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Professional practice paper

Lessons learned from geotextile filter failures under challenging field conditions[☆]

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ABSTRACT

This paper reviews sixty-nine (69) field failures involving geotextile filters which performed unsatisfactorily and are categorized herein as failures. They are grouped into four categories; inadequate design, atypical soils, unusual permeants, and improper installation. In the first category are poor fabric selection, poor fabric design, socked drainage pipe and reversing flow conditions. In the second category are fine grained soils, gap-graded soils, dispersive clays and ochre. In the third category are sludges, turbid water, alkaline water, leachates and agricultural waste liquids. In the fourth category are lack of intimate contact and completely adhesive clogging of surfaces. While not the topic of the paper, it should be noted that, most of these same conditions are known to be troublesome to sand filters as well as to geotextile filters.

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1. Introduction

Geotextile filters were first used in the USA in the early 1960s (Barrett, 1966) and then technically advanced by the U. S. Army Corps of Engineers who experimented with and specified plastic filter cloth (Calhoun, 1972). Early terminology used the term *filter fabric* which still persists to the present although the term geotextile filters is preferred. The geotextiles evaluated at that time were of the woven monofilament type which were in sharp contrast to European experiences which generally used needle punched nonwovens for the same filtration purposes (Bourdillon, 1976; Giroud et al., 1977). While these two types of fabrics continue to be presently used for geotextile filters, there are also woven slit film and nonwoven heat bonded types. The four geotextile filter types are shown in Fig. 1.

In regard to geotextile filter design, there have been a progression of approaches focusing on both excessive clogging and adequate flow. Considerable past research has been directed at the avoidance of excessive clogging whereby some soil particle size is compared to the opening size of the geotextile. At this time the charts by Leuttich et al. (1992) for both unidirectional and reversing flow have gained considerable recognition. The adequate flow aspect of a geotextile filter design is based on a flow rate or permittivity factor-of-safety and is illustrated in Koerner (2012) among others.

The information gathered for this paper on 69 case histories of geotextile failures was obtained as follows:

- forty-five are from published papers by others (they are referenced accordingly),
- twelve are from published papers or reports by the authors (most are referenced), and
- twelve are from unpublished investigations by the authors and others.

Rather than present them individually (which is not possible due to space limitations) they will be addressed in groups consisting of the following four sections.

- design related failures
- a typical soil related failures
- unusual permeant related failures, and
- installation related failures.

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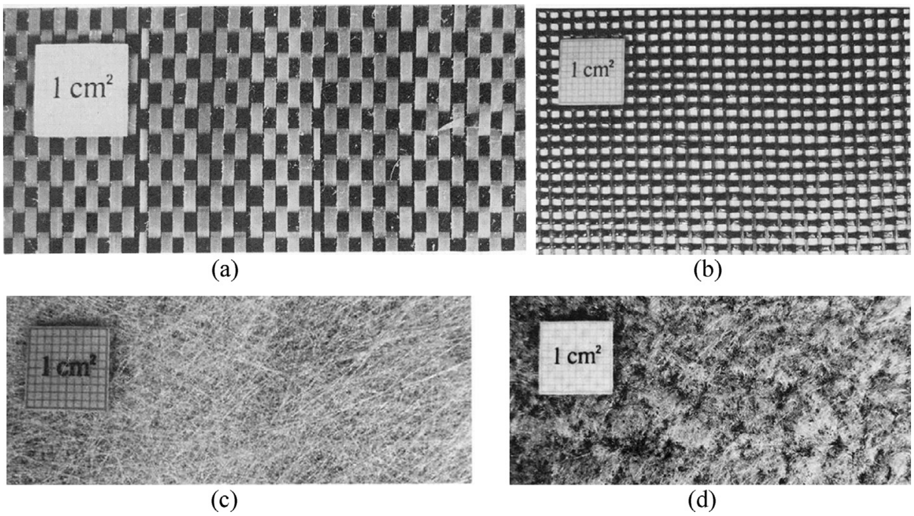


(a) (b)

(c) (d)

Fig. 1. Various types of geotextiles used as filters; all at 40 magnification. (a) Woven slit (split) film, (b) Woven monofilament, (c) Nonwoven heat bonded, (d) Nonwoven needle punched.
After Rankilor, 1981, copyright permission granted by J. Wiley and Sons Ltd.

Note that the word "failures" is used throughout signifying unsatisfactory performance of either the geotextile filter or the accompanying drainage system, the difference sometimes being unknown or difficult to determine in the context of this overview type of paper.

It should be mentioned at the outset, however, that there are hundreds-of-thousands of worldwide successful geotextile filter applications. Geotextile filter applications are even known to be successful with no design, per se, and also with relatively casual installation procedures. What the success-versus-failure rate is for geotextile filter applications is not known but is felt to be extremely high. That said, this paper aims to draw attention to those geotextile filter failures which could have been avoided with proper attention to design, testing and construction.

2. Design related failures

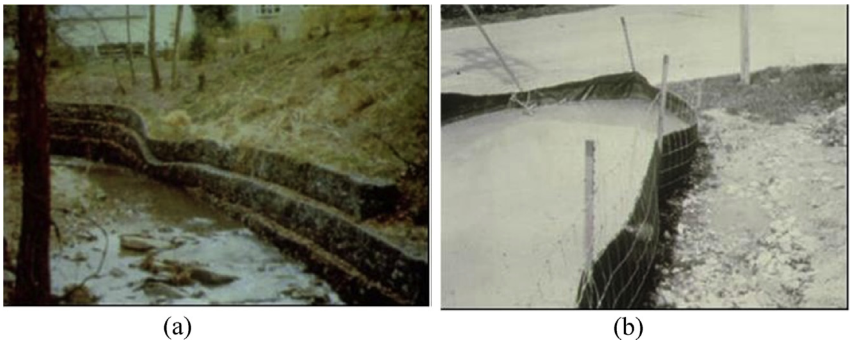
There have been several geotextile filter failures which can be ascribed directly to oversights on the part of the designer (if indeed a design was present to begin with).

