Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441

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Regarding a Reduction Factor for Holes in Geosynthetic Reinforcement, i.e., "RF_{holes}"

by

Robert M. Koerner, Ph.D., P.E., NAE
Director Emeritus – Geosynthetic Institute
Professor Emeritus – Drexel University
610-522-8440
robert.koerner@coe.drexel.edu

George Koerner, Ph.D., P.E., CQA
Director – Geosynthetic Institute
610-522-8440
gkoerner@dca.net

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Background of Reduction Factors

Since the very first uses of geosynthetic reinforcement materials (both geotextiles and geogrids) manufacturers and designers have reduced the as-manufactured tensile strength values so as to incorporate site conditions which are not included in typical short-term laboratory tests (den Hoedt, 1986 and Voskamp and Risseeuw, 1987). At the minimum, reduction factors for installation damage, creep and long-term degradation are usually considered. The usual numeric approach in this regard is as follows. Koerner (2012) describes the procedure and also presents default values for situations where experimental data is not available.

$$T_{allow} = T_{ult}\left(\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CBD}}\right) \tag{1}$$

$$T_{allow} = T_{ult}\left(\frac{1}{\Pi RF}\right) \tag{2}$$

where

T_{allow} = allowable tensile strength ($\geq T_{design}$),
T_{design} = required long-term design strength,
T_{ult} = ultimate tensile strength,
RF_{ID} = reduction factor for installation damage (≥ 1.0),
RF_{CR} = reduction factor for creep (≥ 1.0),
RF_{CBD}* = reduction factor for chemical and biological degradation (≥ 1.0), and

*In the past chemical degradation and biological degradation were considered as separate reduction factors. At this point in time, however, neither bacteria nor fungi have been shown to degrade the usual polymers from which geosynthetics are manufactured. Thus, the two mechanisms are joined as RF_{CBD} but could equally be represented as RF_{CD}, or RF_D, alone.

ΠRF = value of cumulative reduction factors (≥ 1.0).

This approach is admittedly conservative in that the reduction factors are multiplied by one another thus assuming that no synergy occurs between them. Nevertheless, it is the present standard-of-practice for geosynthetic reinforcement design.

The above said, there are other reduction factors that should be added but on a site-specific basis. Two come to mind. A reduction factor for seams in the reinforcement, i.e., "RF_{seams}", is appropriate if indeed seams arise. Data is available, Koerner, 2012, for geotextiles in this regard.

The other possible reduction factor is for holes purposely made in the reinforcement geotextiles or geogrids. (Note that unintentional holes should be included in the installation damage reduction factor.) Such intentional holes occur in the following situations;

- holes for prefabricated vertical drains (PVD's), also called wick drains, used to rapidly consolidate foundation soils (see Figure 1),
- holes for geotechnical monitoring of foundation and embankment soils such as piezometers, slope indicators, etc.,
- holes for guard fence posts, light poles, signage posts, litter fence posts, etc.,
- holes for utilities such as water piping, drainage piping, electrical conduits, etc.
- holes for various infrastructure objects such as catch basins, drainage manholes, fire hydrants, etc., and
- holes for deep foundations such as piles, piers and caissons.

This White Paper is focused on addressing a reduction factor for holes (RF_{holes}) as occurs in the above situations for use in arriving at the T_{allow}-value in the previous equations. In this regard we address both geotextiles and geogrids since both are used as geosynthetic reinforcement.

