Developments and guidance in global geosynthetic specification and regulations

Boyd Ramsey
Boyd Ramsey Consulting LLC, USA
Stephen Corbett
AECOM, UK

ABSTRACT:In past history, advancements and increases in the usage of geosynthetic materials have been affected by improvements in technology and product utility and function, but regulatory requirements have also been a component of many significant advancements. Regulatory requirements embody the technological advances and mandate the utilization of improvements in performance, longevity and effectiveness. As geosynthetic systems have matured, this regulatory framework has become more complex, reaching beyond descriptions and requirements for individual products and increasingly embodying a systemic approach utilizing multiple materials, installation techniques and equipment, manufacturing and construction quality assurance systems and the coordinated execution of these items. This paper summarizes the characteristics and techniques of successful specifications and regulations and presents recent examples from around the world. Multiple applications are included, advancing beyond waste management into other applications that use geosynthetics in increasingly large quantities.

Keywords:geosynthetic, geotextiles, geogrids, geomembranes, geosynthetic clay liners, erosion control products, specification, regulation

1 INTRODUCTION

Geosynthetic materials are somewhere in the range of 50 years old. The geosynthetic products are generally considered to be of 4 types: geotextiles, geogrids, geomembranes and GCLs (both barrier products and a variety of geomats, drainage and erosion control products. The respective functions are listed in the table below:

Table 1: Primary Functions of Geosynthetics (from Koerner)

Primary functions of geosynthetics

Type of geosynthetics (GS)	Separation	Reinforcement	Filtration	Drainage	Containment
2.1 Geotextile (GT)	X	X	X	X	
2.2 Geogrid (GG)		X			
2.3 Geonet (GN) or geospacer (GR)				X	
2.4 Geomembrane (GM)					X
2.5 Geosynthetic clay liner (GCL)					X
2.6 Geofoam (GF)	X				
2.7 Geocells (GL)	X	X			
2.8 Geocomposite (GC)	X	X	X	X	X

In nearly all applications, geosynthetic materials are used in place of,or as a supplement to,traditional building materials – sand, soil, gravel, concrete, asphalt and other materials. In most cases, the geosynthetic is used to provide some function that the traditional incumbent material cannot supply. These materials have been developed and commercialized into a more than 3-billion-dollar annual global business because the products have capabilities that traditional materials do not. A short list of these properties might include:

- Longer durability and lifespan
- Capability to construct designs with geosynthetics that are simply impossible without them
- Shorter construction schedules much less likely to be impacted by weather and other factors
- More consistent performance than naturally occurring materials
- Much improved (reduced) environmental impact with geosynthetics

Geosynthetics are used because they work better, last longer and allow new and improved designs. Despite their great benefits, geosynthetics are usually a very minor dollar percentage of an overall project. This is in contrast with the geosynthetic commonly being essential to the success of the project. Most vertical walls could not be built without geosynthetic reinforcement, landfills and water containment projects that are literally too numerous to count require geosynthetic barrier materials, roadways over soft soils require geosynthetics to service their first traffic. Yet in each of these cases, the geosynthetic is commonly <10% of the total project cost. Yet without the geosynthetic, or with a geosynthetic mis-installed, the project will fail, as several have, with significant cost, in the worst instances hundreds of millions of dollars in remediation expense.Specifications should help to prevent these issues, particularly if properly constructed.

2 SPECIFICATION PHILOSOPHY AND COMPROMISES

Although the following sections list components that are specific to each material type, there are several considerations and components that are common to any good specification, those are briefly discussed here.

The primary purpose of a specification is to protect the design and materials selection and to ensure that the necessary intentions of the designer are met in construction and the execution and operation of the project/site. A good specification should be brief. Unnecessary language should be removed, it will likely cause problems and undesired restrictions.

A good specification will consider the continuity between commodity materials and specialty materials. A commodity material likely already has existing specifications by definition. In contrast,specialty materials likely have fewer existing specification resources. It has been common for modification of commodity materials to result in the next advancement or stage of material with additional performance characteristics. A comment should be made here regarding commodity materials vs. specialty or innovative materials. If you specify and buy a commodity material at the lowest possible price, while you may profit in the short term, you will likely be surpassed by those who are being innovative. Innovation costs more in the short term, but always less in the long term as the new benefits are applied.

A good specification will utilize established test protocols. ISO, ASTM, CEN and other national or international organizations have created existing test protocols that address the details of a test, the number of replicates, the variability of a test, the recommended frequency of testing and other factors. These test protocols should be utilized whenever possible and clear statement of minimum or maximum target values (ranges are preferred) and test frequencies established.