2.1. Poor fabric selection

Poor fabric selection has been the cause of at least one failure evaluated by the authors. It was the filter used behind a small gabion wall as seen in Fig. 2a. In this case the geotextile selected was a woven slit film type, recall Fig. 1a, which has poor control over its opening size due to nonbonding of its intersecting fibers. Data from the 2014 proficiency testing program of the Geosynthetic Accreditation Institute's-Laboratory Accreditation Program (GAI-LAP) shows that the statistical coefficient of variation (c_v) is 33% for the permittivity of this type of geotextile (mean value is 0.21 s^{-1} and standard deviation is 0.07 s^{-1}). This relatively high value was the average of twenty participating geosynthetic testing laboratories. Note that at the minimum (e.g., $\mu - 3\sigma$), the permittivity is negligible and, as such, this type of fabric is often used as a silt fence (thereby trapping turbid water to form a small dam) as shown in Fig. 2b. The *lesson learned* in this regard is one of poor fabric selection highlighted by the use of woven slit film fabrics which should not be used for critical filtration applications.

2.2. Excessive coverage of geotextiles

Excessive blockage of the downstream, or exit, surface of geotextile filters has mobilized hydrostatic pressure causing system failures in several cases. van Zanten and Thaket (1982) were the first to recognize the problem (Fig. 3). This same situation has occurred with paving blocks, rock rip-rap, and most recently with roller compacted concrete on the geotextile's surface. This latter case resulted in a major lawsuit (authors file). In each case it is the sudden drawdown of the water in the facility due to tide decreases,



(a) (b)

Fig. 2. Improper and proper use of woven silt film fabrics (GSI photos). (a) Gabion wall failure, (b) Silt fence success.

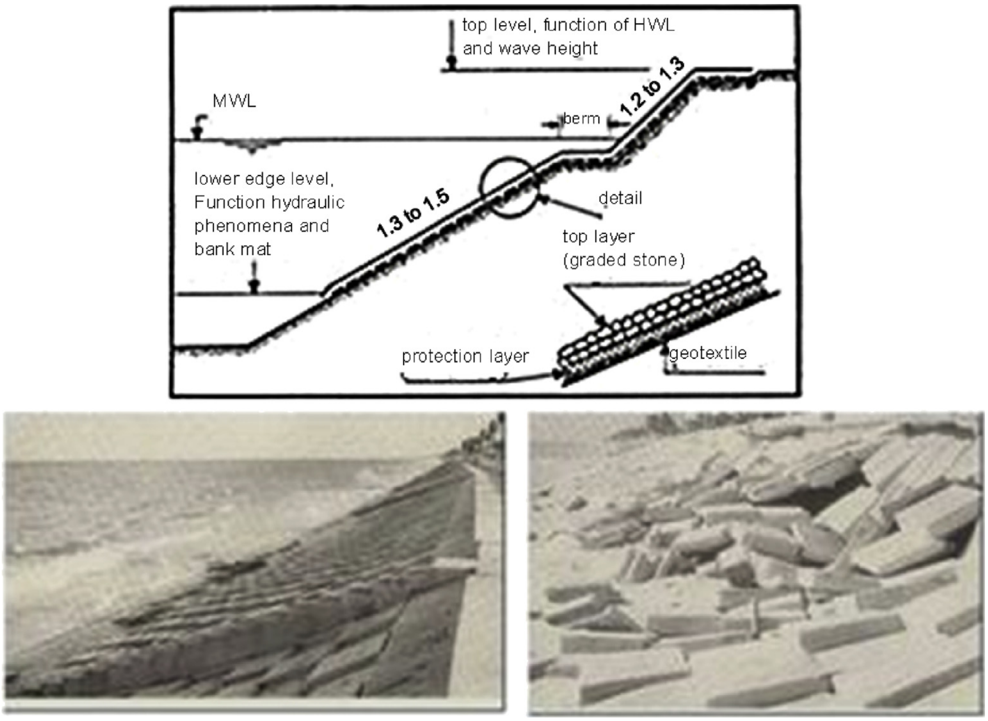


Fig. 3. Typical armoring systems and example of failed block system.
Modified after van Zanten and Thaket, 1982, and authors.

drawdown in reservoirs, or maintenance dewatering which requires water in the subsoil beneath the fabric to be released through the filter and armoring system above it. If the normal stresses of the mass of the armoring is insufficient to counteract the excess pore water pressures in the subsoil, the armoring will be distorted and uplifted accordingly. The *lesson learned* in this regard is that of poor fabric design illustrated by excessive coverage of geotextiles without any attempt at a technical design. Such design based on a coverage ratio is readily available in the geosynthetic literature.

