A2K06: Committee on Subsurface Drainage
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Subsurface Drainage

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Past research and practice have clearly indicated the detrimental effects of inadequate subsurface drainage within transportation systems. At the same time, the extremes of inadequate and proper drainage simply frame the broad range of engineering practice. In this context, a number of questions related to subsurface drainage need to be addressed in the next millennium:

- In what areas and applications is drainage absolutely necessary, versus helpful, advisable, or not really necessary?
- How does one quantify different levels of drainage efficiency relative to the service life (performance) of the pavement system?
- How does one quantify acceptable subsurface drainage in light of the serviceability of a particular application?
- How does one formulate a generic specification, based on relevant and appropriate test methods and properties, to ensure the adequacy of specific products and materials?
- What inspection is required during and after construction?
- How does one guarantee acceptable subsurface drainage during a system's service lifetime?
- What maintenance commitments and training are needed to ensure adequate performance?
- What are the time-dependent benefit and cost ratios of acceptable subsurface drainage?
- How does one best define and quantify life-cycle costs and subsequent performance?

Note that these questions apply not just to pavement drainage systems, but to all types of subsurface drainage applications, such as retaining structures (e.g., walls, abutments, bulkheads), steep soil and rock slopes, and a host of below-grade building structures (e.g., basements, underground shelters, storage tanks).

CURRENT STATUS

The majority of subsurface drainage applications continue to rely on granular (sand or gravel) natural soil materials. Reasonably well-established design methods are based on achieving a balance between large-particle voids (for adequate permeability) and smallparticle voids (for proper soil retention). The performance of the resulting designs has generally been good, but certainly not perfect. Soils and permeants identified as problematic include gap-graded cohesionless soils, uniform-size silt soils (e.g., loess and rock flour), expansive clay soils (particularly when dispersive), quasi-stable soils high in calcium and magnesium (e.g., limestone), turbid liquid permeants (e.g., dredged soils and surface runoff), and permeants highly laden with microorganisms (e.g., agricultural runoff). Problems with these soils and permeants are further complicated by the designer's dilemma of the possibility of filter clogging versus the possibility of downstream drain clogging.

An alternative to the use of natural soil materials to provide subsurface drainage is the use of geosynthetics. The geosynthetic counterpart to a soil filter (usually sand) is a geotextile, and the geosynthetic counterpart to a soil drain (usually gravel) is a geocomposite drain. Geocomposite drainage cores take many different shapes, including biaxial nets, triaxial nets, extended nubs, raised columns, single-sided cuspations, double-sided cuspations, three-dimensional webbings and mats, fluted sections, and oblong pipes. The geotextile placed on the surface(s) of these drainage cores (thereby making them drainage geocomposites) acts as both a filter and a separator. The geotextile is generally laminated onto the core in the factory, requiring only an adequate overlap during field placement.

Usually (though not always) a geosynthetic drainage system will be less expensive than a natural soil drainage system. Many factors are responsible for this cost advantage, not the least of which is significantly faster and easier installation. Conversely, the problems with soils and permeants noted above can be greatly exacerbated by the use of geosynthetics. For example, because of its relative thinness, a filter made of geotextile will become excessively clogged much more quickly than a filter composed of sand. The general performance level of geosynthetics, however, has been very good, and many agencies and engineers are becoming more proficient in geosynthetic design and selection. The geotextile specification embodied in the American Association of State Highway and Transportation Officials' specification M288-96 has been very helpful in this regard.

Hybrid drainage systems combining natural soils and geosynthetics are also an option. For example, the use of a geotextile around a drainage gravel or other outlet system is a common feature of highway underdrains. Another example is the use of intermittent sheet drains and panel drains to augment subsurface flow in pavement base courses and soil backfills behind retaining walls.

Perhaps the most misunderstood issue in the use of geosynthetic drainage systems is durability. The polymers used to make the majority of geosynthetics (polyethylene, polypropylene, polyester) have buried lifetimes much longer than the service lifetimes of the transportation systems they serve. Covered in a timely manner so as to avoid ultraviolet light degradation, geosynthetics do not biodegrade, easily hydrolyze, or otherwise react in the buried environment. Only a long-term oxidation process is of concern, and in the typical oxygen-depleted backfill soil of most drainage systems, that process promises to take decades, if not longer. In this regard, it is necessary to craft durability specifications to ensure that the proper resins, stabilizers, antioxidants, and other materials are used in the respective formulations. Doing so is certainly possible within the context of current practice, and requires only training and implementation on the part of agencies and owners.