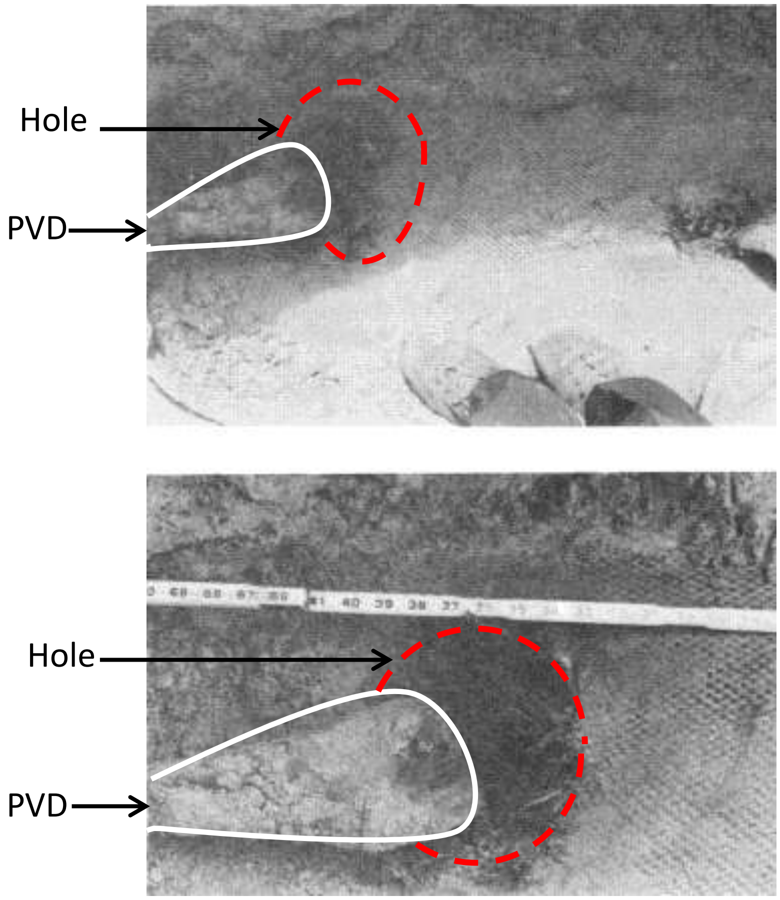

Figure 1 – Photographs of holes made in a high strength geotextile by driving a PVD (wick drain) through 1.0 m of sandy soil, the fabric itself, and then about 15 m of soft foundation soil beneath the geotextile.

<u>Reduction Factor for Holes in "Geotextiles"</u>

The original paper investigating the effect of holes in geotextiles insofar as its tensile strength was concerned was by Nowatzki and Pageau (1983). They investigated woven (two types) and nonwoven light weight geotextiles by comparing different size holes to the wide width tension strength. They used ASTM D1682 testing for wovens and D1117 testing for nonwovens on 250 mm (10 in.) wide by 50 mm (2.0 in.) long specimens. In general, they found the following:

- The woven fabrics lost greater strength than the nonwovens.
- Holes on the bias of the woven fabrics caused the greatest strength reductions.

- Holes in the fill direction of the woven fabrics caused the least reduction.
- They observed a number of grip failures in both types of fabrics.

This research was expanded upon by Koerner, et al. (1987) who used the current testing protocols (ASTM D4595 for unseamed and ASTM D4884 for seamed fabrics), investigated slits in different orientations and holes, and included both lightweight and heavyweight geotextiles. The results of their work are given in Table 1. Here it is seen that upon obtaining the actual percent reduction in tensile strength (Column 4) an assumption of a linear reduction in strength with slit length perpendicular to the tensile force was made. The calculated percent reduction in tensile strength is given (Column 5) with the last column (Column 6) being the percent deviation from a linear reduction assumption (i.e., Column 4 minus Column 5). With the exception of a few outliers, e.g., the seamed heavyweight woven fabric, the linear assumption is felt to be reasonable. In the context of arriving at a RF_{holes}-value such an assumption will be seen to be necessary.

Table 1 – Effects of Holes and Slits in Geotextiles and Geotextile Seams, after Koerner, et al. (1987)

Geotextile Type and Damage Size (1)	Wide Width Strength (kN) (2)	Reduced Strength (kN) (3)	Actual Reduction (%) (4)	Calculated Linear Reduction (%) (5)	Deviation from Linearity (%) (6)
Lightweight nonwoven					
No damage	1.22				
Horizontal slit					
2.5 cm		1.07	12.0	12.3	-0.3
5.0 cm		0.991	18.6	24.6	-6.0
7.5 cm		0.831	31.8	36.9	-0.1
Vertical slit					
2.5 cm		1.19	2.6	negl	n/a
5.0 cm		1.24	0	negl	n/a
7.5 cm		1.15	5.8	negl	n/a
Diagonal slit					
2.5 cm		1.19	2.6	8.7	-6.1
5.0 cm		1.98	11.7	17.4	-5.7
7.5 cm		0.924	24.1	26.1	-2.0
Holes					
2.5 cm ϕ		1.27	3.7	12.3	-8.6
5.0 cm ϕ		0.880	7.7	24.6	-16.9
7.5 cm ϕ		0.809	33.6	36.9	-3.3
Lightweight woven					
No damage	4.5				
Holes					
2.5 cm ϕ		4.02	10.8	12.3	-1.5
5.0 cm ϕ		3.41	24.2	24.6	-0.4
7.5 cm ϕ		2.81	37.6	36.9	+0.7
Seamed lightweight woven					
No damage	4.24				
2.5 cm ϕ		3.66	13.7	12.3	+1.4
5.0 cm ϕ		3.09	27.1	24.6	+2.5
7.5 cm ϕ		2.35	44.7	36.9	+7.8
Seamed heavyweight woven					
No damage	3.77				
2.5 cm ϕ		2.70	28.3	12.3	+16.0
5.0 cm ϕ		2.52	33.0	24.6	+8.4
7.5 cm ϕ		1.99	47.2	36.9	+10.3

