GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

Panorama

Hard 8

Eight welders from Solmax have obtained HDPE welding certification through the International Association of Geosynthetic Installers (IAGI). Congratulations go to S. Bissonnette, E. Bourdages, N. Faucher, Y. Faucher, S. Goyette, R. Marques, R. Rheault, and C. Sasseville.

For more information on IAGI certification, contact International Association of Geosynthetic Installers, P.O. Box 18012, St. Paul, MN 55118-0012; +1 651 554 1895, fax +1 651 450 6167, e-mail iagi@iagi.org, Web site www.iagi.org.

For more information about Solmax, contact Bob Denis at Solmax International, 2801 Marie-Victorin, Varennes, PQ J3X 1P7, Canada; +1 450 929 1234, fax +1 450 929 1227, e-mail international@solmax.com, Web site www.solmax.com.

ASTM update

ASTM International has revised standard D6768, *Standard Test Method for Tensile Strength of Geosynthetic Clay Liners*. The new designation is D6768-04.

Recent work items include:

• WK5429, *Standard Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembrane* is a work item revision to existing standard D6747-02

• WK5461, *Standard Test Method for Determination Residual Blowing Agent in Extruded Polystyrene Foam via Gas Chromatography*

• WK5511, *Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics* is a work item revision to existing standard D1693-01

Also, a new standard has been approved: D6980, *Test Method for Determination of Moisture in Plastics by Loss in Weight* is a new standard, now available as D6980-04.

See also page 22.

For more information, contact Christine Sierk, staff manager, ASTM International, P.O. Box C700, West Conshohocken, PA 19428-2959; +1 610 832 9728, e-mail csierk@astm.org, Web site www.astm.org.

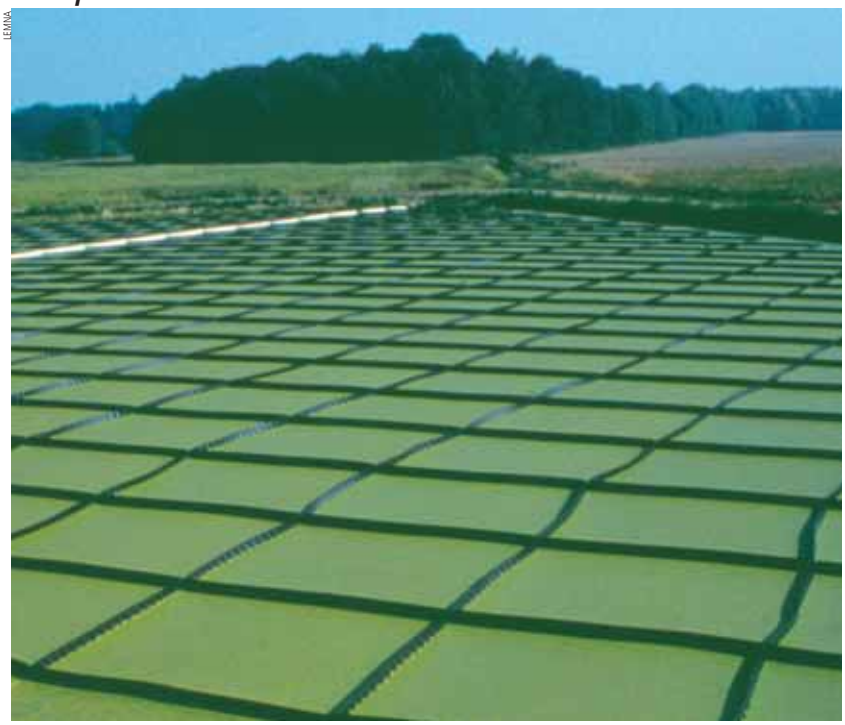
Letter to the editor

Leach pad designs

In the May 2004 *GFR* article "Improving heap leaching" the authors, like many design engineers, present us with an interesting conflict when they state: "It is important to note that the use of a geocomposite drainage layer would likely require the use of a textured polyethylene geomembrane around the perimeter in the stability zone to preserve the geocomposite /geomembrane interface shear strength."

Usual liner design philosophy is that a geomembrane is to be used as a barrier only and not as a load-bearing (stressed) component of a

Snapshot

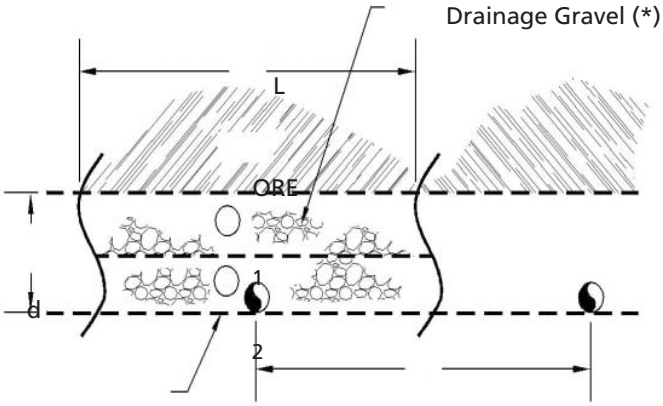


LEVINA

Duckweed and geomembrane covers combine to create a greener form of water treatment at this lagoon in Kochice, Poland.

lining system. Thus, we go to great pains to provide a well-compacted smooth subgrade, and we place protective (cushion) geotextiles under stone drainage layers. And many of us are familiar with German requirements to limit local (individual stone) strains to less than 0.25% by using heavy geotextiles and sand blankets. Then, in landfill caps subject to differential settlement, many engineers prefer to use [linear low density polyethylene] LLDPE rather than [high density polyethylene] HDPE because of the latter's susceptibility to stress cracking, which is, of course, the primary reason for keeping stress out of HDPE geomembranes.

Above. The May 2004 issue of *GFR*.



Right. A conventional drainage system showing the "heel."

But in requiring textured and structured HDPE geomembranes to keep soil on slopes and to "preserve the geocomposite/geomembrane interface shear strength" to maintain the stability of the peripheral ore heap, we are inducing significant stress into the geomembrane that has a rough surface with many stress concentrating geometries.

There is a major disconnect in philosophy here. It appears that, on one hand, we are being unnecessarily cautious; or, on the other hand, exposing ourselves to some long-term risks.

Perhaps LLDPE would be a better material for a heap leach pad, or perhaps we should specify a structured HDPE geomembrane rather than a randomly textured one for the peripheral load-bearing segment of the liner? Or we should specify a higher stress-cracking resistance for this peripheral material. Whichever approach is taken we should be consistent or be able to technically explain any inconsistencies.

Ian D. Peggs, Ph.D., P.E., P.Eng., DABFET; I-CORP International Inc.; www.geosynthetic.com

Response from the authors

The writer makes an important point: Geomembranes should not be considered as structural components. Thus any comprehensive design analysis should include a verification of strain compatibility; that is, a verification that any planar strain induced in the liner is well within acceptable limits (and ideally negligible). Much debate exists about what constitutes "acceptable limits," but that topic is beyond the scope of this response; suffice it to say that the authors know of no heap leach designers that adhere to Germany's hyper conservative limit of 0.25%.

Whether "inducing significant stress into the geomembrane" is problematic or not depends on factors beyond simply considering the increased friction angle (as any force-equilibrium analysis will show). Of course a shear stress is induced anytime the geoemembrane is near an exposed slope (or on an interior slope if covered by any material that might settle), just as a normal stress is induced by the contained material. But these stresses do not necessarily induce planar strain, which is induced only by tensile stress. If the underlying interface is strong enough to allow the shear stress to pass to the foundation soils, then the liner will not carry tensile stress, and, thus, there will be no planar strain. The presence of interface friction is both unavoidable and beneficial. Consider the alternative: A near-frictionless interface would prohibit any placement of material on any un-buttressed liner. The practical problems resulting from this would be difficult—if not impossible—to work around. Thus it is that many applications re-

quire recognition of the interface friction angle near exposed slopes to provide for adequate stability.

As a final point, the standard leach pad design uses crushed stone over smooth geomembrane, an interface with a friction angle considerably higher than geocomposite on textured geomembrane. Therefore, the alternative presented in this paper is safer from a planar strain consideration than the standard design. Rather than presenting a conflict, this gives designers another option in the on-going effort to balance the often contradictory requirements of stability, planar strain, drainage and puncture.

Mark Smith is vice president of South American operations for Vector Engineering Inc., www.vectoreng.com.
Aigen Zhao is vice president of engineering for Tenax Corp., www.tenaxus.com.

NAGS: Strategic plan

By Jane Harris

The North American Geosynthetics Society (NAGS) Board recently met to develop a new, clear direction for the society. The 2003–2004 board members held this two-day strategic planning retreat in May. The event was led by Shirley Readdean, a professional facilitator.

With the help of NAGS president, L. David Suits, Readdean led the group through thought-provoking activities and detailed discussions that enabled attendees to set specific, reachable long- and short-term goals.

The retreat was a huge success.

The following is a summary of the gathering's revelations.

What we want to do

1. Develop conference programs
2. Establish an executive director position. This position would focus on advancing the NAGS conference experience and growing the membership.
3. Create educational demonstration sites:
   a. Offer hands-on material to contractors and quality assurance professsionals
   b. Develop a video series
   c. Offer live Web casts (e.g., time-lapsed demonstrations of key geosynthetic concepts and applications)
   d. Offer paid student participation
4. Establish and maintain a continually updated geosynthetic curriculum
5. Create and maintain a NAGS "hotline"
6. Develop an awards program for:
   a. Student scholarships and fellowships
   b. Research (e.g., Award of Excellence)
   c. Innovation
   d. Student competitions (paper + building, etc.)
7. Implement a fundraising campaign
8. Create a public relations (PR) program and keep a PR person on staff
9. Develop a student membership recruitment program
10. Establish a formal promotion program to encourage geosynthetic related seminars, conferences, etc.
11. Develop a list of presenters to present non-commercial technical presentations using already existing programs (unbiased)
12. Collaborate with other organizers beyond formal conferences
    a.Develop a voice in the formation of codes and specifications
    b. Create strong NAGS visual promotion tools (booths, T-shirts, etc.)
13. Enact a travelling road show for consultants, contractors, educational institutions, etc. Provide kits for eductors. Present in short course/workshop format.
14. Develop a distinguished lecture series.

What can be done immediately

- Conference (late 2005)

New address

NAGS has relocated. Contact:
North American Geosynthetics Society
Attn: Jane Harris – Managing Director
P.O. Box 72030
Toronto, ON M9M 3A6
Canada
+1 416 741 8862, fax +1 416 741 9714
Web site www.nagsigs.org

- Award of Excellence program
- Student paper competition
- Student membership recruitment
- Develop a job description for an executive director position
- General membership recruitment
- Organize demo Web sites
- Fundraising campaign

Within one year
- Ites 11 and 12 on the above list
- Develop PR strategy
- Develop information kits for item 13

Within two years
- Implement executive director position
- Create a NAGS hotline (with help of executive director)

For more information on the North American Geosynthetics Society (NAGS), please visit the Web site at www.nagsigs.org.