2.3. *Geotextile wrapped drainage pipes*

Geotextile wrapped drainage pipes have often failed when the pipe holes or slits are inadequate to accept the incoming flow. Fig. 4 shows a clogged drainage system which after being stripped of its geotextile filter, allowed the flow to readily pass. Designers must recognize that the flow rate factor-of-safety is greatly diminished by downstream drainage core or pipe restrictions. Koerner (1993) proposed the following modification to the conventional flow rate factor-of-safety formula:

Fig. 4. Geotextile wrapped perforated pipe failure (GSI photos).

$$FS = \frac{k_{allow}}{k_{reqd}(DCF)} = \frac{\psi_{allow}}{\psi_{reqd}(DCF)} \tag{1}$$

where

FS = factor-of-safety
k_{allow}, ψ_{allow} = allowable permeability or permittivity
k_{reqd}, ψ_{reqd} = required permeability or permittivity
DCF = drainage correction factor (which equals footprint area/available flow area)

Typical values for DCFs are as follows; note that these values being in the denominator of Equation (1) all reduce the FS-value in directly proportion to their magnitude.

- full footprint coverage; DCF = 1.0, i.e., there is no adverse effect
- geotextile wrapped gravel encapsulating drainage pipe; DCF = 10–40
- geotextile covered geonets and geocomposites; DCF = 10–50
- geotextile wrapped corrugated drainage pipe; DCF = 60–260
- geotextile wrapped solid perforated drainage pipe (as in Fig. 4), DCF = 7500–24,000

Because the DCF can vary widely for common engineering applications using geotextile filters, the selection of the site-specific value is a critical design feature. The *lesson learned* in this regard is that geotextile wrapped, or socked drainage pipe; should not be used particularly solid-wall (non-corrugated) drainage pipe due to extremely high drainage correction factors.

2.4. *Reversing flow directions*

Reversing flow directions represent a very challenging condition for geotextile filters since the basic filtration concept is for the geotextile to act as a catalyst for the upstream soil to form its own filter by selective gradation. If, however, the flow reverses itself, this upstream soil filter suddenly becomes the downstream side with likely disruption, only to reverse again during the next cycle of reversing flow conditions. The disruption of the fabric-to-soil filter occurs with each cycle of reversing flow conditions. Table 1 presents four such cases from the literature. Design guidance for reversing flow conditions is quite limited (see, for example, Luettich et al., 1992) and the Maisner and Myles (2008) reference describes a major lawsuit eventually levied against the designer. The *lesson learned* in this regard is that reversing flow conditions wherein the water is alternating its flow across the geotextile due to tides or pumping by traffic (both highways and railroads) requires careful design and is covered in the cited literature.

Table 1
Geotextile filter failures under reversing flow conditions.

Author	Date	Application	Soil type	Failure
Miller	1978	Tidal weirs	Silty sand	Soil piping caused slope failure
Saxena and Hsu	1986	Railroad	Silty sand	Geotextile clogging caused railroad track distortion
Mlynarek	1998	Highway	Fines in stone aggregate	Geotextile clogging caused pavement distortion
Maisner and Myles	2008	Tidal seawall	Fine sand	Soil piping caused airport runway failure

3. Atypical soil related failures

This section presents a number of geotextile filter failures arising from atypical soils on the upstream side of the filter. All deal with water as the permeant.

3.1. *Cohesionless fine grained soils*

Cohesionless fine grained soils are problematic for geotextile filters. This is due to the contrasting design considerations of having adequate flow capability (requiring relatively open voids) and proper soil retention (requiring relatively closed voids). For poorly graded cohesionless soils passing the #100 sieve (=0.159 mm) this presents the problem of either designing a more open geotextile allowing the fine soil to pass or conversely a tighter geotextile resulting in excessive clogging. Table 2 presents a number of such geotextile filter failures in regard to such upstream soils. Note that all but one had filter openings too large to prevent the upstream soil from migrating into the downstream drainage system. The *lesson learned* in this regard is that cohesionless fine grained soils like rock flour, cohesionless silts, and fly ash represent a design dilemma in that very open geotextiles allow excessive soil to pass downstream (with subsequent upstream cavitation and piping) and very tight geotextiles that can result in excessive clogging. This balance when properly designed requires site-specific soil properties as well as product-specific geotextile properties. Laboratory testing in this regard is also available, see GRI-GT1, ASTM D5105, ASTM D5567 and ASTM D1987.

3.2. *Gap-graded cohesionless soils*

Gap-graded cohesionless soils present a similar problem for geotextile filters as described above but only the fine fraction of the upstream soil migrates to, or through, the filter. Haliburton and Wood (1982) were the first to recognize the situation in the laboratory when using very open woven monofilament geotextiles (percent open areas of 20 to 32%) in which the fine fraction readily passed this type of geotextile. In the field, Lennoz-Gratin (1987) found downstream drain pipe clogging with the fine soil fraction, as did Mlynarek (1998) for a rock rip-rap revetment seawall. The *lesson learned* in this regard is that gap-graded cohesionless soils present a similar challenge as previously described, however, only the fine fraction becomes mobile leaving the coarse fraction remaining in the upstream soil. Usually cavitation and piping does not occur but excessive clogging and/or downstream drain clogging can occur. Again, a properly designed balance has to be reached between carefully measured soil and geotextile properties. Laboratory testing in this regard is also available, see GRI-GT1, ASTM D5105, ASTM D5567 and ASTM D1987.

3.3. *Dispersive clay soils*

Dispersive clay soils upstream of the geotextile filter have been problematic from an excessive clogging perspective in several cases. Hoare (1982) reports on three excessively clogged needle punched nonwoven fabrics, and Crum (2008) mentions dispersive clay clogging of geotextile filters but provides no specifics. The *lesson learned* in this regard is that dispersive clays whereby individual soil particles become fugitive generally results in excessive fabric clogging rather than soil retention issues as the case histories indicate. The situation suggests laboratory testing with the materials under consideration. Such testing should consider the following: GRI-GT1, ASTM D5105, ASTM D5567 and ASTM D1987.

