Vacuum-Assisted Drainage

by Guy Prettyman and Dr. Ed McCoy

There are two principal objectives in the design of natural-turf athletic fields. The first encompasses playability concerns. Fields must provide a smooth and firm, but resilient surface that is free from water ponding.

The second objective involves agronomic concerns. Fields must provide the appropriate soil environment to support a dense, uniform, and wear-tolerant turfgrass stand. A high-quality turf provides superior playability for a given soil condition.

It is well documented that sand-based root zones are ideally suited to meet the playability and agronomic objectives of athletic fields. Yet, even with sand-based root zones, a field will perform poorly if the overall system design does not provide rapid drainage of excess water.

In fact, athletic fields should not be designed to normal or average rainfall conditions, but rather to avoid the occasional catastrophic occurrence of a heavy rainfall during an athletic event. Periodic high-rainfall events create wet and muddy soil conditions, which lead to poor-quality play, injury to players, and slow turf recovery.

Ohio State University constructed a model of a section of PAT field to determine the effectiveness of vacuum-assisted drainage. *Courtesy: Ken Chamberlain*

Three factors

Subsurface drainage depends on three factors. The first is permeability of the soil. Soils with high permeability drain faster and more completely than soils with low permeability.

The distance water must travel to reach a drain line is another important factor: the further water must travel to reach a drain line, the slower the drainage.

The third key factor is the driving force acting on water movement. Under normal conditions, the only force that influences drainage is gravity.

Vacuum power

Dr. W. H. Daniel, a turf specialist at Purdue University, developed a technique that uses vacuum power to assist drainage on athletic fields. He called this system Prescription Athletic Turf, or the PAT system.

The rational behind the PAT system is quite simple in theory. Essentially, a vacuum is applied beneath the soil through special drain lines. The vacuum increases the driving force for water to infiltrate and move downward through the soil.

This vacuum-assisted drainage is intended to enable fields to remain playable even after or during rainfall that would rendered other natural-turf fields unfit. Since its introduction in the early 1970s, more than 40 fields across the world have included the PAT system in their installation.

Study

An Ohio State University study attempted to determine the effectiveness of vacuum-assisted drainage in a PAT field. We constructed a model to simulate a section of a PAT field (see photo). The 12-foot by four-foot model contained a 12-inch, coarse-sand root zone placed over an impermeable barrier. A round, two-inch, slitted drain pipe rested in a trench in the middle of the unit, oriented perpendicular to the long axis.

A collection tank adjacent to the model with a vacuum pump fitted to the tank measured drainage outflow. Soil moisture probes at five locations and three depths in the root zone provided a total of 15 soil-moisture measurements. Probes were installed three, six, and nine inches from the surface at five locations: over the drain line, 2-1/2 feet from either side of the drain line, and five feet from either side of the drain line. The field model supported a stand of Kentucky bluegrass maintained at a 1-1/4-inch height.

To test the system, we created an artificial rainstorm over the model through an overhead array of spray nozzles. For a given test run, we applied rainfall to the unit under gravity drainage until steady outflow was achieved. At each of the 15 probe locations, we measured the outflow over a 10-minute interval and recorded the soil water content.

We then applied a 0.5-psi vacuum to the drain line. Again, when the system reached a steady state, we measured drainage outflow and soil moisture. We repeated this procedure for the 1.0- and 1.5-psi vacuum levels. Three repetitions at each rainfall rate provided a total of nine experimental runs.

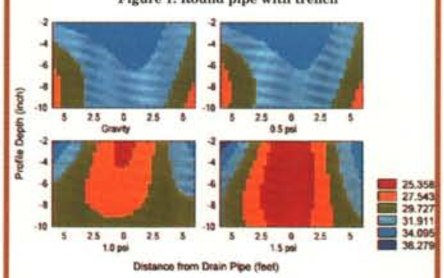
Findings

Data for the five-inch h-1 (+/- 1/4-inch) rainfall rate is presented here. Lower rainfall rates follow the same general behavior, but they aren't shown here.