ϕ: diameter n/a: not applicable

Reduction Factor for Holes in "Geogrids"

The repeating pattern of ribs as manufactured in a geogrid very much lends itself to a linear assumption of strength reduction depending upon the hole size and spacing. Indeed, many testing organizations prefer to perform single geogrid rib tests and then merely multiply the repeating pattern to arrive at a unit width tensile strength. In order to verify this type of linear reduction of rib breakage to unit width strength the following data set is offered. Table 2 presents the raw data which is plotted in Figure 2. It is readily seen that the linear assumption is valid for all three types of manufactured geogrids.

Table 2 – Geogrid Tension Testing Results in kN units, per ASTM D6637

Geogrid "A" – Homogeneous Polypropylene Type

1-Rib	2-Rib	3-Rib	4-Rib	5-Rib	6-rib
0.51	1.07	1.71	2.55	3.24	3.80

Geogrid "B" – Coated Polyester Yarn Type

1-Rib	2-Rib	3-Rib	4-Rib	5-Rib	6-rib
2.60	4.97	7.50	9.05	11.6	1.4.5

Geogrid "C" – Polyester Strap (or Bar) Type

1-Rib	2-Rib	3-Rib	4-Rib	5-Rib	6-rib
1.67	3.43	5.10	6.46	7.82	9.08

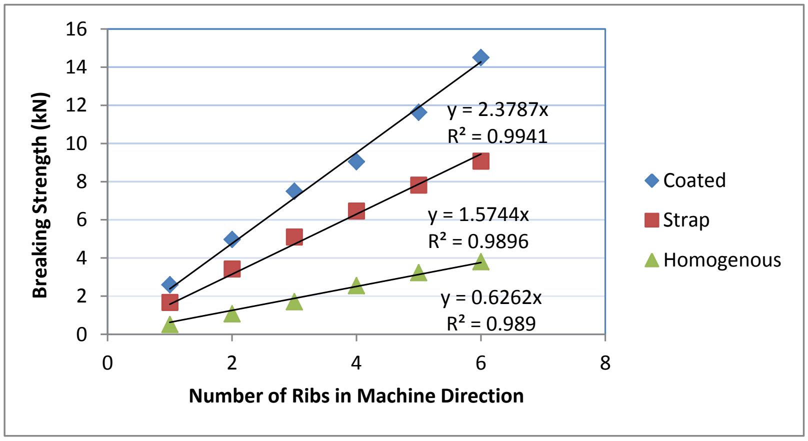

Figure 2 – Single versus multiple-rib testing of various geogrid types.

Conclusions and Recommendation

The inclusion of a reduction factor when holes are purposely made in reinforcing geotextiles and geogrids is necessary to arrive at an allowable tensile strength for design purposes. Such a value of "RF_{holes}" can be included in the typically used formulation as presented earlier.

From a designer's perspective three items are necessary to arrive at a specific value of RF_{holes} for site-specific situations.

1. The number of holes is necessary to determine and is generally known, e.g., PVD drain or post hole spacing.
2. An estimate as to the size of the holes or cuts perpendicular to the stressed direction is necessary and is admittedly difficult to reliably obtain. Excavations as in Figure 1 have been made which in this case resulted in a 250 mm maximum dimension hole which was made by a diamond shaped PVD lance of 200 mm by 150 mm cross section. However, when inducing holes in reinforcement materials using a drilling rig, knowledge of the size and type of bit used is required. An experimental program is planned in this regard. Of course, if the geotextile or geogrid is exposed at the ground surface, the actual dimension can be easily made.
3. An assumption of the strength reduction in units of kN/m or lb/ft is necessary and in this regard a linear reduction for hole or slit size is recommended. Thus, if 300 mm holes are introduced on a 3.0 m guard fence post pattern, 10% of the strength is lost and as a result the value of RF_{holes} = 1.10.

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