Jane Harris is the managing director of NAGS.

Symposium to honor the research achievements of Robert M. Koerner

The Drexel career of Dr. Robert M. Koerner ('56, '63), H. L. Bowman Professor of Civil, Architectural and Environmental Engineering and Director of the Geosynthetic Institute (GSI), has spanned 54 years. In that time, Dr. Koerner has had the good fortune to interact with fantastic students, colleagues and administrators at Drexel and around the world.

Dr. Koerner holds his B. S. and M.S. in civil engineering from Drexel University's College of Engineering and holds a Ph.D. in geotechnical engineering from Duke University. His interest in geosynthetics spans 25 years of teaching, research, writing and consulting. He is a registered professional engineer in Pennsylvania, an Honorary Member of ASCE, a Terzaghi Lecturer in the United States and Austria, and a member of the National Academy of Engineering. Also, Dr. Koerner has authored or co-authored 500+ papers on geosynthetics and geotechnical topics in journals and at national and international conferences. His most widely used publication is the textbook *Designing with Geosynthetics*, soon to be in its fifth edition. Along with the attendant research and development, this legacy has firmly established Dr. Koerner, his colleagues and Drexel University as national and international leaders in the field of geosynthetics.

On 13 September, Drexel University will host a one-day seminar and roast in honor Dr. Koerner's prestigious career and numerous contributions to the field.

Seminar schedule

The following papers/speeches will be presented prior to the evening's dinner and celebration:
- "Duke days: Our beginnings." Dr. Gordon P. Boutwell, president, Soil Testing Engineers Inc., Baton Rouge
- "Project thesis: From metal powders to body parts, personal care and medication." Dr. Alan Lawley, Professor Emeritus, Materials Science and Engineering Department, Drexel University, Philadelphia
- "Acoustic emission in soils and long-term EPA funding." Dr. A. E. Lord, Jr., Professor Emeritus, Physics Department, Drexel University, Philadelphia
- "Acoustic emissions in soil, rock, water and grouting." Dr. W. Martin McCabe, URS Corp., Seattle
- "Nondestructive evaluation methods." Dr. John J. Bowders, professor of civil engineering, University of Missouri–Columbia
- "Preamble to and short history of construction and geotechnical engineering using synthetic fabrics." Joseph P. Welsh, P.E., consultant, Public Landing, Md.
- "From textiles to geotextiles." Dr. Frank Ko, professor of materials science and engineering, Drexel University, Philadelphia
- "Geosynthetics R & D: The early days." Dr. Robert D. Holtz, professor of civil engineering, University of Washington, Seattle

- "Opportunities and solutions, development and growth of the geomembrane industry." Gary M. Kolbasuk, vice president of technology, Raven Industries, Sioux Falls, S.D.
- "Waste management control strategies for landfills." Robert E. Landreth, chief (retired), United State Environmental Protection Agency (EPA), West Chester, Ohio
- "Geosynthetic design from the beginning." Dr. Gregory N. Richardson, president, GN Richardson & Associates, Raleigh, N.C.
- "Contributions to the advancement of GCLs." Dr. David E. Daniel, dean of engineering, University of Illinois–Champaign-Urbana
- "A look back at geosynthetic testing and specification standardization: A celebration of 20 years for ASTM International Committee D35 on Geosynthetics." L. David Suits, soil engineering laboratory supervisor, New York State Department of Transportation, Geotechnical Engineering Bureau, Albany, N.Y.
- "Lifetime prediction of polyolefin geosynthetics." Dr. Y. (Grace) Hsuan, associate professor of civil, architectural and environmental engineering, Drexel University, Philadelphia
- "GSI's efforts in accreditation and certification." Dr. George R. Koerner, associate director, Geosynthetic Institute (GSI), Folsom, Pa.
- Closing comments from Dr. Robert M. Koerner

A limited number of conference proceedings will be available for purchase. Contact Sharon Stokes, 251 Curtis Hall, Civil, Architectural and Environmental Engineering, Drexel University, 3141 Chestnut St., Philadelphia, PA 19104; +1 215 895 2341, fax +1 215 895 1363, e-mail koerner_symposium@drexel.edu, Web site http://drexel.edu/coe/research/conferences/Koerner/info.html.

But the first to be roasted is...
On the evening before the symposium, the Geosynthetic Institute will host an open house and pig roast from 5–9 p.m. The Geosynthetic Institute is located at 475 Kedron Ave., Folsom, PA; +1 610 522 8440, fax +1 610 522 8441, e-mail mashley@dca.net, Web site www.geosynthetic-institute.org.

Exhibit opportunity

Has your company exhibited at a conference presented by the Geo-Institute of the American Society of Civil Engineers (ASCE)? or a Geosynthetic Materials Association (GMA)/Industrial Fabrics Association International (IFAI) conference? or a Geosynthetic Research Institute conference? Through Geo-Frontiers 2005, 24–26 January 2005, Austin, Texas, you'll have the opportunity to reap the benefits of three major conferences in one comprehensive congress for civil, geotechnical and environmental engineers.

Geo-Frontiers 2005 combines an expansive exhibition floor with hands-on workshops, short courses, field demonstrations and tours, and technical paper sessions.

To reserve your exhibit space, contact Bob Smith or Chris Kohn, Industrial Fabrics Association International, 1801 County Rd. B W., Roseville, MN 55113-4061; +1 651 225 6914, fax +1 651 631 9334, e-mail bhsmith@ifai.com,

Web site www.geofrontiers05.org.

Geo-Frontiers 2005: short courses

The following short courses have been added to the Geo-Frontiers 2005 agenda. Geo-Frontiers takes place 24–26 January in Austin, Texas. The event will combine the Geo-Institute's 2005 conference, the Geosynthetic Materials Association's (GMA) biennial Geosynthetics conference and exhibition (last held February 2003 in Atlanta), and the annual Geosynthetic Research Institute (GRI) conference. This new congress will feature short courses, hands-on workshops, and opportunities to discuss design and project development with experts.

The short courses are:

- Surface erosion: Regulations and application of natural and geosynthetic products

Organizers: Shobha Bathia, Jean-Louis Briaud, Sam Allen, Don Lake, Harlow Landphair, Ming-Han Liand, Jett McFalls, Marc Theisen

Sponsoring organizations: Geo-Institute (G-I), North American Geosynthetics Society (NAGS)

- Static and seismic stability of solid-waste landfills
  Organizers: Ellen Rathje, Ken Stokoe, Jon Bray, Ed Kavazanjian
  Sponsoring organizations: Geo-Institute (G-I)
- Quality assurance of geosynthetics used in waste containment
  Organizers: George Koerner, Sam Allen
  Sponsoring organizations: Geosynthetic Institute (GSI)
- Professional practice 101: The essentials of risk management and profitability for project managers
  Organizers: John Bachner
  Sponsoring organizations: Associated Soil and Foundation Engineers (ASFE)
- Practical geophysics for geotechnical investigations
  Organizers: Ronald S. Bell
  Sponsoring organizations: Environmental and Engineering Geophysical Society (EEGS)
- Introduction to waste containment
  Organizers: Craig Benson, Chuck Shackelford, Jorge Zornberg
  Sponsoring organizations: Geo-Institute (G-I)
- Advances in deep foundations
  Organizers: George Goble, Jerry Demaggio
  Sponsoring organizations: Pile Driving Contractors Association (PDCA)
- Reinforced soil structures: Design methods, issues and innovations
  Organizers: Barry Christopher
  Sponsoring organizations: North American Geosynthetic Society (NAGS)
- Innovation in grouting: the developments 2000–2006
  Organizers: Donald Bruce, Richard Berry, George Burke, Michael Byle, Trent Dreese, Thomas Hurley, James Warner
  Sponsoring organizations: Pile Driving Contractors Association (PDCA)

Further information

See page 12 for the Geo-Frontiers 2005 schedule at a glance.

For more information, contact American Society of Civil Engineers, 1801 Alexander Bell Dr., Reston, VA 20191-4400; +1 703 295 6300, fax+1 703 295 6222, e-mail conf@asce.org, Web site www.asce.org. GFR

GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

Insurance- Construction risk management

By Lara and Elizabeth Peggs

Editor's introduction

The bid process in civil engineering has turned mightily in favor of lowest bid rather than best overall bid. This is unfortunate for many projects but especially damaging when environmentally sensitive applications and vital infrastructure improvements are involved. It's dangerous, and it defies the profession's mission to continually refresh its understanding of current options and proper designs. One can never say enough about the value of experience.

Given the thousands of annual installations that rely in part on the performance of geosynthetic materials (e.g., segmental retaining walls with geogrid reinforcement), it is somewhat surprising that it has taken this long to bring an applicable discussion into the construction risk management field. Project insurance, like quality assurance, is often looked upon by facility owners (and, of necessity, lowest-bid contractors) as an expensive, worrisome matter that is best kept down. Certainly, we are all in a business of one sort or another, and the bottomline plays a key role. However, minimizing cost at the expense of long-term safety is disastrously shortsighted. An inexperienced subcontractor who damages a reservoir lining, or landfill lining, or even a golf course pond lining may lead the overall project team and facility owner into multi-million dollar litigation—all for having saved $3,000 or $5,000 or $10,000 up front.

The fact that more of these cases have not cropped up is testament to the performance of the materials; but the rapidly increasing adoption of designs that rely in part on site-specific geosynthetic materials such as geogrids and geomembranes exceeds popular knowledge. It is leading design and construction towards the inevitability of more failures and costly litigation. These failures can be prevented. Greater experience is key. *Insurance providers are taking notice*.

The following article from Elizabeth and Lara Peggs was originally sent to geosynthetic specialists. In this callout one can glean both the short-term challenge and long-term promise for design in this segment of engineering.—*CK*

The moderators of geosynthetica.net have identified an opportunity to expand the role and acceptance of geosynthetic materials while improving the quality of the work performed and reducing liability. Currently, we are working to develop a program for the insurance industry. The program will help engineers, designers, owners and contractors improve the overall quality of the geosynthetic component in their projects.

The Insurance Risk Management Institute (IRMI) hosts an annual conference (no trade-show or exhibit hall). We have been asked to sponsor one of six technology showcases. The technology showcase package offers a 40 x 50 ft. room for two days. During this time, we can host our own program and/or hold meetings and discussions in this room (**Table 1**). The cost of the sponsorship is $3,950. We estimate the overall cost of running the event to be $10,000. We believe there are significant benefits to every aspect of our civil engineering segment, and, as such, we've requested speaker support from the North American Geosynthetics Society (NAGS).

