GEOSYNTHETIC INSTITUTE'S EFFORTS IN ACCREDITATION AND CERTIFICATION

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ABSTRACT

This paper reports on two programs at the GSI that have been very successful for the past ten years. These ongoing efforts were conceived by Robert Koerner in the early to mid 1990's. The programs have been embraced by agencies, companies and institutes on four continents around the world. The programs deal with laboratory accreditation and product certification as they relate to geosynthetics. Each topic is presented as to its current status and anticipated future developments. The essential thrust of the paper recognizes that geosynthetics are a viable and relatively developed subset of engineering materials. As such, the industry needs support programs such as these to champion their quality world-wide. In short, the time is right for both accreditation and certification of geosynthetics.

ACCREDITATION

The Geosynthetic Accreditation Institute-Laboratory Accreditation Program (GAI-LAP) was initiated following numerous requests to accredit the operations of testing laboratories within the geosynthetic community. The following flow diagram outlines the accreditation process.

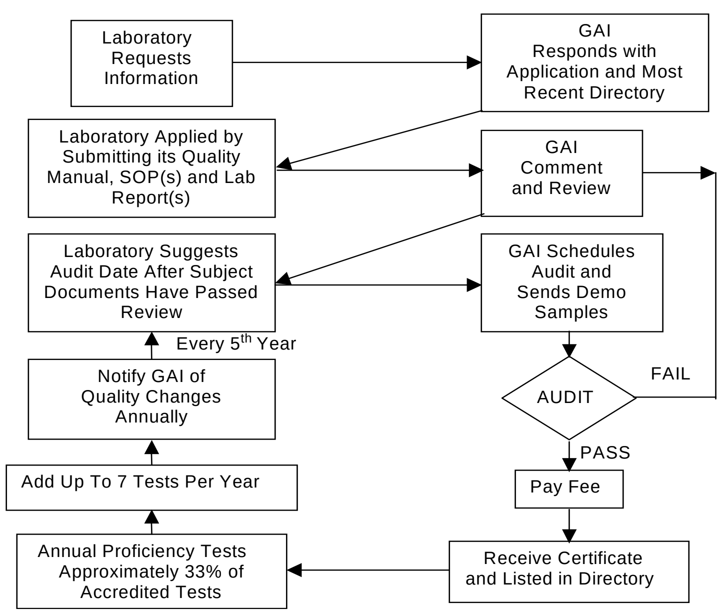

Figure 1. GAI-LAP Flow Chart

The program is intended to monitor a particular geosynthetic laboratory's capability. The program's goal is to accredit geosynthetic laboratories for performing consensus standardized test methods insofar as equipment, documentation and testing protocol is concern. It is important to note that this program is not meant to certify individual test results.

Accreditation was first requested by state and regional Environmental Protection Agency regulators, during a series of courses taught nationally in 1989 (on liner systems) and again in 1990 (on cover systems). Subsequently, a survey of GSI member organizations listed the lack of geosynthetic laboratory accreditation as a severe shortcoming of the industry.

The GAI originally framed the accreditation programs around two international known standards; ISO 9003 and ISO Guide 25. Although the GAI-LAP models itself after these standards it does not profess to be affiliated with ISO or any other accreditation organization. Rather, the program is a hybrid one tailored to the immediate needs of the geosynthetic testing community. At present, the program follows ISO 17025, "General Requirements for Competence of Testing and Calibration Laboratories," which is the second generation of ISO Guide 25. Most accreditation bodies follow this international standard and in the spirit of harmonization are striking cooperative agreements between different accreditation programs.

It is anticipated that the GAI-LAP has a threefold effect on geosynthetic testing. First, it lends credibility to those laboratories that are properly equipped and prepared to do the respective tests. Second, by omission, it eliminates those laboratories that are not equipped to do specific tests. Thirdly, it requires a laboratory to prepare and keep current support documentation for testing. Such documentation includes a quality manual, test-specific standard operating procedures, test reports, project file, equipment files, corrective action records, etc.

