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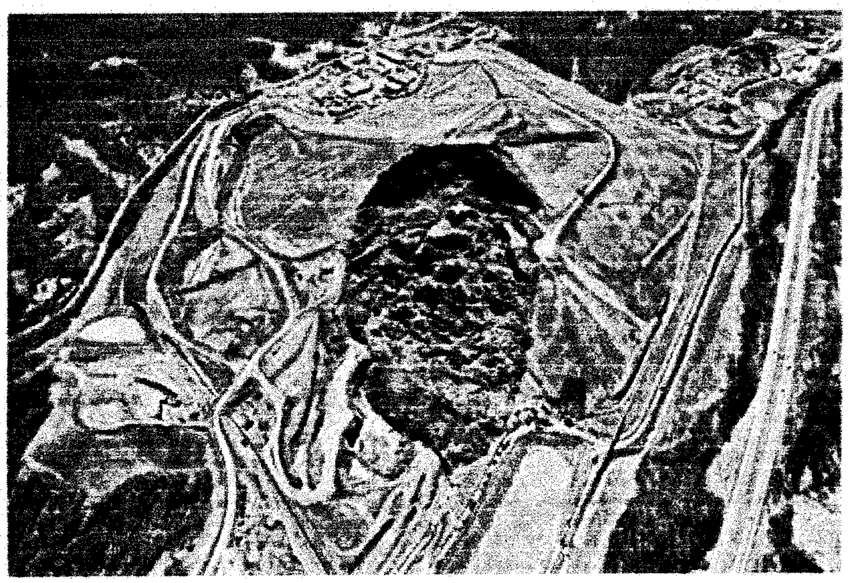
Feature

# Landfill Stability: Let GeoRG Help



***What may be the most definitive free work available on the specific geotechnical issues facing landfills is now available on the Web. The Ohio EPA recently finalized its policy on geotechnical analyses for waste containment facilities.***

By Doug Evans

GeoRG, short for Geotechnical Resource Group, a 15 (or so)–member agency team, along with some help from several notable academicians and other proficient characters, developed the manual at the typical government pace. That is to say that the heady information was, like a wine, dabbled with by connoisseurs for years before its consummation this past fall.

The policy covers landfill slope stability in great detail and even includes some worked-out examples. It also covers geotechnical reporting, subsurface investigation, materials testing, liquefaction, settlement analysis, and hydrostatic uplift.

To put the level of slope stability analysis detail in perspective, if your landfill site is on soft clay and has a high water table, you could be looking at 40-something different slope stability modeling efforts. That seems like a lot, but it's really not when you think about how much there is to think about. Selecting the right shear strength(s) in and of itself is a daunting task. There are usually no less than six different shear strengths to account for in even a simple composite liner system. And a few of those strength values react to weight differently, so the geotechnical rendition of "Who's on First" is forever playing out, depending on how high the hill is.

What brought on this noble cause? Failures, and not just a few of them. I know at least 14 slope failures that have occurred at landfills in Ohio over the past decade. They include a rush of failures in the mid-'90s to which the pace has slowed to only the occasional one every year or two in more recent times. The slope failures run the gamut from catastrophic to barely noticeable.

There was the larger-than-life failure at the Rumpke site near Cincinnati shown in the black and white photograph, where 1.4 million cubic yards of rubbish got up and moved 1,000 or so feet in about two minutes. The cataclysm has been called the largest landfill failure in the United States. I sincerely hope no one ever challenges it for bragging rights. The failure was eventually attributed to some unusually weak material beneath an ancient part of the site.

Failures at other sites, such as the one in the accompanying photograph, occurred during a tie-in between new and existing cells, and a rainstorm that didn't have the decency to wait until construction was completed. Saturated conditions led to the collapse, which required exhuming 120,000 cubic yards of solid waste.