I can not express how strongly I believe that this opportunity is extraordinarily valuable. We have the ability in this forum to develop a symbiotic relationship with an industry that has an enormous amount of control over not just geosynthetic selection but all materials in design and construction. The insurance industry has the power to drive good practice, certification and success.

At IRMI's conference we can:

- illustrate to insurance companies the cost associated with geosynthetics failure to insurers
- provide evidence that most failures are preventable and the millions of dollars lost in failure claims can be saved
- identify the benefits of a program for risk managers to identify risk and financially reward good practice

Photo 1. Textured high-density polyethylene (HDPE) geomembrane being installed over a geosynthetic clay liner (GCL) with the use of a slip sheet. Landfill projects like this, if left to inexperienced teams for the sake of a lowest overall bid, present serious safety and financial risks.

• get a commitment from the five big insurance companies to back the development of the Geosynthetics Risk Management Program.

The benefits of a risk management program

All sectors of the field will benefit.

Manufacturers

Manufacturers will be able to sell the best product for the application. That is, a manufacturer's products will more likely be selected and installed correctly. Selection of superior materials, certification and performance will earn construction companies and owners reduced insurance rates.

Installers

Insurance companies will either financially reward and/or mandate the use of recognized professional installers.

This will:

• increase the recognition and value for installation certification programs
• allow professional installers to compete on a variety of criteria (not only price) and improve the overall quality of installation
• possibly entice insurance companies to sponsor the development of other certification programs—benchmarks upon which insurance companies can evaluate risk without becoming geo-experts. Certification is clearly one method of providing this benchmark for installation.

Engineers/consultants

Peer-reviewed design by geosynthetic experts will result in proper material selection and buildable designs. Testing of materials, appropriate design methodology, and effective construction quality assurance (CQA) plans will be employed to ensure success for the installers and the manufacturers, and ultimately the owners and insurance companies.

Laboratories

Requisite testing will be recommended by the "geo-expert" (engineers who should develop addional work for the laboratories). Use of laboratories with accreditation and certification will be recognized within the geosynthetics risk management program.

The role of associations, certification & research

As the need for information develops, each of these groups will be called upon to aid in the development of key statistics, remedies and certifications that will make this program possible. The Geosynthetics Risk Management Program will create value to the members/participants and expand the need for recognition through certification and participation in these groups. It is even possible that the insurance companies will sponsor the development of such programs. Consider that, in one instance, a significant installation related failure at a golf course cost one insurance company $1.2 million—that can buy a lot of preventative medicine!

Table 1 outlines the benefits assigned to us as presenters of a technology showcase at IRMI's gathering. In addition to the listed benefits, we will also:

• host a roundtable discussion. Our goal will be to ascertain, from the insurance underwriters, what their specific needs will be from the Geosynthetic Risk Management Program.
• write a white paper. This paper will be distributed at the conference.
• work towards a segment in IRMI's Construction Risk Management Manual. This document is circulated annually to 3,500 influential subscribers.
• create one or more articles for IRMI's "Expert commen-

There were 1,200+ attendees at the fall 2004 Construction Risk Conference. Usually, 300–400 are contractors and project owners; 400–500 are insurance brokers who specialize in construction; 200 are insurance company executives, underwriting managers, and claims managers; and the remaining 100 or so are attorneys and consultants.

Sponsor benefits

- Your firm is listed in the conference brochure, which is distributed to approximately 100,000 construction risk and insurance professionals.
- You will be given credit as a joint sponsor of one of the conference breaks.
- Your firm and a description of your services are included on IRMI.com for the period of time between your commitment and the next year's signup deadline.
- Your firm and a description of your services are included within the conference workbook that participants keep and use for reference. IRMI also provides the workbook on its Web site throughout the year. Your information will be seen continuously at no extra charge.
- Your firm's sponsorship is recognized at the opening general session and at your event.
- You may display company brochures throughout the conference at special tables designated for sponsors only. There are no exhibit booths competing with your exposure.
- A sign recognizing your sponsorship is displayed throughout the conference.
- You receive one free registration worth $1,245. Also, you can have two or three other representatives from your firm in your technology showcase room without needing to register them. (Prior notice will be needed for name badges.)
- We allow you to use the conference attendee mailing list two times per calendar year. Only conference sponsors are allowed to mail to the attendee list.
- You are entitled to place a tower ad within the construction conference portion of the IRMI Web site, for only $1,500/year (50% off our regular fee).

Table 1. Sponsorship benefits for the 24th IRMI conference, 8–11 November 2004, Orlando.

tary" column

We are positive that this is the next step in expanding and improving the still evolving geosynthetic industry. Your queries and participation are welcomed.

For more information on the Geosynthetics Risk Management Program and the IRMI event, please contact Elizabeth or Lara Peggs at geosynthetica.net, 6072 N. Ocean Blvd., Ocean Ridge, FL 33435; +1 561 655 2060, fax +1 561 655 9922, e-mail lara@geosynthetica.net, Web site geosynthetica.net. GFR

Elizabeth Peggs is the marketing manager for geosynthetica.net.
Lara Peggs is the content manager for geosynthetica.net.

GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

Designer's Forum- Beneath the bubble: industrial lagoon closure

By Gregory N. Richardson, Ph.D. P.E., Stacey A. Smith, P.E., and Timothy F. Carr, L.E.P.

Editor's note: In the August issue, Designer's Forum featured part one of two on geocellular system performance. Part two will be published in October.

Many industrial waste treatment systems include lagoons that become regulated under RCRA once the treatment system is closed. Most of these lagoons were originally permitted with little regard to their impact on anything other than the water quality of treated effluent. However, under RCRA the historic impact of the lagoon on the immediate ground water quality and potential hazardous constituents in the contained sludges must be addressed. This article presents the design considerations for closure of a lagoon leaving the sludge in place. The interesting twist to this closure is the presence of an air-support "bubble" structure over the lagoon during much of the closure.

Lagoon background

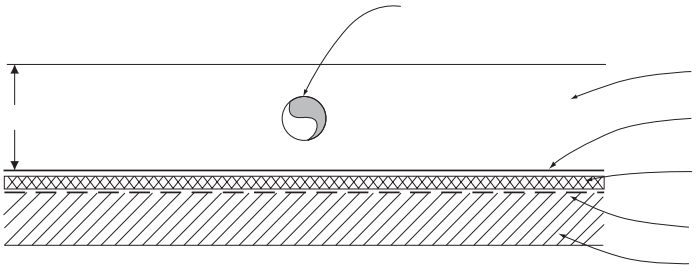
Photo 1. Inside the "bubble."

This 1.5 acre sludge lagoon was the last step in the wastewater treatment process. Historically, the facility effluent was chemically treated to flocculate out solids in the lagoon. Several decades of operations had left a significant volume of sludge within the lagoon. The wastewater was also aerated by two large pile-supported aerators mounted within the lagoon and a number of small floating aerators to remove volatile wastes. As a result of this aeration, the lagoon had been covered by the "bubble" to contain odors as shown in **Photo 1**.

The client required that this bubble remain in place until the sludge was contained by an equally effective means of controlling the odor. This meant that a portion of the closure work would have to take place beneath the bubble. The presence of the bubble limited equipment access to the lagoon and meant that all construction materials had to pass through air portals.

Extensive field and laboratory geotechnical testing of the sludge was performed to define shear strength and consolidation characteristics. Existing shear strengths of the sludge ranged from essentially zero to 50 psf. Consolidation testing of the sludge indicated that the water content of the sludge could be significantly reduced with even minor loading. The dewatering of the sludge increased its shear strength sufficiently so that it became an acceptable subgrade material.

Figure 1. Phase 1 geosynthetics.



Based on the geotechnical testing, a closure plan was developed that called for a staged loading of the sludge to increase its shear strength to at least 65 psf. Additionally, the final stage of consolidation loading was to be larger than the loading applied by the RCRA final cover. This would produce an over-consolidated condition in the sludge that would limit future movement of pore water into the surrounding groundwater. The mechanism for consolidation also had to be compatible with the goal of limiting air emissions.

Reflecting the site constraints, the final cover design included three phases: 1—isolation and initial consolidation, 2—fill placement, and 3—placement of RCRA cover. Each phase had distinct design challenges.

Phase 1—isolation and initial consolidation

The initial and most difficult phase of closure had the dual goals of containment of the sludge related to air emissions and the initial consolidation of the sludge itself. All of the Phase 1 work was performed under the bubble. **Figure 1** shows the geosynthetic components that were key to the success of Phase 1.

A 36-mil metalocene (mPE) geomembrane provided isolation of the sludge. A drainage composite and high strength woven polypropylene reinforcement fabric are below the geomembrane: the drainage composite to collect consolidation water coming from the sludge, and the high strength woven reinforcement to aid in load distribution.

Photo 2 shows the completed geosynthetic system in place beneath the bubble. This photo is generally referred to as "walking on water." Each layer was fabricated outside of the bubble, rolled up and passed through a modified airlock portal and then unrolled for final deployment.

Photo 2. "Walking on water."

The rate that water could be removed from beneath the geomembrane was limited by the capacity of a newly constructed wastewater treatment facility to receive it. Initial loading of the geomembrane was accomplished using only clean water to surcharge the geomembrane. While producing only a limited increase in the strength of the underlying sludge, completion of this phase allowed removal of the bubble shown in **Photo 3**. Prior to removal of the bubble, Styrofoam sheets were floated over the pond to further protect the geomembrane from potential damage from the steel cabling used to secure the bubble. Bringing the bubble down took less than 10 uneventful minutes due to these precautions

Photo 3. Removal of the bubble.

Phase 2—fill placement

With the bubble removed, clear access was available around the full perimeter of the pond. The clean water over the geomembrane was pumped off as the soil cover was placed over the area. Soil cover placement began on the eastern end of the lagoon and moved west. Initially, soil was placed using conventional equipment. This unfortunately resulted in much of the lower strength sludge being squeezed to the west which, in turn, led to a bulge beneath the geosynthetics by the time soil placement reached the middle of the lagoon. The contractor continued placement until this bulge led to a tear in the geomembrane. Fortunately, the tear occurred high on the bulge, so no supernatant from below the geomembrane was released. The tear was repaired, and the contractor realized the need for a new approach to soil placement.

The revised soil placement technique centered around a unique conveyor truck originally designed for placement of rip-rap. As shown in **Photo 4**, the conveyor truck (Telebelt) allowed pinpoint placement of soil without the need for equipment directly on the geosynthetics. The Telebelt could place up to 1500 cubic yards of fill in an eight hour shift and enabled all bulges to be loaded and flattened. The rate of fill placement was limited by the rate of treatment of the new wastewater plant and not the Telebelt. The Telebelt was used to place approximately 5 ft. of cover over the geosynthetics. After this placement, conventional means could again be used to place the fill.