Table 2
Geotextile (GT) filter failures associated with cohesionless fine grained upstream soils.

Authors	Date	Application	Soil type	Failure
Koerner (non published)	1987	GT wrapped concrete pipe joints	Rock flour	Soil loss into pipe
Lennoz-Gratin	1987	GT socked agriculture pipe	Sandy loam	Soil loss into pipe
Mlynarek	1998	GT socked agriculture pipe	Poorly graded silt	Soil loss into pipe
Gabr et al.	1998	GT/geonet composite	Fly ash	Soil loss into geonet
Gardoni and Palmeira	1998	GT wrapped drain	Fine sand	Clogged GT
Khan and Kitazume	2006	GT over seawall joints	Fine sand	Soil loss through caisson wall

3.4. Ferrous iron laden soils

Ferrous iron laden soils leading to *ochre* has resulted in excessive clogging of filters (and to their downstream pipes) on numerous occasions. Ochre is an orange substance rich in organic matter and high concentration of iron oxides that is often found sticking to solid surfaces of many different drainage systems (Forrester, 1995). While ochre is not a soil, per se, it results from certain soil chemistry and is troublesome to say the least (Fig. 5).

Cases of ochre formation in geotextiles are associated with deep horizontal drains (Ford, 1982), the drainage system of a dam (Scheurenberg, 1982), the drainage system of an earth dike (van Zanten and Thaket, 1982), agricultural drainage pipe in France (Puig et al., 1986), land drainage in Holland (Stuyt and Oosten, 1987), and an erosion control system in Germany (Abromeit, 2002). This latter case history described a needle punched nonwoven filter beneath a light armoring system on a tidal river. After eight years of service the geotextile was ochre-clogged reducing its flow capacity by 99.5% of the original. The *lesson learned* in this regard is that a major threat to geotextile filters, as well as with soil filters and all other components of drainage systems, is ferrous iron soils leading to the formation of *ochre*. If ochre cannot be avoided or remediated once it occurs both geosynthetic and natural drainage systems are likely to excessively clog. Laboratory testing in this regard is available and should be considered; see GRI-GT1, ASTM D5105, ASTM D5567 and ASTM D1987 although proper laboratory simulation will be difficult to configure.

4. Unusual permeant related failures

This section focuses on the specific liquid flowing through the geotextile filter under consideration. One could also say the *liquid permeant*, or simply the *permeant*. The tacit assumption in conventional geotextile filter design is that the permeant is water and even further that it is free from turbidity, ions (particularly salts), microorganisms, and/or other foreign matter. To our knowledge all of the filtration design models make this assumption, however, when the permeant is not clear water, failures have occurred as described in this section. All are cases of excessive clogging of the geotextile.

4.1. Oily water and sludges

Oily water and sludges have created geotextile filter failures and in 1980 the first author evaluated an oily film from a refinery which excessively clogged the openings of a woven monofilament filter-point protection mattress. The mattress failed as a result of the hydrostatic pressures that were generated beneath it due to insufficient remaining open area for proper release of the permeant.

In 1988 the authors evaluated several clogged needle punched nonwoven geotextiles placed over outlet drains as shown in Fig. 6. No liquid entered the pipes even though it was under 1.5 m of hydraulic head. This same excessive clogging situation has also occurred in vacuum removal of oil spills in rivers, lakes and oceans but there are no published citations to our knowledge. The *lesson learned* in this regard is that the candidate geotextile(s) must be laboratory evaluated against the site-specific liquid permeant. The permittivity test per ASTM D4491 could easily be configured as a long-term circulating flow test.

4.2. Turbid water with high suspended soils

Turbid water with high suspended solids has caused excessive clogging in both needle punched nonwoven and woven monofilament fabrics. Suits and Minniti (1989) evaluated turbidity curtains used to contain dredged soils which excessively clogged. Similarly, Harney and Holtz (2005) report on clogging to such an extent that the built-up hydraulic pressures caused the fabric to rupture. The *lesson learned* in this regard is that the candidate geotextile(s) must be laboratory evaluated against the site-specific liquid permeant. The permittivity test per ASTM D4491 could easily be configured as a long-term circulating flow test.

4.3. Highly alkaline permeants

Highly alkaline permeants are troublesome when the calcium and magnesium salts come out of suspension and rest on, or within, geotextile filters. In 1985, the first author evaluated such a situation with a pH of 10.5 on a needle punched nonwoven fabric which was

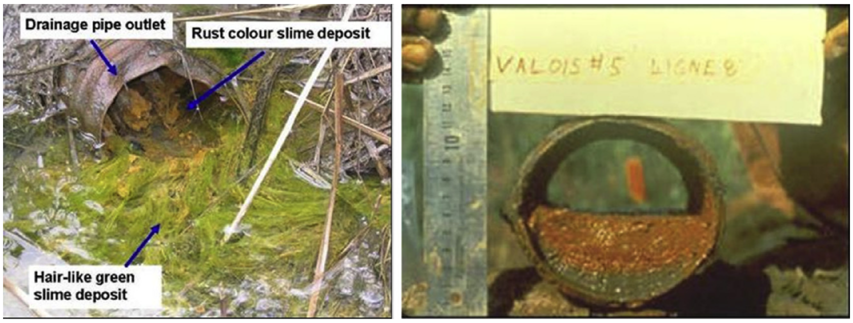


Fig. 5. Ochre deposits around drainage pipes and filters.
After Mendonca and Ehrlich, 2008.