Under gravity drainage at the five-inch h-1 rainfall rate, the apparent infiltration of the unit was two inches in h-1. As vacuum increased to 0.5-, 1.0-, and 1.5-psi, the infiltration rate increased to 2.6, 3.6, and 4.1 inches in h-1, respectively.

Though the highest vacuum level failed to totally infiltrate the five-inch h-1 rainfall, this vacuum doubled the infiltration rate observed under gravity drainage.

Figure 1. Round pipe with trench



Soil moistures for the given vacuum levels appear in **Figure 1**. This figure represents a cross-sectional view of the root zone. The vertical axis represents soil depth in inches, and the horizontal axis represents distance from the drain line in feet. The different colors represent different moisture levels in the root zone, expressed as percent volume.

As seen in this figure, vacuum aids in drying the root zone. This effect is concentrated over the drain line; much higher soil moistures occur five feet from the pipe.

This suggests that vacuum-assisted drainage benefited the system tested. It increased infiltration, but the soil moisture reduction was limited to the region immediately over the drain line trench.

Study 2

After reviewing the results, we decided to repeat our study using Advanedge pipe and eliminating the drain line trench. This approach mimics the current method used to build a PAT field.

We cleared the experimental model of turf and root zone, and removed the drain line trench. We placed a 12-inch Advanedge pipe flat on the impermeable barrier, and connected it to the collection tank.

We filled the unit with very coarse sand, as is currently used in PAT field construction. Again, we established a bluegrass cover, and maintained a 1-1/4-inch height.

Findings

As before, only data for the five-inch h-1 (+/- 1/4-inch) rainfall rate is presented here.

The unit's infiltration rate under gravity drainage measured 4.4 inches in h-1. The addition of a vacuum showed no noticeable effect on the already-high infiltration rate. This may be due to either the coarser sand or the Advanedge pipe.

The vacuum did, however, effect water redistribution within the soil profile. **Figure 2** shows the soil moisture distribution at the different vacuum levels.

As seen in this figure, the drainage

pattern is not concentrated over the drain line as before. The drainage front elongates to the ends of the unit. This suggests that this newer approach to building a PAT field using coarser sand and Advanedge pipe serves to drain the soil profile more completely than the system that uses slightly finer sand and round drain pipe located in a trench.

Discussion

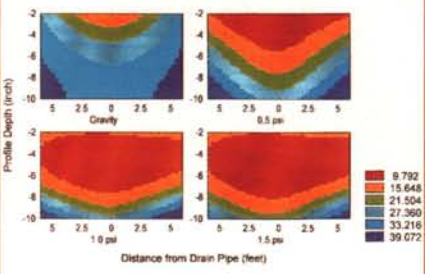
In both systems, the vacuum effected root zone drainage. In the system that used coarse sand and round drain pipe, vacuum contributed to an increased infiltration rate proportional to the vacuum applied. However, the vacuum assist preferentially drained the root zone just over the drain pipe, while the area away from the drain pipe remained wet.

Applied to a uniformly wet root zone, a vacuum first removes water from the profile just above the drain line trench. Once this area is drained, the vacuum draws air from above the turf surface. This air flow results in a rapid pressure drop in the vicinity of the pipe, and reduces the suction applied to soil water at further distances from the pipe. Thus, soil water that is laterally distant from the drain line does not sense the effect of the vacuum application.

In the system that used Advanedge pipe and very coarse sand, vacuum's impact stretched farther from the drain line. Perhaps the 12-inch Advanedge pipe laid flat on the subgrade allowed a wider vacuum distribution and less short-circuiting by air. Of course, the very coarse sand may also have contributed to the overall improved drainage.

Vacuum assisted drainage does beneficially impact removal and redistribution of water in a soil profile. It's important to remember, however, that drainage is but one factor that contributes to a successful natural-turf athletic field. Proper cultural and management practices contribute most to maintaining a high-quality grass field.

Figure 2. Advanedge pipe without trench



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