Photo 4. Placement of soil.

During placement and throughout the next year, settlement of the sludge was monitored using settlement platforms installed while the fill was being placed. In addition to the platforms, pore pressure monitoring was conducted

by using vibrating wire transducers within piping below the geosynthetics. Plotting this data verses time provided an indication of what stage of consolidation the underlying sludge was in. After one year, the consolidation was sufficiently completed so that placement of the final cover could occur. In addition to fill during this phase, perforated pipe was installed over the metalocene geomembrane to allow future removal of liquids on top of it. This will provide a measure of the long term performance of a very common RCRA final cover system.

Phase 3—placement of RCRA cover

Once the majority of primary consolidation was finished in the sludge, the fill was regraded to final cover contours. The RCRA final cover consisted of the following from bottom up:

- reinforced geosynthetic clay liner (GCL)
- 60-mil HDPE geomembrane
- geosynthetic drainage composite
- 28-in. of sandy vegetative support soil
- 6-in. of topsoil with grass cover.

Photo 5 shows the construction of the final cover moving west to east. The soil was graded to provide a typical slope of 3% to the perimeter. **Photo 6** shows the completed final cover over the lagoon.

During this same time, the pipes placed over the consolidation geomembrane, immediately over the waste, were brought to the surface through the cap. As mentioned earlier, these pipes allow for actual leakage monitoring of the final cover. Future infiltration data from these collector pipes will be of great interest.

Photo 5. Geomembrane installation.

Photo 6. Completed final cover.

Summary

The in-place closure of the lagoon provides a strong demonstration of the powerful roles geosynthetics play in environmental applications. The design followed the "design-by-function" mantra with each geosynthetic component performing a specific function in the overall project. In essentially 18 months, the sludge was transformed from a material that could not support a man to a suitable foundation for a RCRA final cover. No other alternatives would allow in-place closure of this lagoon without a high potential for significant air emissions. GFR

Greg N. Richardson is president of G.N. Richardson & Associates, Raleigh, N.C.; www.gnra.com. Stacey A. Smith and Timothy F. Carr work for G.N. Richardson & Associates.

Call for submissions

GFR is currently seeking submissions for its March and April issues. Some of the scheduled topics for March include road and rail longevity, landfill expansion, stormwater management, CQA and risk assessment, and hazardous waste containment. For April, the editors seek articles on shoreline development, sediment control, groundwater protection, leachate management and drainage.

Other topics and projects welcomed. Deadlines begin in early December. Contact the editors for writer's guidelines: The Editors, GFR Magazine, 1801 County Rd. B W., Roseville, MN 55113-4061; +1 651 225 6988, fax +1 651 225 6966, e-mail gfr@ifai.com, Web site www.gfrmagazine.info.

GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

Checking In- A revitalized agenda

By Elizabeth Peggs

In June 2004, ASTM D35 met in Kansas City, Mo., to work on standards development for the geo community—it was an invigorating effort. For those of you who were unable to participate, we have most of the interesting news.

Transportation volume being developed

Margie Laller, along with the publications department of ASTM, is working toward electronic publication of a single volume of standards relating to transportation. The standards will be drawn from a variety of committees, including D35. David Suits is the D35 "point man" for this effort.

A revised international standards reference

Dr. André Rollin recently completed an updated version of the Tabular Comparison of Standards document. The document will illustrate which standards each different standards organization uses to respond to a particular issue. The document does not indicate technical equality of various test methods. A number of practical applications for this document exist, but it has primarily been designed to aid in the evolution of cooperation between ASTM and other international standards organizations.

For more information on obtaining this document, please contact Elizabeth Peggs. (See author bio at end of article.)

The D35 Committee would like to thank Dr. Rollin for his efforts. They are much appreciated.

Change will do you good…

In an effort to improve the scheduling and quality of D35 meetings, the Executive Committee will make some changes to the format and scheduling of the meetings. Some things you can expect to see include:

- additional workshops, symposia and roundtable discussions
- better meeting overlap with D18
- deadlines in concert with D18
- two and a half day format
- one hour opening Main Committee meeting
- notification prior to the meeting week of canceled meetings. (Make sure we have your correct email address!)

Note: "D18" refers to ASTM Committee D18 on Soil and Rock. For more information on the forthcoming activities of this sister committee, please contact Bob Morgan, staff manager, at +1 610 832 9732; or e-mail bmorgan@astm.org. A mailing address for ASTM International can be found at the end of this article.

Not just committee meetings anymore…

Beginning in January 2005, D35 will be increasing the value of meeting participation by offering symposia, workshops and roundtable discussions on topics impacting our future.

A January 2005 evening panel discussion on issues surrounding the contentious topic of aperture stability will

open this new format. Don't miss this opportunity to participate in the development of a valuable standard.

Also, the January 2006 meeting will host a half day workshop on shear testing.

If there is a subject you would like to have considered, please contact any of the ASTM D35 committee leaders.

20 years of hard work, commitment & success

Committee D35 began 20 years ago as a subcommittee of Committee D18 on Soil and Rock. And from its genesis as a small group of professionals to its current role as a very healthy and productive stand alone group, D35 has undergone a significant evolution, one that reflects (and influences) the role of polymeric materials in civil engineering.

The committee's history and achievements were acknowledged at the recent meeting. An exceptional dinner and ceremony were provided. David Suits gave attendees a colorful recount of D35's years. (As it turns out, Suits has been around for every minute of it!) Chairman Sam Allen then delivered a much deserved, thoughtful and provoking review of Suits' contributions to D35, a speech which concluded with a prolonged standing ovation from the audience.

An additional 14 awards were presented to committee members who have been integral in the creation of completed standards. See sidebar for a list of award recipients.

New inorganic paving mat standard proposed

A new standard has been proposed and drafted by David Jones of Owens Corning. The new standard poses many questions that could have some interesting and long-term implications on this and other technologies.

If you are interested in joining the committee and discussing this standard further, please visit www.astm.org.

Dewatering standards

The current dewatering standard might

D35 Awards

The following awards were presented at the Kansas City meeting.

Certificate of Appreciation

Presented to L. David Suits, in recognition of his dedication and professional expertise provided to Committee D35, notably as the Chairman for D35 and as Subcommittee Chair for 35.03. The officers and members express herewith their deep and sincere appreciation for your dedication, efforts and accomplishments.

Individual awards

Sam R. Allen. ASTM Standard D6992-03, Test method for accelerated tensile creep and creep-rupture of geosynthetic materials based on time-temperature superposition using the stepped isothermal method

Donald G. Bright, Ph.D., P.E. ASTM Standard D6213-97, Practice for tests to evaluate the chemical resistance of geogrids to liquids

James G. Collin. ASTM Standard D6916-03, Test method for determining the shear strength between segmental concrete units (modular concrete blocks)

Jean-François Côté. ASTM Standard D7056-004, Test method for determining the tensile shear strength of pre-fabricated bituminous geomembrane seams

Glenn T. Darilek. ASTM Standard D7007-03, Practices for electrical methods for locating leaks in geomembranes covered with water or earth materials

James B. Goddard. ASTM Standard D7001-04, Specification for geocomposites for pavement edge drains and other high-flow applications

Gary M. Kolbasuk. ASTM Standard D7003-03, Test method for strip tensile properties of reinforced geomembranes; ASTM Standard D7004-03, Test method for grab tensile properties of reinforced geomembranes; ASTM Standard D7008-03, Specification for geosynthetic alternate daily covers

Curtis C. McCorsley. ASTM Standard D6917-03, Guide for selection of test methods for prefabricated vertical drains (PVD)

Jonathan McCulley. ASTM Standard D7005-03, Test method for determining the bond strength (ply adhesion) of geocomposites

Andre L. Rollin, Ph.D. ASTM Standard D7002-03, Practice for leak location on exposed geomembranes using the water puddle system

L. David Suits. ASTM Standard D6918-03, Test method for testing vertical strip drains in the crimped condition

Nazli Yesiller. ASTM Standard D7006-03, Practice for ultrasonic testing of geomembranes

be split in two in order to make it more representative of current technology. A second standard for Pressurized Filtration Method has been tabled and is likely to be developed.

Contact information

For more information on the scope of Committee D35, forthcoming activities or membership, please visit the committee online at www.astm.org. Type "D35" in the search box.

Or contact Christine Sierk, staff manager, ASTM International, P.O. Box C700, West Conshohocken, PA 19428-2959; +1 610 832 9728, e-mail csierk@astm.org, Web site www.astm.org. GFR

Elizabeth Peggs is the marketing manager for geosynthetica.net and ASTM Committee D35's recording secretary. She writes frequently for GFR *and can be reached at elizabeth@geosynthetica.net.*

GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

The Franzen Reservoir

By Christopher Kelsey

The 100-million gallon Franzen Reservoir in Turner, Ore., provides two-thirds of the drinking water for Salem, the state's capital and second-largest city with its 145,000 residents. Salem boasts a good quality of life. It's located in the agriculture-rich county of Wilmette, and is a little more than an hour south of Portland and an hour north of Eugene. The Pacific Ocean and the Cascade mountains are each within 90 minutes. In general, the northwestern United States is regarded as an environmentally progressive region, not only in its cultural and political dialogue, but in its approach to development. The abundance of natural resources (fresh water, timber, farm land) has provided more than ample inspiration for environmental concern, and this is well reflected in Salem's dedication to long-term engineering strategies.

Of late, the city has embarked on an extensive water infrastructure improvement plan, the cornerstone of which is Franzen's rehabilitation. The reservoir is fed by the North Santiam River via an aging network of pipes, pump stations and filters. As Salem has grown and the water distribution grid has deteriorated, as all grids do, the need for a system-wide (rather than piecemeal) revision became apparent.

The 50-year-old reservoir was a primary concern. Chief among its needs were:

. • a design that enabled periodic closing of only part of the reservoir without impacting system service
. • a stronger overall structure
. • a liner to prevent leaking
. • a cover to minimize threats of evapora-tion and contamination

Common problems

Many municipalities in the American West are undergoing similar water infrastructure rebuilds...alongside water rights debates and lawsuits. A succession of drier seasons and, in some states, prolonged drought, has heightened awareness of the need for stronger water collection, storage and delivery. All of this has been exacerbated by trends in population growth, which for the past decade have favored regions that are less able to absorb the high rate of growth. Rapid development has depleted fresh water supplies and cast a more critical eye on the purity of what water remains. Even a city like Salem, with its temperate climate and average of 140 days of precipitation, is not immune to the pressure.

