30
Cross Laid Strips	20-160	10-15
Geocomposite Link Structures	100-1200	3-15

POLYMERS USED

Notwithstanding the above, geotextiles or geogrids are manufactured from the following common polymer types.

- PET (Polyester)
- HDPE (High Density Polyethylene)
- PP (Polypropylene)
- PA (Polyaramid)

The table shown below indicates the typical strength/ extension curves of these polymer types when tested in short term load conditions.



It may be appreciated that a quite complex matrix of polymer type and manufacturing processes exist. However, geotextiles and geogrids and the varying polymer types are becoming quite well understood by the many manufacturers of these products since having been first introduced into the market in the early 1950's (geotextiles in Holland) with later introduction of geogrids some years later. Specific manufacturers have committed themselves to specific process and polymer paths.

GEOSYNTHETIC ENVIRONMENT

In soil reinforcement applications there may be a number of environments in which the soil reinforcement product is placed.

Specific considerations may include:

- Time of loading
- Life of structure
- Temperature effects
- Installation effects
- Environmental effects
- Strain characteristics
- Soil interaction performance

To understand how each polymer behaves under a variety of conditions the designer must have an appreciation of the following.

TEMPERATURE

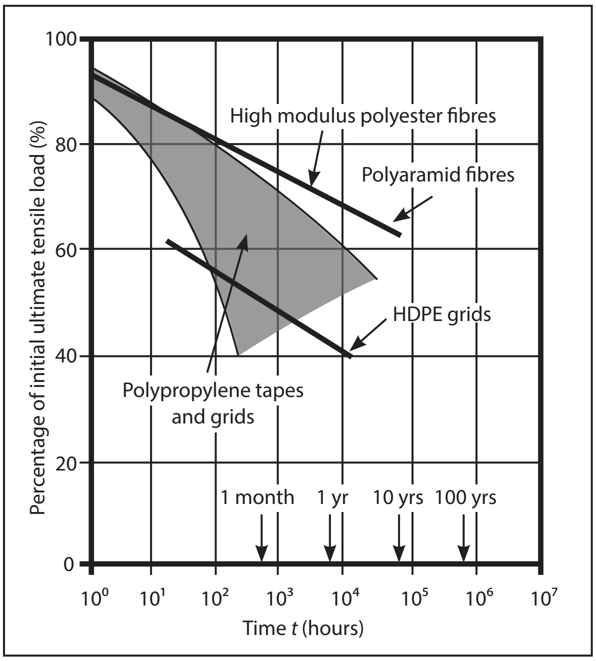
For many polymers, ambient temperatures coincide with the visco elastic phase of the polymer used. The change in material behaviour due to temperature effects from a purely elastic phase to a visco elastic phase of a material is known as the glass transition temperature. When the soil reinforcement application is time dependant then creep becomes a significant consideration in evaluation of the soil reinforcement product. As temperature increases then the creep effects may increase for specific polymers. It can also be seen that some polymers are less susceptible to temperature variations than others. For specific polymers with a glass transition temperature well below ambient temperature then creep effects become a significant influence on the long term strength of the geosynthetic.

Creep tests may be performed on product types and polymer types at varying load levels, varying temperature and time to develop an understanding of these effects.

Glass transition temperatures and melting points for various polymer types

Polymer	Glass Transition temperature Tg (°C)	Melting Point Tm (°C)
Polyaramid fibres	130	370
Polyester fibres	90 to 110	3-20
Polypropylene tapes	-20	130
High density polyethylene - HDPE	-120 to -90	130

A typical example of creep and the subsequent loss of strength with time (at a specific temperature) are shown below for a variety of polymer types.



Stress-rupture characteristics of various polymer types at 23°C

INSTALLATION DAMAGE

Generally manufacturers will publish typical values for the effect on geosynthetic strength as a result of construction practices in placement of the geogrid or geotextile and covering with fill materials.

Some indications for the effect of installation damage are shown below for a variety of soil reinforcement product types. Should the project warrant then specific damage trials should be carried out using the reinforcement product and site materials proposed. Installation damage is an instantaneous effect on strength and is not a time dependent function. Specific advice should be sought in this regard from the geosynthetic supplier, who should be able to demonstrate appropriate reduction factors

Geotextile Type	Soil Type		
	Sand	Gravel	Cobbles
Woven geotextiles	1.05 - 1.17	1.05 - 1.50	1.40 - 1.80
Geogrids - Cross laid strips - Punched sheets	1.00 - 1.15 1.10 - 1.25	1.00 - 1.50 1.30 - 1.60	1.30 - 1.80 -
Geocomposites - Strips - Link structures	1.00 1.00	1.00 - 1.10 1.00 - 1.10	1.00 - 1.25 1.00 - 1.25