A good specification must offer a compromise between index testing and design testing. In an oversimplification, a design test directly assures that a material will perform as expected to achieve the design goal, an index test does not relate directly relate to the design, but instead usually speaks more to product consistency or other considerations. Index tests are generally faster and more broadly utilized with a larger collection of data for comparison. Design tests are usually unsuitable asquality control techniques.

A good specification will address the critical performance indicators: it is most important to assure the materials possesses those properties that are “most important”. For example, a design test may be included in a specification with a “one-per-project” frequency, where an index test may have a frequency that is orders of magnitude more frequent. It is a normal compromise to balance the direct design utility of a test with a desire for a higher frequency. Fabric filtration is a good example of this: a long-term filtration design test, utilizing the exact materials to be filtered may take months, or years to complete. An index test measuring the filtration of glass beads is a common index test, can be completed in hours, but is a compromise in that it does not use the exact material to be filtered. The specification writer must make a compromise between design goals and testing ease and utility.

A good specification will address product and manufacturing consistency. This is usually done with one or more types of index testing. One of the benefits of geosynthetic materials as contrasted with incumbent natural soil materials is that a manufactured product should be more consistent. A good example is the drainage rate of a geosynthetic geocomposite or vertical drain as contrasted with sand. As the sand quality varies with particle size, compaction and other variables, the drainage performance will vary. A manufactured geosynthetic material should be expected to be much more consistent than a soil on an ongoing basis.

A good specification addresses the durability and lifespan of a material. This is typically done through the use of some accelerated testing. This may involve time-temperature superposition and/or the stepped isothermal methodology or exposing the material to higher temperatures than anticipated during normal life or to higher intensity light or chemical concentrations, or some combination of the above. The methods are very complex and should be constructed carefully, however it is important for a specification to contain a component that assures the durability of the material matches the expected design lifespan. Again, this may be an (accelerated) design test such as exposure in a weatherometer, or an index test such as verification of proper concentrations of longer term chemical stabilizers.

A good specification should allow for variation and improvement. Most specifications accommodate this by allowing for "an approved equal". It is important to allow room for advancements in material composition and performance.

There are a few items that should not be included in a specification. It is not advisable to include pricing information – this tends to change over time and while a part of a purchasing decision, it is not suitable for technical analysis. It is further not advisable to include tradenames or specific manufacturers; if you are going to source from a single specific supplier the requirements are of a different type than discussed here. Also, the specification should not address the fate or actions to be taken if a material does not meet some aspect of the specification; this issue is properly a component of an overall quality system and the specification is generally not sufficiently flexible to properly address this situation. Also, the liability issues related to a specification document should be carefully considered. Each significant site and application should have a specification created by an engineer who possess the appropriate and required certifications, professional registrations and experience required by laws in the country of the projects existence.

3 GEOTEXTILE SPECIFICATIONS

As the oldest of the geosynthetics and the product with the broadest range of applications, there are a large number of specifications available for geotextiles. It is important to note that geotextiles are supplied in two primary varieties: woven geotextiles that are made by more historical "loom-type" methods and non-woven (also commonly called 'needle punched") geotextiles. The products share common applications, but also have significant differences, particularly in filtration properties and performance.

Geotextiles are used in many applications; a common listing is filtration, separation, reinforcement, protection and drainage.The functions of reinforcement and drainage, while possibly fulfilled by geotextiles are now commonly supplied respectively by geogrids (and high strength woven geotextiles) for reinforcement and geocomposite materials for drainage.

Geotextile filters have to attend criteria that assure that the base soil will be retained with unimpeded water flow. Available retention criteria and theory concerns the open size(s) of the geotextile to establish the primary performance criteria. Geotextile filtration specifications commonly include apparent opening size, mass per unit area, physical properties and other aspects.

For separation, the primary function of the geosynthetic is to prevent the mixing of multiple soil types, usually where the soil types provide different functionality. The most common application is in road construction, both paved and unpaved roads. A large particle sized base course of gravel or stone for physical stabilization is usually topped with a finer grain soil designed to providedrainage and/or a smoother road surface. If these two soil types are mixed, neither function will be provided to an optimum degree. The geotextile prevents this mixing. One of the common critical attributes in this application is the survivability of the materials during the construction and installation phases. This is measured and controlled by multiple properties.

Geotextiles used as reinforcement are normally high strength woven geotextiles. This function is also provided by the use of geogrids. In some designs non-woven geotextiles are used, in particular in Japan where the use of high strain non-woven geotextiles has been shown to perform well in seismic events. The reinforcement products are subject to more analytical design than for any other function. There are numerous programs now available to allow engineers to design the reinforcements for very steep slopes, basal reinforcements for embankments on soft ground, and reinforcements to voids and as load transfer platforms over foundations with piles or improved with vibro-compacted stone columns or grouted compaction columns. The specification for reinforcements may include both the short term tensile strength and the creep limited tensile strength depending on the nature and the length of time the geotextile will be under load.