Photo 1. Dividing the reservoir in two allows partial draining of the reservoir, if needed, without interrupting overall service.

A new design

The reservoir has always been open-aired and single-celled. Both of these characteristics were considered short-sighted for the reservoir's future use, so the rehabilitation design included a floating cover to provide protection-more on this under "Floating cover"-and the single cell was split into two.

The double cell design provides a significant boost to operational flexibility. The facility still holds 100 mil-

lion gallons, but operators may drain half of the capacity without affecting service to the surrounding communities.

Whether for routine maintenance or in response to crisis, the ability to shift water responsibilities or remove some of the supply from service is a definite advantage for the community. This solution is just one of many of the project facets that led the city to estimate its long-term savings at $25 million, which is a very promising number set beside a project cost of around $16 million.

Furthermore, the two-cell approach allowed the reservoir to be back online sooner. One cell was prepared, lined and covered in time for the winter. Though cooler months do not present high-volume draw on the reservoir, reopening the system was vital due to the turbidity conditions of the North Santiam River in winter. The rehabilitated reservoir, even acting at half capacity, ensured a cleaner supply of water.

A stronger structure

Well before the first half of the reservoir was lined and brought into service, project engineers found that the east cell's north slope presented something of a structural risk. This was not due to its construction but to the soil being prone to weeping. The overall integrity of the embankment was not yet threatened, but the long-term risk of instability prompted a design solution. Because this problem was identified early, total reinforcement was not deemed necessary. Instead, a drainage revision was called for. A geocomposite made of 6-oz./yd.2 nonwoven geotextile laminated to a geonet was installed. This revision collects moisture and directs it to a sump.

Photo 2. Earthwork operations can greatly affect the success of a liner installation. At the Franzen Reservoir site, the grading and ground preperation were exceptional.

Sealing the reservoir

No matter how technologically advanced the design and material selection for a project becomes, without proper attention to ground and slope preparation a liners service life remains at risk. Rocks and poorly compacted soil can stress or tear a liner, necessitating repairs. In Salem, the sites earthwork team, with guidance from the geosynthetic consultant, did an exemplary job of compacting and smoothing the slopes and floor. The thoroughness of their work has made the reservoir a much stronger structure and created an ideal situation for the project materials; meaning: The liner and cover

We carry a complete stock of replace-Our service department, staffed with system perform their intended functions. They are not stressed into performing a role for which they are not designed. This is vital to the full performance of any project.

Following ground preparation, a 22 oz./yd.2 needlepunched nonwoven geotextile was placed. The geotextile provides an essential cushioning layer between the earth floor and the liner. Geotextiles of this sort are used also for separation and stabilization beneath roads, railbeds, and other sites at which loads-especially fluctuating loads-may affect the integrity of the soil beneath. Used here for geomembrane protection, another major use of the geotextile, the nonwoven material significantly reduces the liners risk of puncture or abrasion during liner installation and more dynamic changes in the reservoir's volume.

Polypropylene geomembranes are very stable and provide strong resistance to tensile stresses and tears. They are also quite flexible. Perhaps most important, though, for a reservoir project is the material's ultraviolet (UV) resistance and overall durability during exposure to the elements. The specific material selected for the installation (See "Project information" at end of article) includes an enhancement and stabilization package in its construction that extends its resistance to UV rays and prevents reaction to co-additive elements. The material's seamability also means that various panels can be fabricated in the factory (which reduces on-site seaming costs).

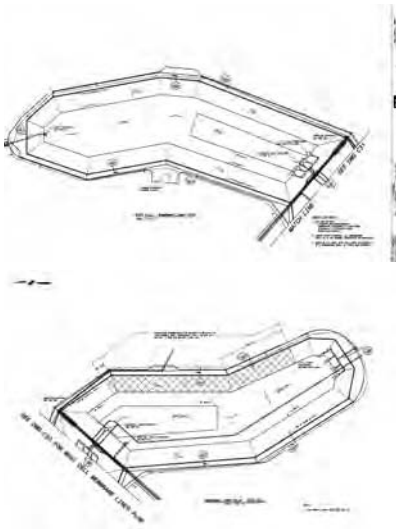


Figure 1. The west and east cell liner plans. The north slope of the east cell (below) did not require reinforcement, but a new drainage plan was required. The slope had suffered weeping that threatened to create instability over the long-term. A geocomposite made of a nonwoven geotextile laminated to a geonet was selected.

For this project, seam tests were conducted on factory seams before shipment, and all field seams were tested. The results were weighted against the requisite values in the project specifications. All seams were then validated with independent testing. In total, the polypropylene liner tested through 15,000 hours- many projects specify to 12,000- which is roughly equivalent to 20 years of service.

Photo 3. The 100-million gallon facility provides Salem with two-thirds of its drinking water. Following liner installation, a polypropylene floating cover was added to insure against contamination.

Floating Covers

Water supplies can be contaminated by numerous sources, many of them natural. Dust and leaves can tax a filtering system, and birds contribute a fair amount of waste. Water loss through evaporation is also a concern in many regions.

For the Franzen Reservoir, the designers followed through with the total water infrastructure projects progressive vision and included a floating cover. The old reservoir had been open air. The rehabilitated reservoir received covers on both cells. The covers were manufactured from the same material as the liner system, thus bringing the same characteristics of weatherability, durability, and overall performance.

GFR

Project information

Principal design: Black and Veatch
Geosynthetic consultant: Bill Way
Earthworks designer: Mac McDougal Inc.
Installer: Colorado Lining
Testing: TRI Environmental
Geocomposite: geotextile laminated to a geonet from SKAPS Industries
Geotextile(cushion): 22-ounce needlepunched nonwoven from SKAPS Industries
Geomembrane(liner and cover): 45-mil reinforced polypropylene (COOLPRO) from Cooley Engineered Membranes

Christopher Kelsey is editor of GFR. He can be contacted by e-mail at gfr@ifai.com; or call +1 651 225 6988.
Lance Reed of Cooley Engineered Membranes contributed project team interviews to this article.

GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

Cold Weather Installations

By John Heap

Photo 1. Winter installations are rarely welcomed, but the county had no choice. The county's landfill had reached capacity.

Community disputes, cost concerns and conflicts with environmental permitting can make landfill construction a difficult infrastructure need to satisfy. At times, the design and approval process takes a project down to the wire. Such was the case with the Campbell County Landfill in northeastern Wyoming.

The county's municipal landfill serves 36,000 residents. The population expanded by 15% in the 1990s and has grown at a rate of about 3.5% annually since 2000. Though the influx of new residents has been welcomed in this region best known for its abundance of energy resources (oil, natural gas and coal), the growth hastened the end of the old landfill's service life. And it ran out of space at the least opportune time: as winter arrived. Of course, the immediate need could not be ignored. A new landfill cell was called for, and a December construction was planned. It's never ideal to begin construction during a cold season, and it's especially difficult when the components are best installed during warmer weather.

Engineers at nearby CE & MT responded with a 600,000 ft.2 (55,740 m2) footprint landfill cell design. The idea called for using state-of-the-art technology and construction techniques to enable the late season construction. The engineers specified materials that provided the most cost effective solution for the county's future landfill needs and accelerated construction window. The selected products needed a proven track record and had to be installed efficiently and quickly (e.g., utilizing factory fabrication technologies for many seams).

DRM Inc. was selected as the general contractor and charged with carrying out the earthworks. Colorado Lining International was retained to provide and install the landfill components (e.g., geomembranes).

The Campbell County landfill is a Subtitle D landfill. Construction on this project began and was completed in December 2003. Extreme weather conditions, a tight project deadline, and budget constraints necessitated careful planning and coordination between all parties.

Project design and product selection

The project engineer specified that the landfill cell must have a multi-layer system designed to protect the groundwater from contamination. Multi-layer designs, supported by numerous installations and environmental monitoring, are increasingly common, especially in the western United States. Water retention and water quality are major concerns in the region.

After evaluating various materials, the decision was made to install a geosynthetic clay liner (GCL) over the certified subgrade in lieu of hauling in and compacting clay.

Under December weather conditions, it would have been virtually impossible to control the temperature of the clay and to obtain proper compaction. This would have pushed the schedule even further into winter, risking a project shutdown. Upon engineering review, the design team looked at the cost difference and decided that a three-ply fabric system made much more sense in terms of budgeting constraints, logistics and

project scheduling.
The engineer specified a composite lining system composed of a GCL base, a 30 mil PVC geomembrane that met PGI specification 1003 (See sidebar), and an 8-oz. nonwoven geotextile protective layer.

Project construction

It was necessary to deploy and seam the liner in temperatures considerably lower than ideal for building a landfill. The installation took place in ambient temperatures as low as 32 F. Typically, geomembranes are not deployed at this temperature, because the material becomes stiff and very difficult to pull out without getting wrinkles and folds in the liner. The material was kept in heated trailer storage on site to protect it from 0-10 F overnight temperatures.

Construction

Debris, large rocks and other items that could puncture a liner were removed from the landfill cell subgrade. Once the subgrade was completed and certified, the geosynthetic clay liner was installed.
The GCL used was a CETCO BentoMat ST with a special edge that self applies loose bentonite along the seams. This bentonite lies between adjacent panels and forms a uniform seal.
Unusually large PVC panels were created in the factory in order to minimize the number of field seams needed. Colorado Lining fabricated 30 panels of approximately 70 x 300 ft. (21 x 91 m), utilizing dielectric fabrication technology. These panels weighed approximately 4,300 lbs. each.
All of the seams within each panel were made in the factory under ideal conditions—with no temperature extremes and no dirt. The seams were then tested in Col-orado's in-house laboratory. Data was logged to verify compliance with PGI 1103 factory seam requirements.
Once completed, the panels were moved to the site and stored in heated trailers to keep the material pliable until deployment.
Usually, PVC geomembrane panels are light enough to be pulled out by laborers. However, given the large size of these panels, a track bobcat with a ground pressure of 4.5 lbs./ft.2 was used to unroll the panels.
The PVC geomembrane panels were deployed from 10:00 a.m. until 3:00 p.m. at the rate of approximately 2–3 acres per shift. These panels were field-welded, utilizing the latest in heat fusion welding equipment. All installed GCLs were covered each day to prevent damage and hydration.
The use of the pre-fabricated panels meant that 60% fewer field seams were needed. Weld speed for the field seams was decreased and dwell time increased to product PGI specification welds. All field seams were tested utilizing the air lance test method —ASTM 4456.

PGI specifications

The PVC Geomembrane Institute (PGI) has developed specifications to assist design engineers select and construct with the appropriate PVC geomembrane. The most recent specification is 1104, which was adopted earlier this year and replaced Specification 1103.