The intent of the GAI-LAP is to prevent errors and inaccuracies by following an approved plan and utilizing standard procedures. By so doing, it is hoped that the funds expended in geosynthetic testing are being well spent with clear objectives in mind. The intent of this endeavor is to have a system in place that will aid communication and be accompanied by a paper trail of documentation. The program is rigorous in comparison to the current state-of-the-practice in geosynthetics laboratory testing. It should be mentioned that despite its voluntary nature, competitive pressures might make accreditation seem like a necessity. This is particularly true for laboratories that do federally funded work or are involved with international work.

Currently there exists a family of geosynthetic laboratories that care about the quality of their work, the up-to-date status of their procedures, and the accuracy of their product, i.e., the test results. This family of laboratories has earned GAI-LAP accreditation. To earn this status, these laboratories have demonstrated the required quality control operations and correct internal operating procedures. These laboratories have proven their ability to do the test correctly via on-site audits and proficiency tests. The group currently consists of 47 laboratories, of which 24 are third party independent, 17 are manufacturers QC, and 6 are either institute or government laboratories. Figure 2 illustrates the ten year trend for both the number of tests and number of laboratories participating in the program. The graph clearly shows that there has been a rapid rise of new test methods, with a near tripling of methods covered in a ten year period. The number of labs showed a steady increase over the first eight years, with a leveling off over the past two years.

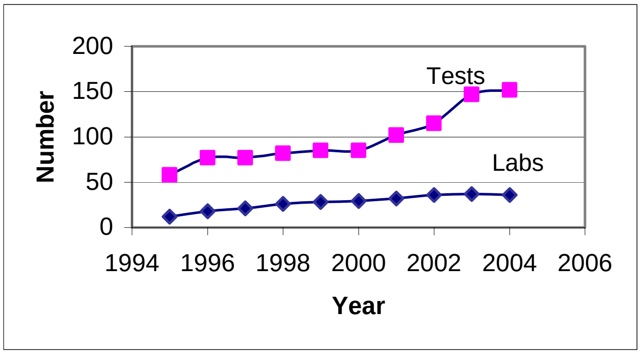

Figure 2. GAI-LAP Trends over its First Ten Years

As the testing arena expands, there needs to be a mechanism in place to add tests to one's repertoire. A maximum of seven tests a year can be added annually without requiring an on-site audit. The following steps are needed in this regard;

1. Submit standard operating procedures (SOP) for each desired test method.
2. Submit laboratory reports for each test identifying the respective standard requirements in addition to the report requirement of ISO 17025.
3. Submit copy of the correct revision of the standard test method
4. Update Document Control Checklist showing new entries.
5. Update equipment inventory showing new or existing equipment covering the new method(s).
6. An internal reference material (IRM) file for the new test. Such an IRM usually identifies the method, description, reference material (or gauge standard), units, average, upper control limit, lower control limit and frequency for each GAI-LAP accredited test.
7. Conduct a proficiency test.

This submitted information is reviewed and must be judged adequate before tests are accredited. Obviously, the proficiency test result needs to be within the control limits for the specific test desired.

In lieu of on-site audits each year, compliance is judged based on proficiency testing. This program can provide the assurance that testing procedures and equipment are adequate and helpful in efforts to maintain control of quality in the laboratory. Results can be compared with others on a national or international basis. All data is maintained in strict confidence but all data is disseminated with the group. As such, the repeatability and reproducibility of each test can be determined. Knowing the average and the standard deviation for each geosynthetic test allows a rank to be assigned to each submittal. One's quality for a given test can be judged from such a rank.

Since the inception of the accreditation program approximately two percent of the submittals have been outliers beyond the required two standard deviation reproducibility database. In all cases, root cause of these outliers was identified and corrective action identified individually. Subsequently, "lessons learned" articles for recurring problems in the form of hints for better testing have been published to add in the educational process. This information is sure to aid in the establishment of precision and bias statements for all geosynthetic test methods.

As stated earlier, a major goal of the GAI-LAP program is to assure that all labs are generating repeatable and reproducible results, i.e. we want everyone to get the "same" numbers. A result is complete only when accompanied by a quantitative statement of its uncertainty. The uncertainty is required in order to decide if the result is adequate for its intended purpose and to ascertain if it is consistent with other similar results. In keeping with the ISO quality standard and in an attempt to quantity this rather complex issue we have compiled Tables 1 and 2.