Geotextiles with a protection function are intended to minimize damage to other materials, for example geomembranes, due to contact with stones and soils both above and below the geomembrane and for asphalt overlays with cracks in the old pavement. The protection is normally achieved by using thick (5mm or thicker) non-woven geotextiles as protection layers. Design is by carrying out site trials or laboratory tests to simulate the surface loading. Factors to be included in specifications may include a protection efficiency test (Cylinder test or Pyramid Puncture test) and or a puncture resistance test (CBR or Cone Drop). Mass per unit area is also related to the protection function and is commonly specified.

Drainage using geosynthetics is accomplished using geosynthetics with a three-dimensional structure. These may be geotextiles, but increasingly structures called geocomposites and include: geonets, deformed sheets (cuspated), mini pipes or other voided polymeric structures. These are most commonly used with a geotextile filter component on one or both sides as required by the service situation. Very thick needle-punched products can be used as both filters and drainage carrier layers. Important drainage specification components are: In-plane flow capacity under load, compressive creep behavior under vertical and inclined load and durability.

4 GEOGRID SPECIFICATIONS

Geogrids are geosynthetic materials that are used in the construction industry in the form of a reinforcing material. It can be used as a soil reinforcement or used in the reinforcement of retaining walls, steep slopes, dams, levees and other structural bodies. There is a broad range of geogrids available with a variety of materials and constructions. Geogrids are made from polymers such as polypropylene,polyethylene or polyester or other polymers. Geogrids arein the form of open grids so that soil can strike through the apertures and the two materials (soil and geogrid) interlock together to give composite behavior.

A good geogrid specification should include all of the parameters described above. Critical performance criteria are commonly some variant of tensile properties; this may be short-term, longer term or accelerated evaluation of these properties. This may be a wide width specimen of >10 centimeters in tested coupon size, it may be the testing of a joint or junction, it may be the testing of a strand of the geogrid. Other methodologies to evaluate critical performance may be pull-out strength; measuring the force required to remove the reinforcing materials from the soils that are being reinforced. The specifications will vary with the applications: soil stabilization is different from wall construction and as the scope and scale of these two applications vary, additional testing or types of testing could be necessary.

As these products are nearly always buried, the lifespan and durability component of the specification commonly refers to survivability or some sort of reduction factor for damage that is done to the materials during the installation processes. These materials cannot be repaired/replaced after installation, so the requirement to “get it right” the first time is legitimate. Depending on the chemical composition, these materials could be subjected to chemical reactions that will reduce the strength of the material. Chemical compatibility, as well as other long-term performance characteristics should be considered and possible estimates verified by testing or historical performance data.

5 GEOMEMBRANE AND GCL SPECIFICATIONS (BARRIERS)

There is a broad range of barrier materials available and the specifications for these are quite common. It is notunusual to utilize both these materials together in a composite barrier system with both a geomembrane and a clay component. The effectiveness and utility of composite barrier systems is well recognized and most of the world disposes of household waste into facilities using a composite barrier system by regulatory requirement.

Another key consideration is the amount of acceptable leakage. While it is certainly desired that every barrier be “perfect” with no leakage, achieving that goal is expensive. Without considerable support in the form of Construction Quality Assurance, Barrier Integrity surveys and other additional steps, zero leakage is not a realistic goal. However, for many applications, the consequences of minor leakage are not harmful or significant. This is most evident where the liquid being contained is water; be it potable, wastewater, process water, saline water or other. If the emission through the barrier system is water, it is highly unlikely that the consequences of a leak would be seriously damaging to the environment. Thus, some designs have moved from composite systems to systems that potentially may have some leakage, but are significantly less costly and easier to install; geomembrane only or GCL only barriers.

There are well established globally applicable specifications for geomembranes published by the Geosynthetic Institute, the Fabricated Geomembrane Institute and others. Additionally, there are many fine examples of national regulations that address the requirements of a barrier material. These contain all of the segments are components specified above. For geomembranes, suitability is commonly evaluated via physical properties with durability of the materials being testing on an annual or per-formulation frequency. For GCL's the level and type of clay (bentonite) is critical to the performance level and this is commonly tested and certain performance required. Durability of the GCL is commonly not a concern for the clay, as most of these are mined materials that only change format when exposed to specific chemicals or environments. However, the durability of the non-clay components; fabrics, textiles etc., should be verified.

For both these material types another performance consideration is interface friction and slope stability. Evaluations, or historical data should be reviewed to assure that the materials have sufficient stability if placed on a slope and that soils placed on these materials will also be stable at the slope angles expected, plus an additional safety factor. The effects of water, rain events, storms, drainage rates and moisture levels should be a part of this consideration.