Specification 1104 identifies certified properties (e.g., thickness, tear strengths, dimensional stability), index properties (e.g., specify gravity, elongation, hydrostatic resistance), and seam strengths for 10 through 60 mil PVC geomembranes, as well as provides cross- references to the applicable ASTM standards.

The specification table is available free at the PGI's home page:

http://pgi-tp.ce.uiuc.edu

Photo 2. Cold-weather seaming is difficult because the material is at risk for stiffening, wrinkling or folding. Geomembrane rolls were stored in a heated trailer on site until it was ready for deployment.

Project completion

An innovative construction approach allowed the Campbell County landfill to be completed on time and under budget despite adverse weather conditions. The main keys to this project's success were excellent coordination of construction activities and the procurement of heated storage.

A composite lining system was chosen to provide excellent long-term durability with multiple layers of protection. Choosing GCLs over compacted clay reduced installation time. Also, GCLs and PVC geomembrane have an excellent interface friction, providing the site with increased stability. Custom fabrication of PVC panels minimized the number of field seams needed to install the liner. As a result, third party quality assurance/quality control (QA/QC) costs were reduced.

Photo 3. Large panels of PVC were fabricated in the factory to reduce the field work. This was especially important given the weather conditions. The prefabricated panels were larger than normal.

Project information

Design: Consolidated Engineers & Mterials Testing (CE & MT) Inc. General contractor: DRM Inc. Installer: Colorado Lining International Geosynthetic clay liner (GCL): Bentomat ST from CETCO Geotextile: 8 oz. nonwoven Geomembrane: 30 mil PVC

John Heap is president of Colorado Linings International, Parker, Colo.; www.coloradolining.com. He serves as the treasurer of the PVC Geomembrane Institute.

About the PGI

Founded in 1988 by a group of industry leaders, the PVC Geomembrane Institute has been dedicated to advancing the use of PVC geomembranes through education and research. The organization and its membership accomplish this by aiding engineers in specifying PVC for environmental applications including (but not limited to) landfills, industrial waste ponds, canals, mining and wetland treatment containment. PGI membership spans all aspects of the PVC geomembrane industry, including manufacturers, fabricators and installers of the material. The organization was incorporated in Michigan and operates under the direction of a volunteer board of directors led by its president, Pat Diebel of Canadian General-Tower Ltd. Other current board members include secretary Andrew Mills of Layfield Plastics and treasurer John Heap of Colorado lining International.

Photo 4. The installer's experience helped complete the project on time and under budget.

In 1998 the PGI underwent a reorganization that ended in a partnership with the University of Illinois at Urbana-Champaign (UIUC). The partnership lead to the formation of the PGI Technology Program (PGI-TP) lead by Dr.Timothy Stark with the universtiy's civil engineering program. Dr.David E. Daniel and Dr. Krishna R. Reddy serve as co-directors of the program.

Since 1998, the PGI's main office has resided at UIUC. The main objectives of the program to date have been to conduct research and disseminate technical information about PVC geomembranes, and to provide

technical information and assistance to engineers and specifiers as needed.

Resources
At the PGI Web site, visitors can download technical information, such as a fabrication and installation document, a quality control document, technical articles, and specifications. A CD-Rom may also be requested.

Contact
For more information about using PVC geomembranes, visit the PVC Geomembrane Institute's (PGI) Web site at www.pvcgeomembrane.com. The 1104 PGI Specification is listed on the Web site to assist designers in specifying and selecting PVC geomembranes. Information is also available by contacting the office of the PGI at +1 217 333 3929.

Dewatering Industrial Sludge

By Moninder (Witty) Bindra

Incitec Pivot manufactures super phosphate at a plant in Geelong, Australia. A byproduct of manufacturing super phosphate is the formation of silica in fluorosilicic acid (H2SiF6). The silica and acid, along with any entrained super phosphate dust, are captured in the process pond for storage. The level of solids content in the process pond tends to increase over time, as the pond is not agitated. Every few years, the solids must be removed to reset the storage capacity. Due to the highly corrosive nature of the acid, the means of solids removal are expensive, messy and potentially hazardous.

Improving the process

The objective of the project was to separate the solids in the process pond (primarily silica and super phosphate) from the liquid (approx 20% fluorosilicic acid). Removed solids can be recycled into the product, while the liquid can be either bled back into the process or treated. To make the return of solids timely, the level of moisture in the solids must be minimized.

Photo 1. The switch to woven geotextile bags for sludge solids removal enabled secondary conditioning to begin after two weeks when previously the facility operators had to wait up to six months.

For the Geelong project, high-strength woven bags were used to remove the solids. The bags met the primary requirement of being able to separate the very fine solids from the process liquor while providing a high solids-content cake after only five to 10 days of drying. The heavy individual yarns are woven into a unique twill pattern to form a strong geotextile with excellent hydraulic characteristics.

A piping manifold was manufactured to supply sludge to up to six bags (10 m long x 4.5 m circumference). Sludge was supplied from the pond via a diaphragm sludge pump. This system enabled remote bag filling by only one or two operators.

After the bags were full (approximately 20 tons of 50% solids sludge), the supply piping manifold was disconnected and relocated to enable six other bags to be set up. The first set of bags was then left to dry for as long as possible. Drying periods varied from five days to three weeks. (A longer period is better.) However, due to the very high solids content of the supplied sludge, and the "pressure filtration" effect provided by the bag, the cake was spade-able almost from day one.

The bags were split open, following the drying period, and the sludge was picked up using a large front end loader. The sludge was further dried and conditioned before being returned to the process.

The results were excellent. An estimated 250 tons of sludge were removed using 14 of these sludge bags. The sludge removal was performed during normal operations and did not disrupt plant operations. Additionally, the high solids content after drying allowed the sludge to go to secondary conditioning within two weeks of removal; previously, this took up to six months. The bags also had a low visual impact. The high strength of the bags allowed a large volume of sludge to be removed at a high rate. Each bag acted as a pressure filter,

with incoming sludge forcing liquor to be filtered out through the bag mesh, leaving behind solids.
It's difficult to quantify the cost savings using this method. However, the author believes that client has saved up to $100,000 (Australian dollars) by using this method over other sludge removal techniques. GFR

Project information
Contractor: Green Waste Environmental, Melbourne
Consultant: Permathene Pty. Ltd., Sydney
Geotextile: Syntex from SI Geosolutions
Moninder (Witty) Bindra works for Permathene Pty. Ltd., Sydney, Australia; www. permathene.com.

Moninder (Witty) Binda works for Permathene Pty. Ltd., Sydney, Australia; www.permathene.com.

GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

Erosion Control: The ends of the spectrum

The term "erosion control," like "civil engineering," is fairly nebulous. It encompasses a number of common problems such as soil loss along streambanks, stormwater rills in landfill covers, and sediment containment at construction sites. A number of thorny issues are enmeshed with this dialogue: contaminant sequestration, water quality and sustainable vegetation, to name just a few.

It is best to tackle the subject piece by piece. This is one in what will be a regular series of articles.

Whether a project lead is a geotech, an environmental specialist, a county engineer or general contractor; whether the client is a private landowner, government agency or municipality; the options for design and construction outweigh the problems. Two solutions that are trending in erosion control across a broad swath of applications are short-term, totally degradable products on the soft armor side and flexible concrete constructions on the hard armor side. Both merit consideration and exemplify how diverse the needs of designers, regulators and communities have become.

Photo 1. Here today, gone tomorrow: Totally degradable erosion control blankets are being specified on a wide-scale. Project managers like the quick establishment of vegetation, and clients are drawn to the "green design."

Single approaches have faded. The art of material combination is in.

The green movement

For many years, designers have relied on photodegradable plastic nettings as a component in straw and coconut blankets. This material construction, for short-term use (generally less than two years), has been used to great success on project sites. Soils are contained while vegetation is allowed to grow. In some combinations, the netting has been stabilized against ultra violet (UV) rays. For those applications, the stabilized netting provides a necessary level of root support. That is, plant roots can tangle themselves around the netting until deeper roots reach into the soil and vegetation provides surface cover.

So the mingling of photo-accelerated or stabilized nets and organic mats is well established. However, the green movement in architecture and engineering has brought heavy attention to the degradability of construction materials, almost to the point of making these standard erosion control blankets (ECBs) seem new—as if they've been developed in response to the movement.

In most situations, the green movement represents a sensible approach to development. Certainly, it has made more people (including engineers) aware of human impact on the overall environment. It has elevated the need for degradable materials, and has given greater weight to questions regarding the long-term vision in a design— even for short-term applications. It is a louder discussion. More people influence projects now (which often complicates resolution). That's important to realize, because it's added another level of pressure in the process of design and selection. It's also brought about a renewed interest in totally degradable materials.

Prior to the green movement's popular establishment, there was a respectable group of well-engineered ECBs

that were, at times, confused with poorly thought-out approaches (e.g., the pell-mell application of straw and seed to steep slopes). Many practitioners anticipated the direction of the field, but that brought about some hasty developments by firms looking to capitalize on "erosion control." As such, it took some time for standards to be agreed upon and for the true character of the industry to take shape. The green movement's focus on minimal environmental impact while demonstrating performance has helped ECBs establish themselves in the designer's toolbox.

ECBs are also known as rolled erosion control products (RECPs). Some basic varieties and characteristics are listed in Table 1. If you've passed a construction site with even a mild slope, you've seen these materials. You

Table 1. Application and design matrix for temporary erosion control blankets (ECBs): General guidelines for the use and selection of temporary erosion protection (adapted from Sprague 1999).