Fig. 6. Oily wastewater sludge clogging geotextile covered drains (GSI photos).

clogged to the extent that a permittivity test could not be performed. Crum (2008) has experience with geotextile filters used in dams, and states: "In addition to particle clogging, the filter fabrics can provide a medium for chemical precipitation or biological growth". The *lesson learned* in this regard is that the candidate geotextile(s) must be laboratory evaluated against the site-specific liquid permeant. The permittivity test per ASTM D4491 could easily be configured as a long-term circulating flow test.

4.4. Landfill leachate

Landfill leachate clogging of drainage systems beneath municipal solid waste has occurred on numerous occasions. Bass (1984), under contract to the U. S. Environmental Protection Agency, found that filters, pipes, cleanouts and sumps had been clogged to varying degrees. His summary in Table 3 illustrates that every aspect of such drainage systems are suspect. Subsequently, Koerner (1993) evaluated three excessively clogged geotextiles around leachate removal pipes and found relatively high contaminant levels of the associated leachates; see Table 4. The micrographs of Fig. 7 illustrate how such *bioclogging* can readily occur with both woven and nonwoven fabrics. The conclusion was that total suspended solids (TSS) and/or biochemical oxygen demand (BOD) values greater than 2500 mg/l were sensitive to excessive fabric clogging, see Koerner and Koerner (1989) and Koerner et al. (1993).

Table 3
Summary of problems with landfill leachate collection and removal systems.

Failure mechanism	Facility type	Cause	Comments
Sedimentation	NS	C	No filter installed
Sedimentation	NS	U	General experience
Sedimentation	Co-disposal	U	In one year old system
Sedimentation	Co-disposal	U	Of gravel layer and pipe
Sedimentation	Municipal	U	General experience
Sedimentation	NS	C	General experience
Pipe breakage	NS	O	By clean-out equipment if bends greater than 22°, general experience
Pipe breakage	Municipal	D	Different settling, improper bedding
Pipe breakage	Municipal	C	Joint not glued
Pipe deterioration	NS	D	Problems with ABS pipe, general experience
Pipe deterioration	Hazardous	O	From acid or solvent disposed of in wrong cell
Tank failure	Co-disposal	D	Leachate holding tank
Capacity exceed	Co-disposal	D	Under design, other problems noted
Outlet inadequate	Co-disposal	D	Caused leachate buildup
Biological growth	Industrial	D	100 ft Long biological growth flushed out under high pressure
Biological growth	Municipal	U	Reduction in flow every two years; flushed out
Biological growth	Municipal	U	Of filter fabric
Biological growth	Co-disposal	U	On 3/4 inch stone, not clogged
Chemical precipitation	Municipal	O	EPA test cell, not clogged
Chemical precipitation	Co-disposal	U	Iron oxide, not clogged

NS = not specified; C = construction related; U = undetermined; O = operations related; D = design related.
Adapted from Bass, 1984.

Corcoran and Bhatia (1996) performed a similar exhumation and found an excessively clogged heat bonded nonwoven geotextile from a leachate with BOD values ranging from 3000 to 20,000 mg/l. Other geotextile filter leachate clogging failures in the literature include Hamilton and Dylinggowski (1989), Brune et al. (1991), Cazuffi et al. (1991), and Mitchell et al. (1993). Leachate collection systems using geotextiles are illustrated in Fig. 8 which indicates the various configurations. Using a "drainage correction factor (DCF)" as defined in Equation (1), the "socked pipe" configurations with their extremely high DCF-values are not recommended. The *lesson learned* in this regard is that the candidate geotextile(s) must be laboratory evaluated against the site-specific liquid permeant. The permittivity test per ASTM D4491 could easily be configured as a long-term circulating flow test. In addition, the ASTM D1987 test method was developed specifically to evaluate geotextiles filtering landfill leachates.

4.5. Wastewater and agriculture waste

Wastewater and agriculture waste liquids are of particular concern with respect to the possibility of excessive clogging of geotextile filters. Davis et al. (1997) discuss sewage lagoon filtration systems where test plate analyses showed bacteria "too numerous to count". There was also iron and manganese present and the geotextile permittivity decreased from an original value of 0.10 s^{-1} to in-situ values ranging from 0.0046 to 0.0017 s^{-1}. Martel et al. (1999) investigated wastewater filtration at temporary military base camps and also focused on TSS and BOD values. Their field work was complimented with a comparable laboratory study. Note, however, that the concentrations were very low in comparison to the raw landfill leachates just discussed.

That said, perhaps the ultimate problematic permeant to challenge a geotextile filter from a biological clogging perspective is

Table 4
Comparison of selected leachate characteristics at three exhumed sites (Koerner, 1993).

