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The Development of a Benefit/Cost Ratio Matrix for Optimal Selection of a Geosynthetic Material

by

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Introduction

The design-by-function protocol for selecting a particular category of geosynthetic materials for a general application area is quite straightforward. The following matrix is almost intuitive in the minds of those who have a familiarity with geosynthetics.

Table 1 - Identification of the Usual Primary Function for Each Category of Geosynthetic Material

Category of Geosynthetic (GS) Material	Primary Function				
	Separation	Reinforcement	Filtration	Drainage	Barrier
Geotextile (GT)	√	√	√	√	
Geogrid (GG)		√			
Geonet (GN)				√	
Geomembrane (GM)					√
Geosynthetic Clay Liner (GCL)					√
Geopipe (GP)				√	
Geofoam (GF)	√				
Geocomposite (GC)	√	√	√	√	√

Upon identification of a particular category of geosynthetics, however, the selection of an individual product is usually quite a challenge for designers, owners, and specifiers, and is certainly very competitive among various manufacturers supplying materials within a certain category. As such, the choice is certainly not straightforward. For example, the most recent Geosynthetics Magazine "Specifiers Guide" lists the following number of manufacturers and/or suppliers of the different products within the major categories of geosynthetics.

- geotextiles = 23
- geomembranes (non HDPE) = 5
- geomembranes (HDPE) = 8
- geomembranes (fPP) = 6
- geomembranes (PVC/EPDM) = 9
- geomembranes (reinforced) = 13
- geogrids = 17
- GCLs = 3
- geonets = 7
- geocomposites = 13
- geocells = 6
- geoerosion control matl's = 21

Even though some products within each category can sometimes be readily eliminated for a given situation, there will usually be more than one "approximately equal" alternative product.

This White Paper is intended to assist a designer, owner, or specifier in making the final selection of an individual geosynthetic product. It is based on numerically quantifying a specific product's benefits for the pertinent site-specific application and then dividing the resulting value by the estimated installed cost. The highest resulting "benefit/cost ratio" value will be the likely optimal product. At the least, and considering that many of the benefit values are numerically subjective, the use of calculating a number of benefit/cost ratios should eliminate some of the products which are less suitable for the application under consideration.

Benefit Considerations

The specific benefit considerations for most geosynthetic materials can be placed in several general groupings; each of which has numerous properties necessary for comparison purposes. For all of them, there are standardized test methods available and manufacturers list values in their literature and on their websites. Geosynthetics Magazine also has an annual "Specifier's Guide" wherein comparative test data can be obtained.

Insofar as <u>durability</u> is concerned, the usual properties of interest are chemical compatibility, buried durability, exposed durability, and other product specific long-term degradation mechanisms such as stress crack resistance. For <u>mechanical</u> property considerations, there are tensile or compressive strength tests, the accompanying elongation properties, tear/puncture/impact resistances, and expansion/contraction properties. For filtration and drainage considerations there are permeability or transmissivity, soil retention, and long-term flow behavior. For barrier considerations there are liquid and gas diffusion properties.

Finally, the very important installation aspects of geosynthetic materials must be considered. In this grouping are the placement of the material, its seaming or joining, its sensitivity to damage until the covering layer (soil or other geosynthetic) is placed, and its capability of reasonable repair of holes and tears.

Cost Considerations

Geosynthetic materials being polymeric resins by nature (an obvious exception being the bentonite within GCLs) follow the basic price of hydrocarbon products. In addition to the basic resin from which the geosynthetic is made, there are various additives used for the final formulations. These include antioxidants, carbon black or colorants, plasticizers, fillers, etc. Price volatility of all of these components for a particular formulation must be considered for a valid estimated cost per unit area of product. Fortunately, most manufacturers will freely give cost estimates for their particular products. In addition, to the factory cost of the basic material are considerations of project size and location. Obviously, larger and easily accessible projects are reflected in lower unit costs.

Lastly, the cost in the matrix to follow should be the installed cost. Thus, in addition to the particular geosynthetic product being delivered to the job-site, installation costs in accordance with the project's plans, specifications, and quality assurance document must be estimated. In this regard, either the product's manufacturer or a separate installation contractor should be queried for a reliable installation cost estimate.