Category	Composition	Suggested applications	Functional longevity
I. Single net short-term temporary degradable ECB	The blanket shall be a machine-produced mat of straw fiber covered on the top side with a photo accelerated extruded plastic or woven biodegradable netting having maximum openings of 1.27 x 2.54 cm (0.5 x 1.0 in.). The blanket shall conform to the general design criteria.	Erosion control and vegetation establishment on roadside embankments, abutments, berms, shoulders and median swales where natural vegetation will provide long-term stabilization. *General Design Criteria* Slopes: Gradient 3H:1V Swales Limiting Shear Stress: Unvegetated: 74.4 Pa (1.55 lb./ft.^{2}); Vegetated: Not applicable	2–12 months
II. Double net short-term temporary degradable ECB	The blanket shall be a machine-produced mat of straw fiber covered on the top and bottom sides with photo-accelerated extruded plastic or woven biodegradable nettings having maximum openings of 1.27 x 2.54 cm (0.5 x 1.0 in.). The blanket shall conform to the general design criteria.	Erosion Control and vegetation establishment on roadside embankments, abutments, berms, shoulders, median swales, and low flow channels where natural vegetation will provide long-term stabilization. *General Design Criteria* Slopes: Gradient 2H:1V Channels Limiting Shear Stress: Unvegetated: 79.2 Pa (1.65 lb./ft.^{2}); Vegetated: N/A	2–12 months
III. Double net extended-term degradable ECB	The blanket shall be a machine-produced mat of 30% coconut with equivalent performance properties and 70% straw stitched or otherwise mechanically bonded between plastic nettings (UV-stabilized top side) or woven biodegradable nettings having maximum openings of 1.27 x 2.54 cm (0.5 x 1.0 in.). The blanket shall conform to the general design criteria.	Erosion control and vegetation establishment on roadside embankments, abutments, berms, median swales, and medium flow channels where natural vegetation will provide long-term stabilization. *General Design Criteria* Slopes: Gradient: 1.5H:1V Channels Limiting Shear Stress: Unvegetated: 86.4 Pa (1.80 lb./ft.^{2}); Vegetated: N/A	12–24 months
IV. Double net long-term degradable ECB	The blanket shall be a machine-produced mat of 100% coconut or other fibers with equivalent performance properties stitched or otherwise mechanically bonded between two UV-stabilized plastic or woven biodegradable nettings having maximum openings of 1.27 x 2.54 cm (0.5 x 1.0 in.). The blanket shall conform to the general design criteria.	Erosion control and vegetation establishment on roadside embankments, abutments, berms, median swales and high flow channels where natural vegetation will provide long-term stabilization. *General Design Criteria* Slopes: Gradient 1H:1V Channels Limiting Shear Stress: Unvegetated: 108 Pa (2.25 lb./ft.2); Vegetated: N/A	24–36 months

will see more.
In the coming year, engineers and contractors will find an array of new offerings that target green project needs. This is a revitalized segment of product design, especially for markets seeking materials that degrade fully within a year. The speed of vegetation establishment is being stressed, in part as the construction demands of private and public entities converge. Whether it's a swale within a dogleg on a golf course or a roadside hill, clients want it green and fast. And rapid degradability (without impairing the sustainability of vegetation) will be sought. These are stronger products for short term use.
Diverse applications benefiting from this greener focus include roadway design, sod farming and golf course construction. For roads, slopes and ditches quickly establish vegetation. For sod farming, biodegradable netting is being used to more easily establish and cleanly remove rolls of sod. Clients on the installation end benefit as well, while the netting, regardless of UV influence, is naturally absorbed. As for golf course construction, the market has slowed (due to the number of courses finally cresting demand), but it is still a healthy area to be involved in. And the lessons learned in quicker installations in this arena translate well to other, public projects.
Since the number of municipalities and regulators want to see this sort of variety and vision as part of a design-again, it's the art of combining technologys-identifying the appropriate situations for these materials will be useful to anyone at work in this segment.
A number of resources are available for engineers and contractors looking to demonstrate green components but who need the hard data and case studies to back them up. In the United States, a number of state departments of transportation test and share product data. The Erosion Control Technology Council (ECTC) published numerous useful items at its online home (www.ectc.org). And the annual GFR Specifier's Guide (published in December) provide a long list of product data for the erosion control field.
Of course, there is no panacea for erosion. New offerings in the short-term ECB market are not going to end the need for longer-term, tougher solutions. True enough, the turf reinforcement mat (TRM) market, which focuses generally on applications beyond the scope of ECBs, is also undergoing a renewal of options and increased versatility.
But for those finding a need or opportunity to go green, the options are really expanding. Some contacts are noted at the end of this article.

Hard armor On the other end of the spectrum, we find hard armor and its chief element: concrete.
Concrete has often been designed around, in part due to performance concerns—it's porous, so lesser formulations weather and crack—and in part due to aesthetic concerns. New types of concrete, however, are proving to be quite durable over time, especially when supported by other materials, such as a geotextile underlay. Geotextiles provide separation between the concrete product and the soil, enabling drainage and stability to soils while the hard armor assuages surface forces. Also, end product makers have created some aesthetically interesting alternatives, including flexible, vegetated concrete.
Two principal types of armor in this group are cable concrete and articulated concrete blocks (ACBs). Both function similarly, and to a large extent each term is simply the preference of the speaker, the specifier, whomever. What is important to note is how, as with degradable erosion blankets, these hard armor types are not new but are receiving renewed interest.

Cable concrete
Cable concrete joins concrete forms by way of high-strength flexible cords. This allows interlocking panels of the material to conform to site contours (such as channel depressions) while providing ample space between blocks for vegetation. Geotextile fabric, when attached to the panels (Photo 2) or placed prior to the installa-

tion of the cable concrete, provides soil separation, drainage and, overall, stability for an installation.
The incorporation of vegetation is one of the characteristics that has put concrete back on the designer's map. It allows a desired durability—for example, it accepts service vehicle traffic—while enabling a more natural look. Cable concrete does this well.

Photo 2. Flexible "cable concrete" being installed. A geotextile sheet is fused to the underside. Its separation characteristics provide drainage and stability to subsoils.

Articulated concrete block
ACBs create flexible revetment systems through a matrix of concrete blocks that are, often, interlocked. Cells can be open (e.g., promote vegetation through holes in blocks) or closed (solid blocks). The systems can use cables for connecting panels and anchoring the overall installation. As with cable concrete, a geotextile underlay is preferred to provide soil stability. This may be installed prior to the ACB panels or attached to the panels. Either way, it allows the articulated concrete to do what it does best: guard against hydrologic forces and other loads.
Whether it's a bank exposed to waves, a boat ramp, or an overflow channel, ACBs provide long-term support. See page 44 for more information.

A growing design field

As communities struggle to minimize their environmental impact while maintaining needed infrastructure, they must also counter the ways nature erodes itself. Just as a landfill cover is subject to erosive rain events, so too is a hillside untouched by human development. Conflicts of this nature set against the need for long-term vision have made erosion control, however broad the term becomes, a flourishing segment of design.—CK

Resources

Companies who provided information and/or images to this article are noted below. More firms and product data can be found in GFR's December issue, the 2005 Specifier's Guide.
Soft armor contacts:
Megan Nelson, Conwed Global Netting Solutions, 2810 Weeks Ave. S.E., Minneapolis, MN 55414; +1 612 623 2535, Web site www.conwedplastics.com.
Diane Hitt, East Coast Erosion BlanketsLLC, 555 Mountain Home Rd., Sinking Spring, PA 19608; +1 610 927 0757, Web site www.erosionblankets.com.
Roy Nelsen, North American Green,14649 Hwy. 41 N., Evansville, IN 47725; 800 772 2040, Web site www.nagreen.com.
Hard armor contacts:
Doug Buch, Armortec, P.O. Box 20308, Bolwing Green, KY 42102; 800 305 0523, Web site www.armortec.com.
Charlie Chase, International ErosionControl Systems, 24585 Pioneer Line, West Lorne, ON N0L 2P0, Canada; +1 519 768 1420, Web site www.internationalerosion controlsystems.com.

Reference: Nelsen, R. 2003. "RECPs and vegetation for effective erosion control. "GFR, v.21, no. 7, p.20.

Volume 22, Number 7

The civil engineer's desktop

By Christopher Kelsey

Most things in the engineering profession are reduced to data at some point. Sites are mapped, soils are collected. Designs are proposed then modeled against expected forces and site conditions. The mechanical properties of construction materials are incorporated. The cost of construction is figured.
That's a highly incomplete list, but it surfices to show why analysis, design and specification assistance is generally appreciated. Software is one form of relief to which engineers may appeal.

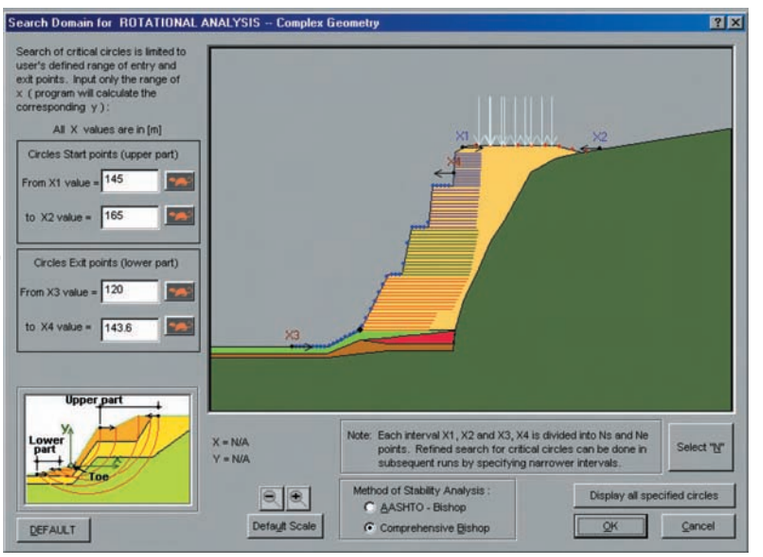
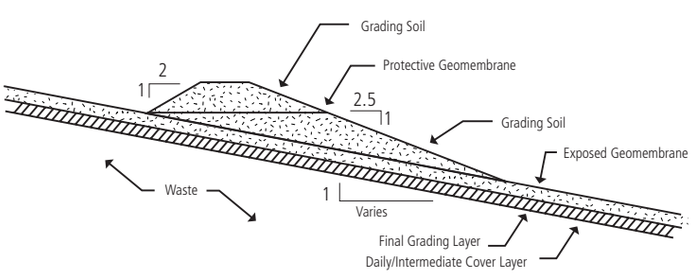


Figure 1. Software provides design assistance in many ways, such as in calculations involving slip surfaces.

Calculations

Software tools provide valuable assistance in performing calculations and representing projects in drawings. It's hard enough identifying what we might call the most correct group of calculations, those that will produce the most efficient and successful designs. Embankments, rain events, rivers: Nothing in the trade feels truly cooperative. So one must perform enough calculations to assess a variety of design life scenarios. This is vital not only to a projects overall performance but for meeting the intermediary challenges. For example, specifying materials, gaining regulatory approval, and persuading clients.
The volume of calculations needed has helped foster an engineering software industry. Slope stability, erosion control and drainage management are just a few of the complicated areas in which these tools are being used. Largely, software retains values that will be required in other calculations. Being able to shorten the number of steps one must take (without actually losing those steps) is a great advantage. It can help run a number of project scenarios; thus, moving towards the goal of overall efficiency. It should be stressed at this point that design software is



DSWA Swale Anchor

Figure 2. Converting data into workable drawings is a key function of many software tools. Seen here:detail of a swale bench anchor.

not a substitute for experience. Dov Leshchinsky noted thin in his March 2002 GFR article on designing for soft soils. His point was apt. He added: ".....however, it can be an excellent tool to reduce the tedium and increase productivity while producing an optimal construction base on a rational approach."