ENVIRONMENTAL FACTORS

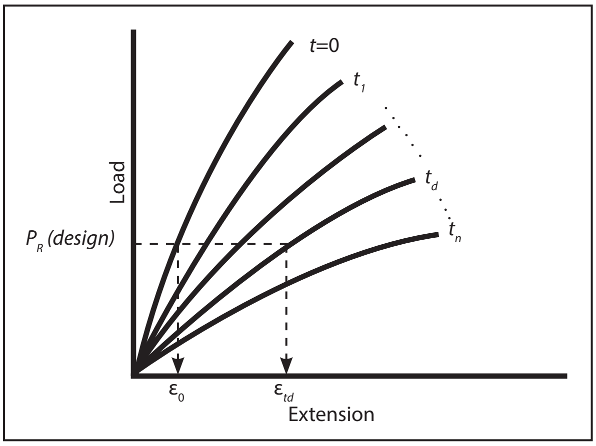
Specific environmental factors appropriate to a particular project should always be considered carefully.

Highly alkaline or acidic conditions may preclude a product for long term reinforcement applications. The presence of specific industrial waste or contaminants should be assessed. Product data sheets should also be carefully examined to determine at what temperature the product information was derived particularly with respect to long term creep performance. Many areas of Australia should use a design operating temperature of 30°C as the default value.

STRAIN CHARACTERISTICS

The designer must have an appreciation of the application in which the soil reinforcement product is to be placed and any limitation that may be wished to be placed on the strain developed within the geosynthetic, such that strength and serviceability criteria are satisfied.

For example, the use of a geosynthetic within a road pavement structure to redistribute traffic loadings and reduce potential bearing failure over a low load bearing subgrade, implies the use of a high modulus geosynthetic. In such applications, the justification for the appropriate reinforcement geosynthetic is based on short-term wide width tensile tests (transient load conditions) with creep performance of the geosynthetic in this application, of little interest. What is important, is the initial strain characteristic as determined under the short term load condition (generally 2% strain). In other applications of long term loading such as geosynthetically reinforced slopes the designer may need to limit total long term strain in the geosynthetic to some maximum value such that a serviceability criteria is met. In specific circumstances the designer may additionally impose restraints on the "creep strain" component of total strain such that post construction long-term deformations are minimised. All manufacturers of geosynthetic reinforcement products must be able to provide data in the form of isochronous creep curves such that the expected creep strain and total strain can be determined for a particular structure type and design life at a specific design temperature. Limiting to a specific value of strain and type of strain will reduce the potential long term strength capability of the geosynthetic.



Method of determining the initial extension ε_0 and the total extension ε_{td} over time period t_d for geotextile reinforcement by use of isochronous creep curves

Bridge Abutments	<0.5% Creep Strain Long Term Application
Retaining Walls	<1.0% Creep Strain Long Term Application. May limit total strain <5%
Reinforced Slopes	<10% Total Strain Long Term Application
Embankments	<6% Total Strain Short Term Applications
5-10% Total Strain Long Term Applications. May limit creep strain to <1%.	
Road Pavements	<2% Total Strain. Short term application

Indicative Values of Strain for varying applications

SOIL INTERACTION

Much has been written regarding the interaction of various geosynthetic reinforcement products and soil. The most significant component is that of bond which determines the load transfer between the reinforcement and the adjacent soil. The assessment of bond is required when the critical (or potential) failure plane crosses the reinforcement.

The two components of bond that allow the transfer of stresses from the geosynthetic into the surrounding soil are that of friction and end bearing.

Generally geosynthetic products commonly used for soil reinforcement will develop this interaction in the following simplistic models

Woven Geotextiles	Friction (Wide Rolls Flat Construction)
Woven/Knitted Geogrids	Majority Friction Some End Bearing (Flat open mesh structure – relatively low grid junction strength
Extruded Geogrids	End Bearing Some Friction (Unitised rigid junction open mesh structure – nodes at junction with relatively high grid junction strength
Cross Laid Geogrids	Majority Friction Some End Bearing (Wide flat mesh relatively low junction strength)

Whilst the type of soil reinforcement product used can marginally effect the bond developed between it and the soil, there are no compelling reasons to single out one product as being technically superior to the other in this regard for applications of basal reinforcement under embankments, slope reinforcement or in combination with some facing element for retaining walls.

The greatest influence on stress transfer and efficiency of the geosynthetic used will be the soil type that the geosynthetic is in contact with. Manufacturers should be contacted for specific advice on the interaction characteristics of their products for a range of soil types. The designer must be aware of the soil type to be used (specified) in conjunction with the geosynthetic.

OTHER CONSIDERATIONS

Some specific considerations may involve the use of proprietry facing elements.