Table 1, presents the accuracy of laboratory equipment found in most geosynthetic labs. This is the first component, and rather minor contributor if controlled, to variations in results. But it is necessary that we are dealing with calibrated equipment to the tolerances shown in the last column of Table 1. As you can see, accuracies greater than 1% are uncommon. However, no discussion about uncertainty can be approached without knowing that we are dealing with well maintained and controlled equipment.

Over the years, many different approaches to evaluating and expressing the uncertainty of measurement results have been used. Because of this lack of international agreement on uncertainty measurement, there is much confusion. The uncertainty in the result generally consists of several components which may be grouped into categories according to the way in which their numerical value is estimated. Factors involved are generally considered, but not limited to, instrument differences, operator, sampling, time, and variation in the environment.

Table 1. Accuracy of Typical Geosynthetic Laboratory Equipment

Equipment	Standard Used for Verification	Accuracy
CRE Machine for load/force	ASTM E4, Practices for Force Verification of Testing Machines	+/- 1%
CRE Machine extensometer	ASTM E83, Practice for Verification and Classification of Extensometers	+/- 0.5%
Pressure Gauge	ASTM D5720, Practice for Static Calibration of Electronic Transducer Based Pressure Measurement Systems for Geotechnical Purposes	+ 1%
Thermocouple	ASTM E77, Test Method for Inspection and Verification of Thermometers	+/- 0.5 deg C
Timer/ Stopwatch	MIL 45662A	+/- 0.25%
Volume	E694, Specification for Volumetric Ware	+/- 0.5%
Gas Flow	NIST 18010C	Class dependant
Water Flow	NIST 18020C	Class dependant
Balance	ASTM D4753, Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock and Related Construction Materials	0.5%
Mass	ASTM E617, Specification for Laboratory Weights and Precision Mass Standards	Class 1, 2, 3, or 4 dependant
Micrometer/ Caliper/LVDT	ASTM D6027, Practice for Calibrating Linear Variable Differential Transducers for Geotechnical Purposes	+/- 1%
Gage Block Set	NIST Traceable	+/- 0.001 in.

These factors are subsequently grouped together to establish a repeatability limit carried out by a single laboratory and a reproducibility limit attainable between determinations performed in different laboratories. In the simplest of presentations, the uncertainty is then calculated as the square root of the sum of the squares of the repeatability (Sr) and the reproducibility (SR). Table 2 presents the GAI-LAP current best estimate for the majority of the tests in the program. The uncertainties are large in some cases but typical of other construction materials.

Table 2. Uncertainty of Most GAI-LAP Tests

#	Standard	Name	Repeatability Sr	Reproducibility SR	Uncertainty %
1	ASTM D374	thickness	0.14	0.23	**27**
2	ASTM D413	adhesion	0.1	0.17	**20**
3	ASTM D471	liquid effect	0.035	0.088	**9**
4	ASTM D570	adsorption	0.057	0.108	**12**
5	ASTM D638	tensile	0.06	0.1	**12**
6	ASTM D696	coef. thermal exp.	0.03	0.05	**6**
7	ASTM D746	impact	0.1	0.2	**22**
8a	ASTM D751	thickness	0.09	0.17	**19**
8b	ASTM D751	mass/unit area	0.12	0.19	**22**
8c	ASTM D751	tear	0.11	0.19	**22**
8d	ASTM D751	grab	0.09	0.16	**18**
8e	ASTM D751	hydrostatic	0.15	0.36	**39**
9	ASTM D792	specific gravity	0.002	0.005	**1**
10	ASTM D882	strip tensile	0.03	0.08	**9**
11	ASTM D1004	90 deg. tear	0.08	0.2	**22**
12	ASTM D1149	ozone	0.3	0.4	**50**
13	ASTM D1203	volitile loss	0.09	0.23	**25**
14	ASTM D1204	dimensional change	0.25	0.17	**30**
15	ASTM D1238	melt flow index	0.03	0.095	**10**
16	ASTM D1388	stiffness	0.21	0.27	**34**
17	ASTM D1505	density	0.01	0.01	**1**
18	ASTM D1593	PVC thickness	0.07	0.1	**12**
19	ASTM D1603	CB content tube	0.01	0.01	**1**
20	ASTM D1621	compression	0.12	0.18	**22**
21	ASTM D1693	ESC bent strip	0.58	0.94	**110**
22	ASTM D1777	textile thickness	0.14	0.23	**27**
23	ASTM D1790	low temp. impact	0.04	0.15	**16**
24	ASTM D1822	impact	0.06	0.12	**13**
25	ASTM D1987	bio fouling	0.3	0.4	**50**
26	ASTM D2136	low tem. Bend	0.2	0.3	**36**
27	ASTM D2240	durometer	0.01	0.03	**3**
28	ASTM D3015	CB disp. hot plate	0.17	0.15	**23**
29	ASTM D3030	volitile matter	0.04	0.1	**11**
30a	ASTM D3083	soil burial	0.24	0.35	**42**
30b	ASTM D3083	water extraction	0.1	0.22	**24**
30c	ASTM D3083	seam strength	0.09	0.14	**17**
31	ASTM D3776	weight woven textiles	0.04	0.19	**19**
32	ASTM D3786	mullen burst	0.06	0.09	**11**
33	ASTM D3895	Std. OIT by DSC	0.05	0.13	**14**