Site no.	Landfill type	pH	COD (mg/l)	TSS (mg/l)	BOD_5 (mg/l)
1	Municipal	6.9	32,000	28,000	27,000
3	Industrial	9.9	3000	12,000	1000
4	Municipal	6.1	24,000	9000	11,000

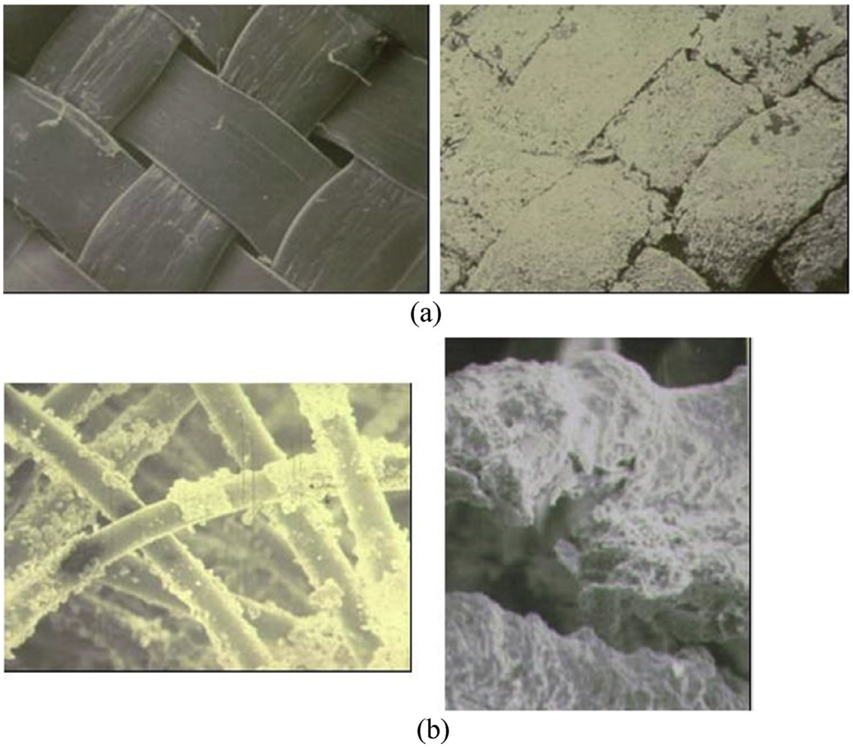


Fig. 7. Micrographs of different geotextile filters before and after “bioclogging”. (a) Woven monofilament geotextile, (b) Needle punched nonwoven geotextile. After Koerner, 1993.

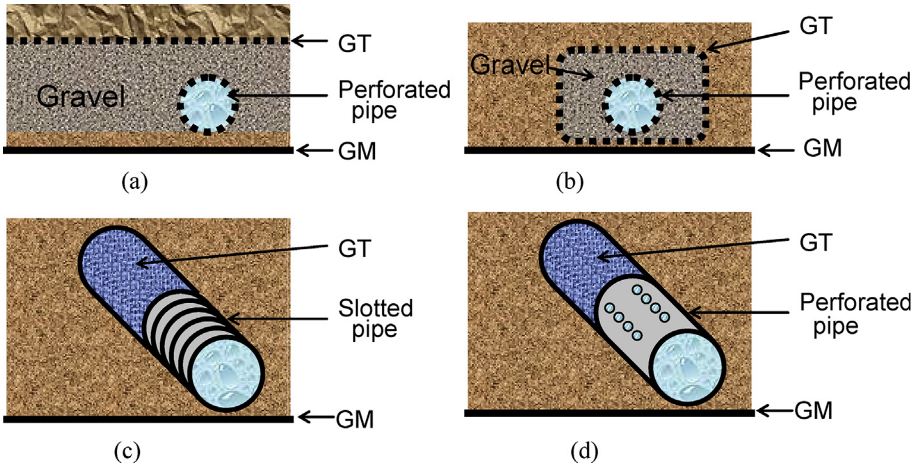


Fig. 8. Typical design-related drainage correction factors, DCFs. (a) Full footprint filter (DCF = 1), (b) GT wrapped drain (DCF = 10 to 40) , (c) Socked corrugated pipe (DCF = 60 to 260), (d) Socked smooth perforated pipe (DCF = 7,500 to 24,000). After Koerner, 1993.

direct agriculture manure slurries. Barrington et al. (1998) have evaluated such situations using three different geotextiles where each resulted in a five-order-of-magnitude decrease in permeability. This was obviously considered to be “excessive” in all cases. The *lesson learned* in this regard is that the candidate geotextile(s) must be laboratory evaluated against the site-specific liquid permeant. The permittivity test per ASTM D4491 could easily be configured as a long-term circulating flow test.

5. Installation related failures

Even with the best of designs and the highest quality filter materials, improper installation practices can, and have, resulted in inadequate performance. This section presents several failures due to improper installation.

5.1. Lack of intimate contact

Lack of intimate contact is, *by far*, the most common field problem associated with installation problems of geotextile filters. Of course, when the geotextile is to be placed horizontally flat on the ground surface and backfilled, intimate contact is automatically achieved. Even wrinkles and folds in the geotextile are generally not of great concern. That said, flat horizontal fabric can be uplifted out of place during service as the following four papers illustrate.

Jubien (1985) describes a site where the subgrade soil was a fine sand beneath a needle punched nonwoven geotextile and water flow uplifted the fabric into the voids of the large overlying stone armor layer. The lack of intimate contact of the geotextile in the stone voids resulted in underlying sand movement eventually causing sliding of the armor downslope.

The authors investigated a similar site in 1987 where the geotextile was fixed to a concrete parapet and the backfilling process caused a large geotextile bubble in the form of a long wave with no normal stress being applied. It was left in this state and subsequently the soil beneath (being a cohesionless sand) easily eroded away over time causing failure of the parapet by overturning.

Faure et al. (1994) report on trench drain problems where the vertically oriented fabric was not in intimate contact with soil on both sides. In several of their cases, the water ran parallel (not through) the fabric and scoured the trench. This eventually caused instability of the trench walls followed by surface subsidence.