It is now a consideration when using the increasingly popular segmental concrete block or similar elements such as a gabion as a facing element and a geosynthetic as a soil reinforcement element that manufacturers are able to provide specific connection data appropriate to the facing type being used with the particular geosynthetic being used. The general approach at the moment is that the facing element connection strength as determined in a laboratory under standard methods of test should be at least equal to the tensile forces generated at that specific geosynthetic layer in the structure.

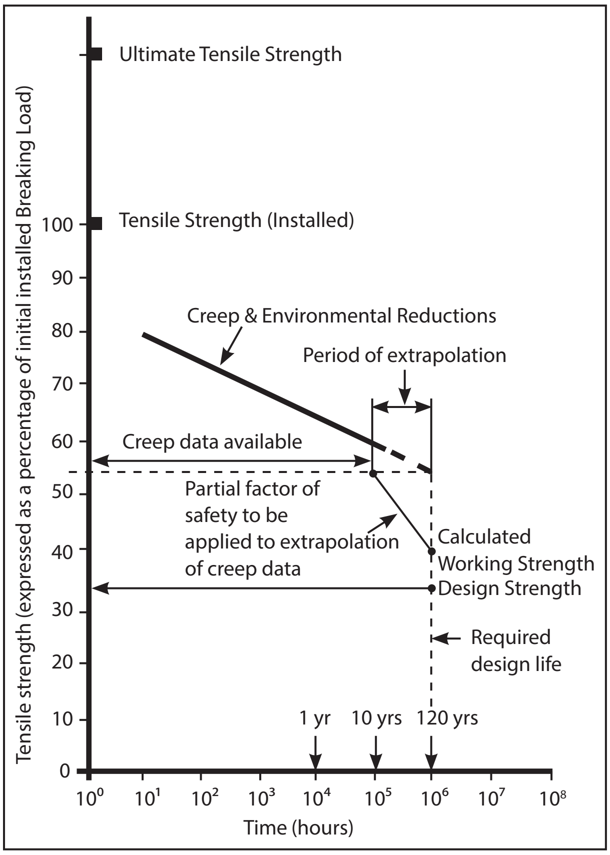
Connection data is highly sensitive to changes in the brand, strength grade and type of the geosynthetic supplied. Additionally and for example a particular segmental block may be marketed under a unique brand name but may have slight variances in manufacturing details due to geographic, cost or specific engineering requirements which can alter connection data offered to the specifier. The specifier should be satisfied that the connection data provided is appropriate to the block type actually being used.

Material data sheets and the information presented on them for geosynthetic reinforcement products must be clear and unambiguous. Specific items include:

- Ultimate Tensile Strength is best stated as a 95% confidence value.
- Ultimate Tensile Strength should be quoted at a maximum short term strain value of 10% (i.e. may not be break).
- Ultimate Tensile Strength should be determined using recognised test methods. The rate of strain used may have some effect on the strength achieved.
- An appropriate range of reduction factors for creep effects, installation effects and environmental effects should be shown.
- Appropriate information on the soil environment for which the product is suitable for use (i.e pH range).
- Clear terminology should be used on the data sheet. Data sheets that report values in poorly defined terms should be avoided.
- All manufacturers must be able to substantiate their claims regarding product performance with independent test results.
- Data sheets should clearly indicate the temperature at which the data sheet values are valid.

WORKING STRENGTH DETERMINATION AND SPECIFICATION

Various methodologies exist for determination of the working strength of a geosynthetic reinforcement product. It is not the intention of this paper to cover this aspect in any great detail.



In simple terms the designer must clearly state his reinforcement requirements such that the most appropriate product is supplied. The specification must as a minimum

- allow supply of a range of polymer types; "The geosynthetic shall be manufactured from polyester polypropylene, polyaramid or HDPE polymers".
- clearly state working load required to satisfy the design; "and have a minimum design working load of 50kN/m".
- clearly state design life; "for a design life of 100 years".
- clearly state any serviceability criteria; "Maximum total strain in the geosynthetic shall be 6% with creep strain limited to a maximum of 1% over the design life of the structure".

- clearly state potential installation damage;
  "The geosynthetic will be placed in well graded granular fill with a d90 of 75mm."

- clearly state any specific environmental concerns relevant to the project;
  "The geosynthetic shall be resistant to all naturally occurring soil alkalis and soil acids (i.e. 2 ≥ pH ≤ 10)".

- clearly state other requirements such as wrapping of rolls, U.V stabilisation, specific connection details, laying instructions etc.

Remember the best intentions of the designer are undone if the construction practice is not well implemented and controlled, but that's another story.

AUTHOR BIOGRAPHY

Martin Smith is a civil engineer with over 30 years experience in the sale and specification of a range of geosynthetic products. Martin has previously worked as a technical consultant to Maccaferri, Ten Cate Geosynthetics, Gabions Australasia and now works in a capacity as technical consultant to Global Synthetics P/L. This paper is reproduced in 2011 from a paper presented by Martin at an IPWEA conference.