34	ASTM D4218	CB content-muffle	0.03	0.06	**7**
35	ASTM D4355	xenon arc	0.2	0.3	**36**
36	ASTM D4437	field shear and peel	0.09	0.11	**14**
37	ASTM D4491	permittivity	0.16	0.32	**36**
38	ASTM D4533	trap. Tear	0.09	0.14	**17**
39	ASTM D4545	factory shear and peel	0.09	0.11	**14**
40	ASTM D4594	GT temp. stab.	0.2	0.3	**36**
41	ASTM D4595	GT WWT	0.11	0.24	**26**
42	ASTM D4603	viscosity PET	0.1	0.15	**18**
43	ASTM D4632	GT grab	0.08	0.13	**15**
44	ASTM D4716	transmissivity	0.19	0.32	**37**
45	ASTM D4751	AOS	0.081	0.14	**16**
46	ASTM D4833	pin puncture	0.09	0.12	**15**
47	ASTM D4844	GT seam strength	0.12	0.32	**34**
48	ASTM D4885	GM wide width	0.11	0.14	**18**
49	ASTM D4886	abrasion	0.25	0.35	**43**
50	ASTM D5035	strip tensile	0.07	0.087	**11**
51	ASTM D5101	gradient ratio	0.2	0.25	**32**
52	ASTM D5141	silt fence test	0.35	0.55	**65**
53	ASTM D5199	thickness	0.018	0.045	**5**
54	ASTM D5261	mass/unit area	0.05	0.12	**13**
55	ASTM D5262	tensile creep	0.2	0.3	**36**
56	ASTM D5321	direct shear	0.2	0.22	**30**
57	ASTM D5322	9090 immersion	0.25	0.35	**43**
58	ASTM D5323	2% secant modulus	0.06	0.1	**12**
59	ASTM D5397	NCTL stress crack	.13	.16	**21**
60	ASTM D5493	perm. under load	0.1	0.15	**18**
61	ASTM D5494	pyramidal puncture	0.1	0.14	**17**
62	ASTM D5514	hydrostatic puncture	0.15	0.2	**25**
63	ASTM D5567	HCR	0.25	0.3	**39**
64	ASTM D5596	CB dist. microtome	0.11	0.15	**19**
65	ASTM D5617	multi-axial	0.15	0.2	**25**
66	ASTM D5721	oven aging	0.11	0.15	**19**
67	ASTM D5747	9090 immersion	0.25	0.35	**43**
68	ASTM D5884	tear R-GM	0.1	0.14	**17**
69	ASTM D5885	HP OIT by DSC	0.023	0.091	**9**
70	ASTM D5887	GCL flux	0.22	0.37	**43**
71	ASTM D5890	swell index	0.035	0.145	**15**
72	ASTM D5891	fluid loss	0.033	0.12	**12**
73	ASTM D5970	outdoor exposure	0.21	0.27	**34**
74	ASTM D5993	GCL mass/unit area	0.023	0.039	**5**
75	ASTM D5994	GM core thickness	0.14	0.23	**27**
76	ASTM D6140	asphalt retention	0.25	0.3	**39**