Burlingame (2008) reports on two case histories where "there was inadequate contact between the soil being filtered and the geotextile". Settlement and distortions of the overlying rock rip-rap occurred in both instances.

Where there is even greater concern, however, is where the geotextile is to be purposely placed vertical or near vertical. This is certainly the case in the installation of prefabricated highway underdrains. In a nation-wide investigation of geosynthetic drainage systems, Koerner et al. (1994, 1996) report on the exhuming of ninety-one field sites. Of them, forty-one were geocomposite highway edge drains and of this group ten (10) had the upstream geotextile not in contact with the adjacent stone base course beneath the pavement. This is readily seen in Fig. 9. Illustrated in Fig. 9a is the large void commonly created by the trench excavation equipment. This void, under saturated conditions, allows the fine soil particles in the pavement subgrade to act individually and easily pass through the upstream geotextile and enter the geocomposite drainage core. Since highway gradients are often very low, the particles simply do not flush-out and instead they accumulate thereby blocking flow within the drainage core. Fig. 9b shows the proposed remedy to this situation in that the edge drain is now recommended to be moved to the shoulder side of the trench and the upstream side is then backfilled with a hydraulically flowing sand so as to fill the void beneath the pavement and thereby establishing intimate contact with the geotextile.

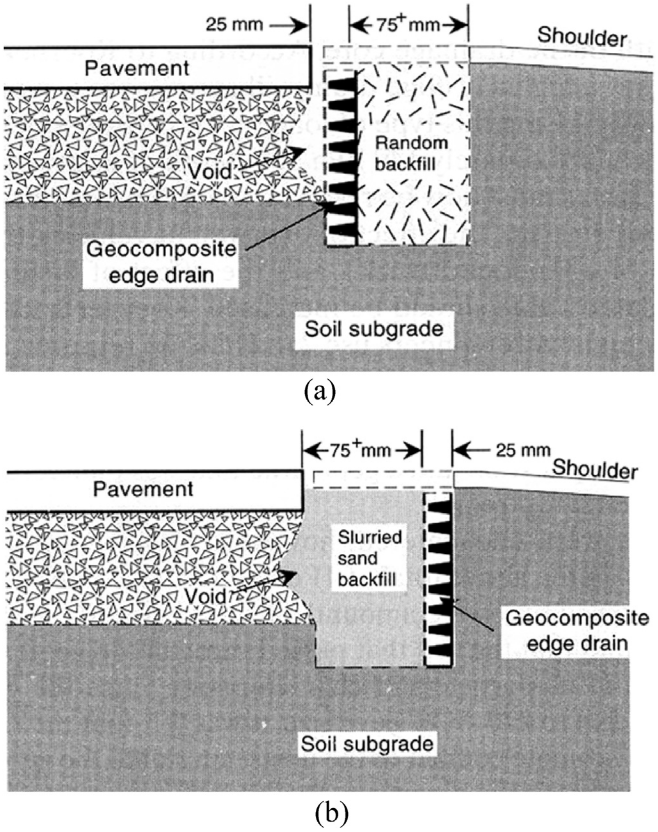


Fig. 9. Intimate contact issue and its avoidance of upstream voids when installing geocomposite highway edge drains. (a) Occurrence of large void(s) beneath a highway pavement preventing intimate contact of the upstream geotextile against the stone base course, (b) Suggested remedy for backfilling large voids via hydraulically placed sand with the geocomposite edge drain moved to the shoulder side of trench. After Koerner et al., 1994, 1996.

An additional four cases of geotextile filter failures were observed in this study. Two cases involved excessive clogging due to reversing flow conditions (recall Section 2.4), another was a socked drainage pipe (recall Section 2.3), and still another was an erosion control filter which had flow occurring beneath it, i.e., a lack of intimate contact as described in this subsection. The *lesson learned* in this regard is that neither construction quality control on the part of the contractor nor construction quality assurance on the part of the inspector was properly practiced. While CQC and CQA practices are common in the geoenvironmental field they appear to be lacking in the geotechnical/transportation/private practice fields.

5.2. *Glued or blocked geotextile surfaces*

Glued or blocked surfaces of geotextile filters obviously are troublesome insofar as proper functioning is concerned. The authors evaluated a bridge abutment failure in 1989 which utilized hexagonal concrete panels, see Fig. 10a. The openings between panels were to have 300 mm wide strips of geotextile filter to keep the soil from escaping as shown in Fig. 10b. Unfortunately in this case history, the contractor glued the entire fabric strip width to the point where absolutely no flow was allowed, see Fig. 10c and d. The result was that the abutment failed and the bridge deck deformed to the point of requiring temporary support, see Fig. 10e and f. The *lesson learned* in this regard is that neither construction quality control on the part of the contractor nor construction quality assurance on the part of the inspector was properly practiced. While CQC and CQA practices are common in the geoenvironmental field they appear to be lacking in the geotechnical/transportation/private practice fields.

6. Summary

This paper has focused on inadequate performance of geotextile filters under difficult and challenging field conditions, see Table 5 for a summary listing. Sixty-nine (69) situations are presented of which forty-five are taken from the literature (references are cited), twelve from the authors published papers or reports (most references are cited), and twelve from unpublished investigations by the authors and others. Soil filters, usually of natural sand, can also be problematic and have been reported in the literature as well. In fact, the exact same challenging field conditions for most geotextile filters also negatively affects soil filters. Focus here, however, was only on geotextile filters. As mentioned in the abstract, however, it should be noted that the vast majority of geotextile filter applications have been successful and the situation presented herein represent the relatively few "outliers" in the technology.