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There have also been no less than five landfill liner failures that occurred during cell construction. Some have been reluctant to term these types of incidents as slope failures because they occur during construction, don't involve waste, and therefore can be readily repaired. Whatever term you give it, rebuilding 3 or 4 acres of composite liner and leachate collection systems takes serious collateral for an unproposed deconstruction event.

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People have asked me why there have been so many slope failures at Ohio landfills. I'm not sure. Ohio's landfills are no different than landfills in other states. Ohio does allow 3-horizontal to 1-vertical final slopes, but that's not terribly uncommon; besides, there has only been one tiny cap failure. The lone cap failure's only redeeming interest is that the cap slid in a location where off-spec green dye for radiator fluid had been disposed of, revealing a rupture zone that had that iridescent green glow associated with cartoonish radiation. Just think of the possible headlines had the failure been large enough to attract the attention of sensationalizing journalists or even been really noticeable to passersby.

I suspect that Ohio's landfill slope failure rate is probably not that atypical, but rather that it is perhaps a little too commonplace to sweep those unproposed deconstruction blemishes under the rug as quickly as possible. Let's face it: In the event of a slope failure no owner, consultant, or contractor wants to see his or her nightmare nakedly exhibited for poking and prodding. Along those same lines, no agency wants to chance the dubious criticism sure to be hurled at its apparent ineptitude for allowing such a thing to be permitted. The Ohio EPA's forward thinking is more likely the harbinger of having the nation's largest landfill failure—so large, in fact, that official consternation called for the evacuation of nearby residents twice, and so contrarily unmanageable that it caught on fire 18 times before it could be patched up, making it impossible not to be an iridescent glow on the media's radar.

In any case, the Ohio EPA took the high road and went about the most decidedly estimable work of conducting forensic investigations into failures and sorting out the unforeseen scenarios and inadequate parameter determinations that had plagued the recent slew of unproposed deconstruction events so that the esoteric information would be thoroughly documented for all.

The policy is over 200 pages focusing mainly on geotechnical issues as they relate to landfills. The beginning of the manual drones on a bit in typical electrifying bureaucratic style pointing out the ever-so-slight nuances of requirement and recommendation (like there's really a difference), and unconsolidated and underconsolidated, etc. Once into it, the policy quickly points out that many instabilities are brought about by construction or operational activities planned or performed independently of the design process and how important it is for the owner, engineer, and contractor to have a continuing dialogue. Examples of construction and operational activities that have contributed to failures include the following:

- Placement of soil or waste from the top of a slope downward
- Lengthy or unplanned excavations

- Regrading of waste for operational or closure purposes
- Leachate recirculation
- Overfilling
- Blasting
- Stockpiling materials
- Waste relocation
- Relocation of access roads
- Suddenly increasing or reducing the freeboard in lagoons
- Inadequate base liner length to resist interim slope driving forces

The policy lists the key components of a geotechnical analysis as the subsurface investigation, the materials testing program, the liquefaction potential evaluation (Ohio has seismic impact zones), settlement analyses, bearing capacity analyses, the hydrostatic uplift evaluation, and deep-seated and shallow slope stability analyses for both static and seismic conditions. Flowcharts abound; government does like to have those boxes to X on its checklists.

The subsurface investigation section recommends one boring for every 4 acres of facility and that the borings extend at least 50 feet beneath the deepest part of the proposed facility. In addition, this section points out that the critical soil layers (those most prone to instability) may only be a few inches thick, so the exploration should employ continuous sampling, at least in part, and it admonishes the averaging of soil characteristics because it masks the meek idiosyncrasies of critical layers.

To drive home the point that the weakest interface at low normal stresses may not be the weakest interface at high normal stresses, the materials testing section expounds on the basic tenet that failure planes propagate through the materials and interfaces that exhibit the weakest shear strength at a given loading. The text does a good job of covering the differing strength testing methods and provides some special considerations on the testing of GCLs. The data validation and conformance testing portions, although needed, get a little monotonous. The section wraps up by explaining the detailed development of compound non-linear shear strength envelopes.