NEAR FUTURE

Adequate subsurface drainage will continue to be emphasized in all types of transportation-related systems early in the next millennium. In addition to current practice with natural soils and geosynthetics, some relatively new approaches will be implemented in the near term:

- Open-graded base courses will be used where conditions warrant the added flow in the base course material; their stability will be enhanced to acceptable levels.
- When open-graded base courses are employed, they will be used with geotextile separators placed against the underlying soil subgrade to preserve the high in situ transmissivity of the base course itself.
- Relatively impermeable pavement base courses will have drainage augmented by geocomposite strip and panel drain systems.
- Prefabricated pavement edge drains employing geosynthetics will continue to be used, but with improved installation procedures (e.g., backfilled sand placed upstream of the edge drain).
- Conventional retaining walls will use geosynthetic drainage systems instead of the usual 300 mm of sand.
- Retaining wall drainage will be augmented with geofoam, thereby ensuring that lateral pressures do not exceed active conditions.
- Retaining walls using prefabricated facing elements that have in situ drainage capability will be further developed and utilized.
- Unstable soil slopes will be rebuilt with combined reinforcement inclusions and geosynthetic drainage systems.
- Retrofitting of existing unstable soil slopes with prefabricated geosynthetic drainage systems will become common (e.g., anchored spider netting with rods containing drainage capability).

There will have to be an economic justification for efforts to provide better drainage than in the past. Fortunately, the economic tools needed to develop this justification are either known to the transportation community or available from economists. Certainly, the current net worth of investment costs is well known. Less well known is how to assess a system's performance so as to determine the benefit term of the benefit and cost ratio. In this regard, highway, wall, and slope performance is not simply either adequate or inadequate; rather, performance falls on a continuum from adequate to inadequate, and changes in performance over time may turn out to be nonlinear (see Figure 1).

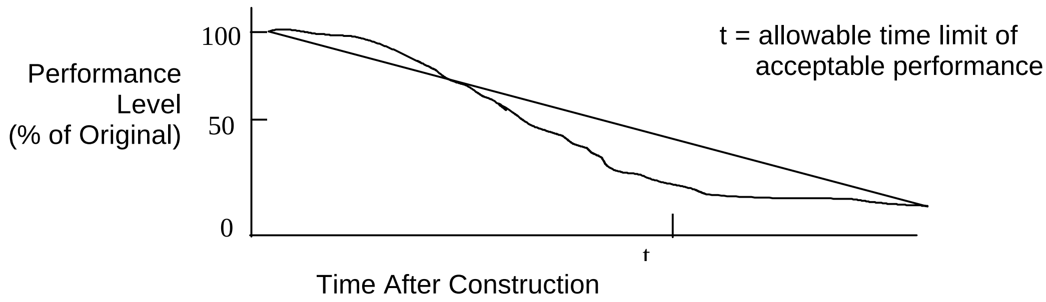

FIGURE 1 Nonlinearity of performance levels.

It is in the area of determining performance where the greatest near-term effort is required. One simply cannot rate alternative systems on the basis of a qualitative assessment. One must have control sections, sections with different alternatives, and quantitative methods for assessing each alternative. Considering initial as well as maintenance costs, rational decisions can be made as to the optimum choice of materials and systems for site-specific situations. The availability of such information on multiple sites will make it possible to generalize about optimally performing subsurface drainage systems; that is, one will be able to quantify the benefits of decisions regarding improved subsurface drainage.

Clearly, much work needs to be done to support definitive decisions as to choices among currently available or emerging materials and systems. One issue to be addressed is the possible use of recycled plastics in drainage products where applicable. In any case, the quality of the constructed facility and all of its individual components will be of primary importance. Indeed, “quality” must be a keyword of the 21st century.