77	ASTM D6214	chem. peel and shear	0.12	0.17	**21**
78	ASTM D6241	CBR puncture	0.15	0.2	**25**
79	ASTM D6243	GCL direct shear	0.25	0.3	**39**
80	ASTM D6244	pavement comp.	0.25	0.35	**43**
81	ASTM D6364	short term comp.	0.1	0.15	**18**
82	ASTM D6392	thermo peel and shear	0.09	0.11	**14**
83	ASTM D6454	TRM compression	.13	.19	**23**
84	ASTM D6475	ECB mass/unit area	.06	.16	**17**
85	ASTM D6496	GCL peel	0.036	0.084	**9**
86	ASTM D6524	TRM resiliency	.15	.20	**25**
87	ASTM D6525	ECB thickness	0.14	0.23	**27**
88	ASTM D6566	TRM mass/unit area	.05	.18	**19**
89	ASTM D6567	TRM light penet.	.11	.17	**20**
90	ASTM D6574	radial transmissivity	.16	.19	**25**
91	ASTM D6575	TRM stiffness	.2	.25	**32**
92	ASTM D6636	GM ply adhesion	0.06	0.1	**12**
93	ASTM D6637	GG tensile	0.11	0.24	**26**
94	ASTM D6638	connection strength	.18	.21	**28**
95	ASTM D6693	GM pullout	0.06	0.1	**12**
96	ASTM D6706	pullout	.15	.24	**28**
97	ASTM D6766	9090 GCL	.2	.3	**36**
98	ASTM D6767	bubble point	.08	.12	**14**
99	ASTM D6768	GCL tensile	0.066	0.113	**13**
100	ASTM D6818	TRM tensile	.1	.17	**20**
101	ASTM D6992	TTS using SIM	.12	.20	**23**
102	ASTM E96	WVT	0.2	0.25	**32**
103	ASTM F904	ply adhesion	0.2	0.25	**32**
104	ASTM G154	UV practice	.17	.31	**35**
105	ASTM G155	xenon arc practice	.15	.22	**27**

Although preliminary, the results of Table 2 point out the poorly behaved tests. Well behaved tests are those with uncertainties less than 10. Robert Koerner (2002) in his paper entitled "Beyond Factor of Safety: The Probability of Failure," uses Duncan's (2000) approach which requires these values for their probabilistic designs. It is imperative to tighten up on these factors affecting uncertainty. Participation in the GAI-LAP will facilitate this worthwhile aim.

A Conflict Resolution Service is also available within the accreditation program. A summary of the procedure for this service is listed below;

1. After contacting both parties, try to resolve the conflict quickly by a phone conversation.

2. If this is not possible, request the test report/data sheets in question be sent and try to access inconsistencies that may have led to conflict.
3. If resolution is not apparent, request SOPs, latest equipment calibration/verification and IRM/gauge standard file for the test in question. Try to determine if there is a procedural inconsistency or an equipment problem.
4. If resolution is still not apparent, request a sample of the material in question for testing at the reference test laboratory. Try to determine if there is a material variability, or a nuance with the material, which leads to the inconsistency.
5. Upon a peer review of all the evidence acquired, assign a route cause opinion of the data in question.
6. There is no charge for the above service.
7. A written description of the resolution is made for the purpose of knowledge preservation.

The service is popular and appears to be adding credibility to the geosynthetic testing industry. It is a pleasure working the labs participating in the GAI-LAP program and I thank them for their participation. If you have questions, please check out the GSI home page at the following address **<<www.geosynthetic-institute.org>>** for more details.

CERTIFICATION

The geosynthetic certification program is identified as the Geosynthetic Certification Institutes-Product Certification Program (GCI-PCP). The program is set up to verify a manufacturer's ability to consistently provide product conforming to a particular generic specification. This program, combined with conformance testing by a GAI-LAP accredited laboratory, is aimed at achieving customer satisfaction by assuring product conformity knowing that the geomembrane was manufactured with a ISO 9000 quality system in place.

Figure 3, shows a flow chart of the essential steps in the certification program. The program is administered on a six-month cycle and is combined with conformance testing by a GAI-LAP accredited laboratory. Note that there is a rigorous review of the six-months previous to the audit of statistical process control data to assure quality between audits. In general, the program is aimed at achieving customer satisfaction by assuring product conformity to a given generic specification.