Ohio does have some seismic impact zones, so the requisite liquefaction potential brought on by the federal rules has been expanded on and an example calculation is offered.

The settlement analysis section provides some very specific design criteria for the liner and leachate collection system. The slope of the liner and leachate collection pipes must meet the applicable minimum regulatory requirements for 100% of the primary settlement and secondary settlement when using a time frame of 100 years. One would apparently be wise to leave a little extra slope in the design to accommodate future expansions because the initial design will be held accountable for the allowable settlement. An example calculation is provided for clarity.

Issues relating to hydrostatic uplift and overexcavation into aquicludes are covered. A factor of safety is given and direction is provided on worst-case scenarios using the highest temporal phreatic or piezometric surfaces with the deepest excavation depth. As in previous sections, the methodology is stepped through and an example calculation is included.

Notwithstanding the above mentioned analyses, the document spotlights slope stability. This is understandable in that the primary geotechnical issue is usually the stability of the landfill slopes and cover systems in the multitude of various configurations that occur during the life span of a typical landfill. There are the so-called internal slopes, the as-constructed liner slopes with their attendant leachate collection and protective layers. There are also the many different permutations of interim slopes that occur during daily waste filling operations and as a cell reaches capacity. Finally, there are the final slopes that include the deep-seated global failures involving the entire waste mass and the shallow-seated failures of the cap system, both of which must withstand the eternal test of time.

Deep-seated failures using drained, undrained, and seismic conditions are addressed for both rotational and translational modes of failure. Differing factors of safety as related to quality of data are also discussed. The Ohio EPA requires the use of residual shear strengths on geosynthetic lined slopes greater than 5% for deep-seated failures and further defines deep-seated slopes as those loaded with more than 1,440 psf. Phreatic and piezometric surfaces are covered, and static and seismic analyses are dealt with separately. A section on determining an appropriate horizontal ground acceleration is also included along with an XSTABL computer slope stability model example calculation.

Shallow-seated rotational and translational failures are covered focusing on capping and combined liner and leachate collection systems. These slopes can rely on peak shear strengths provided the normal stress does not exceed 1,440 psf. Particular detail is provided on modeling saturated conditions of the cap or liner and propagating a horizontal ground acceleration through the waste mass to the crest of the landfill for seismic conditions. The policy concludes by providing longhand example calculations for both saturated and unsaturated conditions, and also includes a final cover example through a tack-on cap channel using the XSTABL computer software program.

An overriding theme throughout the policy manual speaks to providing a coherent and complete analysis. Although perhaps a little elementary, it is apparently necessary to point out that an analysis needs to not only go out and find the information but also tell the story in an understandable fashion. The document points out in many chapters that the analysis should include both a narrative and supporting information. The narrative is requested to include the following:

- The scope, extent, and findings of the subsurface investigation
- The scope, extent, and findings of the laboratory material testing program
- The logic and rationale for the selection of the analysis input parameters
- The logic and rationale for the selection of the critical section
- Graphical depictions of the plan and profile views of critical sections
- A discussion of all the failure modes and conditions considered and analyzed
- Conclusions from the evaluation of the critical cases

The supporting data and information should unconditionally include these:

- Field data and site mapping from the subsurface investigation
- Laboratory data from the material testing program
- The actual calculations and/or computer output

The policy is titled Geotechnical and Stability Analyses for Ohio Waste Containment Facilities, but regardless of your location, the manual will make for a valuable addition to your technical resource library. Did I mention that it is free? The information and worked-out examples will no doubt be useful. The policy can be downloaded at www.epa.state.oh.us/dsiwm/document/guidance/gd_660.pdf. I understand that it has been one of the busiest hits on the Ohio EPA's Web site for months. Be forewarned though that it is an 18-megabyte Adobe PDF file, so those with slower connections may want to request a CD by emailing georgia.frakes@epa.state.oh.us or calling 614-644-2621.

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