With regard to quality, the transportation industry as a whole and the design and construction of drainage systems in particular require an enormous effort. This effort must begin with education in the quality issues embodied in Organization for International Standardization (ISO) 9000 for engineering, manufacturing, and contracting organizations. Proper use of a quality management system can greatly enhance construction quality control, which today is frequently lacking. In turn, construction quality control is greatly enhanced by on-site construction quality assurance based on regulatory or independent consulting inspection, which also is currently lacking.

DISTANT FUTURE

Materials

Natural drainage soils will always play a role in subsurface drainage, but that role will gradually diminish. Pressure for resource conservation alone will be a motivating factor in this regard. The use of reclaimed natural drainage soils, while certainly worthwhile, is not yet economically feasible. Attempts by the U.S. Environmental Protection Agency to develop giant soil-washing machines have not proven very effective.

Geofoam is an exciting new material that is being used to reduce lateral earth pressures. A drainage function could conceivably be incorporated in the same hybrid material. Work is being initiated in this area of material development.

Geosynthetics will continue to provide new and improved drainage materials, and the very strong manufacturing effort of the past should be encouraged into the new millennium. The companies involved will all be ISO 9000 certified (i.e., registered) in the near future. Clearly, review and endorsement of such systems by the Highway Innovative Technology Evaluation Center (HITEC) is a step toward widespread acceptance. It remains to be seen, however, how much weight will be given to HITEC endorsements in the implementation decisions of highway agencies.

Design

The current procedures used by design engineers will be challenged by high rainfall intensities. The selection of a site-specific design storm event is still quite subjective. The behavior of the subsurface flow through different material layers also requires additional investigation. Finally, the all-important collection and outlet systems (which are currently the nexus of numerous drainage system failures) require simpler and more straightforward designs that are relatively easy to construct and maintain.

Construction

A missing element of construction is the integration of initial cost and maintenance costs, which has the potential to change significantly the economics of improved subsurface drainage. Such change could in turn dictate the material type and use selected. A key aspect of these changes is the contractor becoming an integral part of the process, a shift encouraged by increased use of design-build-maintain construction. Such contracting practices could also result in drainage systems that are easier to build and maintain. This aspect of cost dovetails with the concept of “no-dig” installation and retrofitting of existing systems. In this regard, the contractor is of pivotal importance since no-dig requires innovation in both construction equipment and labor techniques.

Monitoring

A wealth of nonintrusive and nondestructive evaluation techniques are available or being researched. The use of closed-circuit television cameras on robotic sleds for pipe inspection is a currently available technology. These remotely driven cameras might also be adapted for geographic information system and Global Positioning System capabilities. New strides will be made as well with the use of fiber-optic sensing devices. Moisture, density, stress, and strain are all candidate parameters for monitoring with these devices. Feedback loops are also possible, whereby maintenance could be implemented as warranted.

Maintenance

One can imagine micro-boring devices capable of drilling drainage channels in existing poorly drained soils. Such devices might even provide porous channel linings for stabilization purposes. Other concepts could utilize electrokinetic geosynthetics to provide an electro-osmostic flow, thereby removing moisture from beneath or behind transportation systems. A number of materials might be used for this purpose, such as carbon fibers, conductively filled polymers, metallic fibers (metals, metallized or metal coated), and composites formed from conductive or nonconductive elements. Such electrical methods might be used in conjunction with reinforcement inclusions in cases of poor foundation subgrades or mechanically stabilized earth walls and soil slopes.

SUMMARY

During the past 100 years, the pivotal role played by adequate subsurface drainage in the performance of transportation systems has been recognized. The next 100 years should see a complete solution to the problem. In the 1920s, Professor A. Marston ran for the Iowa State Legislature on the slogan, "Let's get Iowa out of the mud!" Perhaps the slogan for the next 100 years will be, "Let's use water for creative purposes." Clearly the removal, collection, redirection, and utilization of subsurface water can (and should) be controlled. Water promises to be one of the greatest sources of struggle during the 21st century, even to the extent that some people predict armed conflict over its ownership and use. Paradoxically, the transportation industry is attempting to eliminate water and its negative side effects with absolutely no consideration of its possible subsequent use. Elimination of the negative aspects of subsurface water and enhancement of its beneficial usage is a key goal for the next millennium.