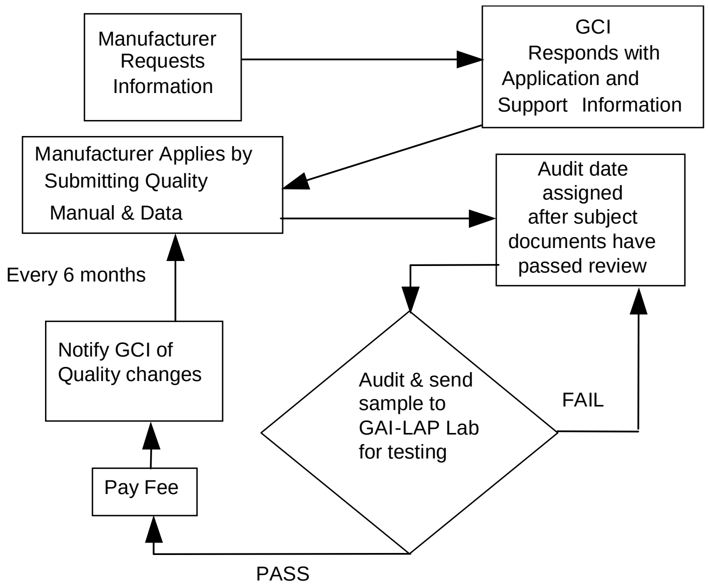

Figure 3. GCI-PCP Flow Chart

If the auditor is satisfied with the submittal an audit is arranged. At the audit a review of the on-going and past statistical data is discussed. The auditor accesses all operating systems which directly influence the finished product. Of particular interest is the quality of the incoming resin and master batch, which includes both carbon black and the antioxidant package. The manufacturer's certification on the part of its suppliers is openly discussed in addition to a frank discussion about endurance aspects of the formulation.

If the outcome of the review is positive and certification is granted, the manufacturer carries the right to identify its product as "GSI-GMXX Certified." Like many engineered building materials geosynthetics now have a comprehensive means of assuring their quality. Such activities like the certification program will aid the end users overall confidence in geosynthetics. With the awareness of certification programs, it becomes critical to have the user community avail themselves of this program. Geosynthetics can no longer be characterized as new materials. They are readily available, are regularly designed, commonly tested, and contractor installed throughout the world. Further maturation of our industry suggests that the geosynthetics are viable and will be used with confidence for a long time to come.

To date, two companies have obtained GCI-PCP certification for HDPE geomembranes conforming to the GRI GM13 specification. They are Serrot Corporation of Henderson, Nevada (now part of GSE Lining Technology) and SL Limitada of Antoagasta, Chile. We congratulate both of these companies and thank them for their leadership.

SUMMARY AND CONCLUSION

In every technology there is a beginning, maturing, and long-term sustainable time frame. This paper suggests that some geosynthetics have entered into the maturing stage, at least for some applications. Like many engineered materials geosynthetics now have a comprehensive means of assuring their quality. Such activities like accreditation and certification will aid the end users overall confidence in geosynthetics. With the awareness of the activities describes herein, it becomes critical to have the user community avail themselves of these programs.

Standardization is inevitable for the geosynthetic industry, and we hope that the industry will benefit by the experiences presented in this paper. Geosynthetics are rapidly finding their way into myriad applications in a great number of transportation, geotechnical, hydraulic, and environmental applications. Each one of these applications requires different functions of the geosynthetic and therefore different physical, mechanical, hydraulic and endurance properties. Since we often are not designing on a case by case basis, it is believed to be prudent to implement checks and balances to assure that such materials function properly for the long term. The precedence for this mindset has been established by such construction materials such as wood, concrete, asphalt, aggregate etc. Geosynthetic materials have come of age to take their rightful place along side such materials.

I would like to take the liberty to close with an anecdote that I overheard spoken to my father by an attorney who regularly reviews GSI activities. The attorney was genuinely impressed with both of these programs and parted with a comment that you "must love your son very much to entrust him with such a vital part of the business." I do not know if this was admiration, jealousy or guilt, but I am very thankful to be Bob Koerner's son and very grateful that he had the foresight to prepare for the future. It is a pleasure working with him and I look forward to a bright future of collaboration.

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