6 DRAINAGE MATERIALS

There is a very wide range of drainage materials manufactured within the geosynthetic families and specifications tend to have less commonality than other categories. However, the basic structure and objectives still apply.

The defining parameter is movement of liquid or gases through the geosynthetic: how much, how fast and under what conditions. This may be well defined such as transmissivity or flow rate; key conditions should be documented and the performance requirements, both initially and over the longer time periods of use should be established.

The determined flow rate, as the critical performance mechanism, should be evaluated or compared to historical performance at both design and index conditions. The compression forces that will, over time or as the result of a single event (commonly heavy equipment traffic) reduce the flow through the drainage media should be understood and applied to this testing. Commonly, these materials lack the structure to resist severe mechanical forces and thus should not be used above the limits that they can be exposed to and continue to supply the needed liquid or gas movement.

Durability is also a concern as these materials commonly cannot be repaired/replaced after installation. This may be evaluated as flow rate reduction over time, or a change in the dimensions of the material. This is commonly accelerated by time temperature supposition, or some other manner. Physical properties are commonly used as index tests and thickness and filtration properties are also common components of specifications.

7 EROSION CONTROL MATERIALS

Similarly, to drainage geosynthetics, there is a broad range of erosion control materials manufactured with a variety of constructions. Further, erosion control products have perhaps the least developed number and specificity of specification requirements.

Erosion control falls into two general categories – hard armoring, utilizing stone, concrete or other materials with a geosynthetic component, or softer installations where the erosion is controlled through other mechanisms. Again, durability is a concern and a conscious decision should be made which technique will be used. For hard armoring, strength, surface impact resistance and durability are important. The softer techniques tend to be shorter term and designed to promote plant growth that provides the erosion control longer term. The geosynthetic component of the soft armor has the function of protecting and sometimes sustaining the plant growth for one or more growing seasons, but the eventual longer-term protection is provided by adult plants. Thus, durability is design specific.

With these materials it is also somewhat more common to conduct large scale testing and some laboratories have been established around the world with specific goals to meet this requirement.

Anchoring of the product and other installation techniques are also an important factor and should be a consideration in specification writing. As with all the other materials, there is a cost-performance trade off to be made. There exist organizations specifically established to support the erosion control marketplace and they are included in the references.

8 CONCLUSIONS

Again, the goal of this document is not to provide the reader with a completed geosynthetic specification. The range and scope of civil, geotechnical and geosynthetic engineering applications is too broad accommodate a single, or simple, specification. However, it is important, time saving and appropriate to build on existing information and technology. This paper identifies available existing resources and can provide a very good "jumping off point" for the specification writer. The resources, protocols, organizations and weblinks listed in the references are a good start. There is also more detailed guidance on this topic available from the International Geosynthetics Society and published on their website. Please remember that each significant site should have a specification created by an engineer who possess the appropriate and required certifications, professional registrations and experience required by law in the country of the projects existence. Geosynthetics are very useful and effective materials, but require care and informed experience for selection, design, installation and continued usage to achieve a successful project.

ACKNOWLEDGEMENTS

The author would like to thank his co-authors and the great many regulators, engineers, practitioners and colleagues we have worked with over the years.

REFERENCES AND WEBLINKS

The listing of "good example specifications" is too lengthy to present here in this format. Additionally, as time passes, these links will need to be updated to remain useful and viable. Therefore the links have been consolidated and are presented at the website of the international Geosynthetics Society and linked here: http://www.geosyntheticssociety.org/igs-spec-paper-docs/

Additional reference textbooks are below:

Bezuijen, A., et.al., Editors (2012) Geosystems: Design Rules and Applications, CRC Press ISBN: 9780415621489

Booker, J.R., et.al. (2004), Barrier Systems for Waste Disposal Facilities, Spon Press, ISBN: 9780419226307

Ingold, T. S. (1993) Geotextiles and Geomembranes Handbook, Elsevier Science,eBook ISBN: 9781483292625

Koerner, R. M. (2012), Designing With Geosynthetics, 6th Edition, Xlibris Publ. Co.,

Müller, W.W., (2007) HDPE Geomembranes in Geotechnics, Springer ISBN: 9783642072109

Rowe, R.K., Editor. (2001) Geotechnical and Geoenvironmental Engineering Handbook, ISBN 9781461517290

Scheir, J., (2009) A Guide to Polymeric Geomembranes: A Practical Approach, Wiley, ISBN 9780470519202

Shukla, S.K. (2016) An Introduction to Geosynthetic Engineering, CRC Press, ISBN 9781138027749

Toepfer, G.W., (2015) The Complete Field Guide to Ensuring Quality Geosynthetics Installations: Volume 1: Fundamentals & Geomembrane, Integrity Matters, ISBN: 9780692379691