The Benefit/Cost Ratio Matrix

To illustrate the development and use of a benefit/cost ratio matrix, we propose the *example of selecting an exposed geomembrane to line a surface impoundment for industrial waste water*. It is, of course, a very common application for which there are numerous candidate geomembranes that are available (recall the previous listing of available nonreinforced geomembranes). In the table to follow, it will be seen that five candidate geomembranes are listed along with their nominal thicknesses, and the identification that they are nonreinforced (NR). With this information, and the project size and location, manufacturers and/or installation contractors can give reasonable installed cost estimates. Also in the table to follow, it will be seen that the property values are grouped according to durability, mechanical, barrier, and installation/maintenance. Within each grouping there are the individual properties of concern.

In the example matrix (which is completely hypothetical), relative numeric values are assigned to each of the property values selected. These properties are each given "weighting values", varying from 10 (most important)-to-1 (least important). The numeric values are selected by the designer/owner/specifier on the basis of each property's relevance to the site-specific application.

Next, the individual candidate geomembranes are numerically valued for each of the specific test properties under consideration. It is here where a familiarization with the different geomembranes is extremely important. Without such familiarization (a.k.a., experience), the value of the entire process becomes less definitive and less reliable. The scale we suggest for these “value factors” ranges from five (most suitable)-to-one (least suitable).

By multiplying each property’s “weighting factor” times the individual geomembrane’s “value factor” and then summing the resultant values, a total benefit value for that particular geomembrane is obtained. This total benefit value divided by the estimated installed cost of the specific geomembrane results in the desired values of the benefit/cost ratio for each candidate geomembrane.

Finally, by comparing each geomembrane’s benefit/cost ratio to the others, the highest numeric value becomes the candidate geomembrane. It suggests that this is the optimal geomembrane for the site-specific application under consideration. Note that the unit of cost, e.g., dollars per square foot, dollars per square meter (the example), euros per square meter, etc., is irrelevant as long as all of the products are treated similar to one another.

Concluding Comments

This type of basic concept for a benefit/cost ratio determination as just described, is felt to be intuitive and the preceding process is no more than a formalized procedure for the decision-making process. Obviously, it can be done in a similar manner for all geosynthetic materials vis-à-vis their site-specific applications.

An important last step in the process is to be sure that the selected material’s cost remains constant for the actual bidding of the project when it is eventually commenced. For example, if costs have risen, the outcome might be quite different since the single item of installed cost in the denominator of the ratio is much more significant than any of the specific numbers that go into arriving at the benefit value in the numerator of the ratio.

Table 2 - Example Benefit/Cost Ratio Matrix for Geomembrane Selection of a Surface Impoundment Liner Containing Industrial Waste Water

Material Property	Weighting Factor	GM1 (1.5 mm – NR)		GM2 (1.25 mm – NR)		GM3 (1.0 mm – NR)		GM4 (1.0 mm – NR)		GM5 (0.75 mm NR)	
Durability:											
Chem. Resistance	7	5	35	5	35	4	28	5	35	3	21
UV Resistance	10	5	50	4	40	4	40	5	50	2	20
Expected Lifetime	10	5	50	4	40	4	40	4	40	2	20
Stress Crack Resistance	10	2	20	5	50	5	50	5	50	5	50
Mechanical:											
Tensile Strength	4	5	20	3	12	3	12	3	12	2	8
Tensile Elongation	8	2	16	3	24	4	32	3	24	5	40
Tear Resistance	8	4	32	3	24	3	24	3	24	3	24
Puncture Resistance	9	5	45	4	36	3	27	3	27	3	27
Impact Resistance	9	3	27	4	36	4	36	5	45	4	36
Shear Strength	5	5	25	5	25	4	20	4	20	4	20
Exp./Cont.	4	1	4	2	8	3	12	3	12	4	16
Barrier:											
WVT	4	5	20	4	16	4	16	5	20	3	12
SVT	1	1	1	1	1	1	1	3	3	4	4
Installation/Maintenance:											
Placement	7	2	14	3	21	4	28	4	28	5	35
Seaming	10	2	20	3	30	3	30	1	10	5	50
Drainage Sensitivity	8	3	24	3	24	3	24	3	24	3	24
Repairs	8	3	24	3	24	3	24	2`	16	2	16
Total Benefit	n/a	-	427	-	446	-	444	-	440	-	423
Installed Cost (Dollars per sq. meter)	n/a	-	6.50	-	5.90	-	8.00	-	8.00	-	5.60
Benefit/Cost Ratio	n/a	-	65.7	-	75.6	-	55.5	-	55.0	-	75.5

Note: The result is that GM2 and GM5 are essentially equivalent for this hypothetical example.