Images that speak

There's an old adage about a picture saying a thousand words. In geotechnical engineering, it's a drawing- and while the images don't speak (in a literal sense, though that option may not be far off), it's not necessarily unusual to see a drawing that has, actually, close to a thousand words within it.

A number of elements might be marked: elevation changes, constructed layers, drainage patterns, pipe penetrations, etc.

Cluttered as they sometimes seem, drawings play a big role in finding the right design; and in conveying the design's utility to a client, other project partners, oversight agencies, etc. As such, a high volume of software being developed works with popular drawing programs such as CAD; thus translating the calculations done in one area of the software into visuals.

A number of firms are bolstering options in this field by offering design drawing references: manuals that bring together a number of drawings. Some of these publications are traditionally bound, but most are electronic resources. In them, users find templates for approaching various applications, such as vegetated stormwater channels, segmental retaining wall construction, and erosion control.

A note on software packages

Many software makers offer suites of design and data collection tools. These items often allow a fairly seamless transfer of information between programs, enabling a designer to work various angles of a project within the same program interface without repeating calculation and input steps. It's a very handy tool.

The only concern a designer might have is this: Do suite packages make the user too dependent on one company's offerings? For the most part, this is a concern of comfort and not one of program package utility.

Proprietary products and geosynthetics

Many manufacturers of geosynthetic materials offer free design calculators and software particular to their proprietary products' recommended applications. These programs can be immensely helpful for designers who are less familiar with incorporating geosynthetics into their projects. For seasoned users who may have developed singular preferences in brands, or just all-around familiarity with the selection and performance of polymeric materials, the programs can greatly expedite the design process. For the mid-level user—most designers fall into this category—proprietary software might best serve as a refresher course, or as a comparative resource for project approaches.

There may be limitations. Some proprietary software does not allow calculations to stray beyond certain manufacturer product offerings. But this is not in and of itself a hardship on the designer. It isn't an absolute rule. A number of firms even sell their software— they've simply applied their experience with product selection and application design to a commercial-style software program.

Regardless, there is much more to learn from these programs. With the exception of a few software makers, geosynthetic manufacturers are the only companies actively creating design assistance software for polymeric materials and affiliated technologies (such as organic erosion blankets). If we take into account the thousands of annual projects on which the materials are used, that points to a huge gap in the field's software resources. So offerings from proprietary product manufacturers or otherwise are definitely worth consideration. The programs may reveal approaches that the user had not previously thought of.

Table 1. A sample of software programs for data collection and project design. Contact information for these firms can be found at the end of this article.

Program	General slope stability	Reinforced walls	Roads	Drainage/Seepage	Erosion control	Geofabric reinforcement	Geotechnical analysis	Suite software package	2-D Modeling	3-D Modeling	Data monitoring	Dos	Windows	PDA options	Supplier
ReSSA(2.0)	♦					♦	♦						♦♦		ADAMA
MSEW (2.0)		♦				♦	♦						♦		ADAMA
FoSSA (2.0)			♦	♦			♦						♦		ADAMA
Slope W/	♦					♦	♦		♦				♦		Geo-Slope
Seep W/				♦			♦		♦				♦		Geo-Slope
GeoStudio 2004							♦	♦							Geo-Slope
PLog											♦		♦	♦	gINT
gINT Logs							♦				♦		♦		gINT
gINT Professional							♦				♦				gINT
Erosion Draw 5.0					♦										Salix
Bio Draw 3.0					♦										Salix
E-SenSS	♦				♦								♦		Salix
Road/Eng Civil Assistant			♦				♦		♦				♦		Softree
Terrain Tools 3D										♦					Softree
Terrain Tools CE											♦			♦	Softree

Table 2. Software for geosynthetic selection, as listed at www.ggsd.com, August 2004. The list, though incomplete demonstrates how geosynthetic materials, despite wide-spread use, have yet to be directly incorporated into most commercially marketed design assistance software. Manufacturers have filled the void.
*Most of the programs listed here have been updated recently. Please contact the companies directly for the latest information on their software offerings.

Program	Status	Operating system	Supplier
EC-Design	Freeware	Win3x, Win95/98	Synthetic Industries
ECMDS	Freeware	DOS,Win95/98, WinNT, Win2000	North American Green
EnkaRoad	Freeware	Win95/98	Colbond Geosynthetics
EPI Spec Disk	Freeware	Win95/98	Environmental Protection Inc.(EPI)
Erosion Works	Freeware	Win3x, Win95/98	American Excelsior
GeoCoPS	Commercial	Win 95/98, WinNT	ADAMA Engineering
Geofilter	Freeware	Win 95/98, WinNT	TC Mirafi
MACRA 1	Freeware	Win3x, Wi95/98,WinNT	Maccaferri
SPECMaker	Freeware	Win95/98, WinNT, Win2000	Presto Geosystems
SpectraPave	Freeware	Win3x, Win95/98	Tensar
Tensar Pave	Freeware	Win95/98, WinNT, Win2000	Tensar
TENWEB	Freeware	Win95/98	Tenax

It is always good to add resources to an office library.

Resources

An online directory: www.ggsd.com
The Geotechnical and Geoenvironmental Software Directory (GGSD) catalogs 1565 programs in the fields of geotechnical engineering, soil mechanics, rock mechanics, engineering geology, foundation engineering, hydrogeology, geoenvironmental engineering, environmental engineering, data analysis and data visualization. Also, it lists 788 worldwide suppliers and publishers of these programs.
Programs are indexed by program name, program category, operating system and program status, and the directory entries are listed by category. Program publishers and suppliers are indexed by organization name and by country. The directories of programs, publishers and suppliers are cross-referenced. The directory also gives 27 links to other Web sites that feature geotechnical, geoenvironmental or related software. And there is a free GGSD Newsletter to keep you informed of new software.
The GGSD, first published in 1996, is compiled and maintained by Tim Spink. It receives over 2 million page hits per year.

Suppliers noted in Table 1:
ADAMA Engineering, Inc., 33 The Horseshoe, Covered Bridge Farms, Newark, DE 19711; +1 302 368 3197, fax +1 302 731 1001, e-mail adama@geoprograms.com, Web site www.geoprograms.com
Geo-Slope International Ltd., 1400, 633
- 6th Ave. S.W., Calgary, AB T2P 2Y5, Canada; +1 403 269 2002, fax +1 403 266 4851, e-mail info@geo-slope.com
Geo-Slope International Ltd., 1400, 633 6th Ave. S.W., Calgary, AB T2P 2Y5, Canada; +1 403 269 2002, fax +1 403 266 4851, e-mail info@geo-slope.com, Web site www.geo-slope.com.
gINT Software, 7710 Bell Rd., Windsor, CA 95492-8518; +1 707 838 1271, fax +1 707 838 1274, e-mail sales@gintsoftware.com, Web site www.gintsoftware.com.

Salix Applied Earthcare, 225 Locust St., Ste. 203, Redding, CA 96001; +1 530 247-1600, fax +1 530 247 1601, e-mail info@salixaec.com, Web site www.salixaec.com
Softree Technical Systems Inc., #8-650 Clyde Ave., West Vancouver, BC V7T 1 E2, Canada; +1 866 519 6222, fax +1 604 926 3075, e-mail mail@softree.com, Web site www.softree.com.
For contact information of the suppliers noted in **Table 2**, please visit www.ggsd.com.

Recent offerings from manufacturers
The GSE Drainage Design Manual. Engineers from GSE, GeoSyntec, Thiel Engineering, and Earth Tech came together to create this June 2004 publication offered in bound and CD-Rom formats. The reference covers geonet and geocomposite basics, landfill applications, design methods and concepts, design flow charts, and design examples. Contact Dhani Narejo, GSE Lining Technology, 19103 Gundle Rd., Houston, TX 77073; +1 281 443 8564, fax +1 281 230 6739, e-mail dnarejo@gseworld.com, Web site www.gseworld.com.
Erosion Control Materials Design Software (ECMDS) 4.3. The latest version from North American Green helps designers working with their products establish best management practices (BMPs) in erosion control and meet National Pollutant Discharge Elimination System (NPDES) regulations. Contact Lynne Knauff, North American Green, 14649 Hwy. 41 N., Evansville, IN 47725; +1 812 867 6632, fax + 1 812 867 0247, e-mail lknauff@nagreen.com, Web site www.nagreen.com. GFR

Articles
Leshchinsky, D. 2004. "Design software for soft soils." GFR, v.22, no. 5, pp. 18-23.
Spink, T. 2001 "Software for geosynthetic engineering." GFR v.19, no. 3, pp.. 24-27
Zhao, A.,Bauters, T., and Ellithy, G. 2001. "Web-based interactive landfill design software." GFR, v. 19, no. 6, pp. 30-35.

Questions and advice
Send your software tips, recommendations and questions to the Editors, GFR magazine, 1801 County Rd. B W., Roseville, MN 55113-4061; +1 651 225 6988, fax +1 651 225 6966, e-mail gfr@ifai.com, Web site www.gfrmagazine.info.-CK

GFR Engineering Solutions for Roads, Soil, Water and Waste

Volume 22, Number 7

The back page- Second looks

Industrial sludge

The chalky consistency of the effluent sludge seen here testifies to how well the geotextile bags worked on this industrial project. The solids were formerly left to collect in a storage pit, which when in need of refreshing was cumbersome and somewhat dangerous to correct. Using geotextile bags to filter the silica, fluorosilicic acid and superphosphate dust—the by-products of the primary industrial process—greatly accelerated the solids drying time, and made removal of solids an easier process.

See page 32 for more information.

ACBs and dam improvements

To increase Lake Lapeer Dam's hydraulic capacity, articulated concrete blocks (ACBs) with a geotextile underlay were installed in an emergency spillway. Prior to the renovation, the dam could not convey its required 200-year peak discharge of 1,400 cfs as mandated by Part 315 of the Natural Resources and Environmental Protection Act.

ACBs use panels of interlocked concrete cells to provide a long-term durable surface. The cells can be open to allow vegetation to grow through. This was the sort used for the Lake Lapeer project.

The geotextile layer provides valuable separation between the block and the subsoil (see winter installation photo), thus providing a drainage medium during regular rainfall and improving the stability of the subgrade. This allows the blocks to perform their primary function of mitigating surface erosion under high-flow conditions.

Due to the lake's risk of flash spilling during storm events, the redesigned spillway was set at a lower elevation to reduce fluctuations in the water level. The use of articulated concrete with a geotextile beneath allowed the lining system to support vegetation and have the flexibility needed to withstand some settlement without cracking.

For more about the use of hard armor and other erosion control options, see page 34.

Note: The Spicer Group (www.spicergroup.com) provided information for this project synopsis. GFR