That said, the authors hope is that the designer and specifier of geotextile filters are aware of the above difficult and challenging field conditions which have resulted in inadequate performances as presented in this paper. In as much as soil retention and opening

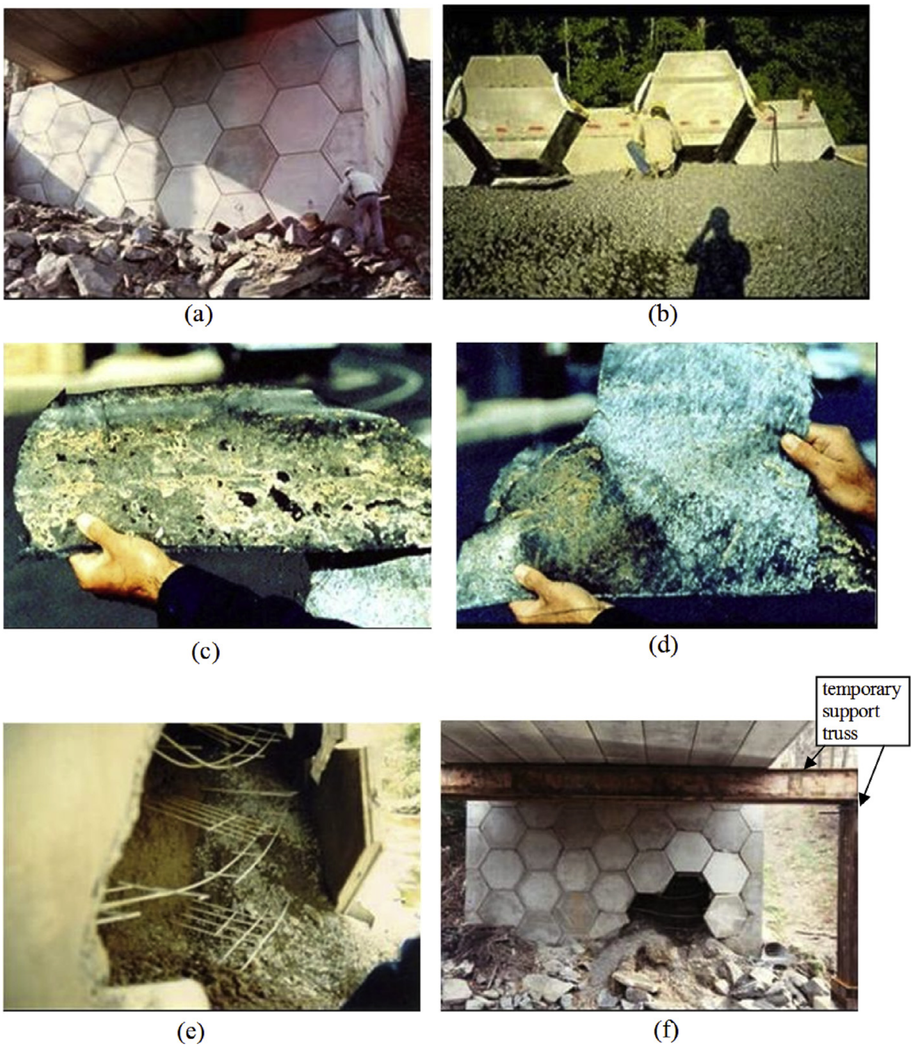


Fig. 10. Case history of improperly installed geotextile filter causing bridge abutment failure. (a) Bridge abutment as constructed using hexagonal concrete panels, (b) Geotextile filter strips over openings, (c) Sample of pieces of completely glue-sealed geotextile “filter”, (d) Another sample of a piece of completely glue-sealed fabric, (e) Close-up of failure showing steel grid reinforcement of concrete panels, (f) Abutment failure showing temporary steel support truss support bridge girders.
After GSI, 1989.

Table 5
Summary of geotextile filter failures presented herein.

Category	Type	No. occurrences	Resulting situation
Design	Poor fabric selection	1	Inadequate fabric voids
	Poor fabric design	5	Inadequate fabric voids
	Socked drainage pipe	2	Inadequate fabric voids
	Reversing flow conditions	6	Soil loss and piping
Atypical soils	Cohesionless fines	6	Soil loss and piping
	Gap-graded soils	3	Soil loss and piping
	Dispersive clays	2	Excessive fabric clogging
	Ochre clogging	6	Excessive fabric clogging
Atypical permeants	Oil and sludges	2	Excessive fabric clogging
	Turbid water	2	Excessive fabric clogging
	High alkalinity water	2	Excessive fabric clogging
	Landfill leachates	10	Excessive fabric clogging
	Wastewater and Agricultural	5	Excessive fabric clogging
Field installation	Lack of intimate contact	16	Soil loss and piping
	Glued filter fabric	1	Excessive fabric clogging
		69	

size can, and should, follow standard design procedures, the atypical soil and liquid permeants of Sections 3 and 4 should give cause for concern. One simply must know the nature of the upstream soil and of its liquid permeant if subsequent problems of geotextile filters are to be avoided in the future. Without this basic information one is simply guessing at the selection of a proper geotextile and hoping for the best in its subsequent performance. Lastly improper installation can negate the best of designs and the highest quality geotextiles. We must always be conscious that installation is critical to proper functioning of geotextile filters, as well as all types of geosynthetics.

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