A well-designed network of paved paths can keep the course open to carts during wet weather and help maintain a smooth flow of traffic through the course. Curbing further enhances the effectiveness of cart paths — assuming, of course, that the golfers abide by the rules of the road.

TRAFFIC . . .

HOW MUCH CAN YOU *BARE?*

Wear and compaction can leave you with unsightly bare spots.

BY BOB VAVREK

A general definition of traffic as it pertains to golf turf might be *the movement of people and vehicles across the playing surfaces*. When all is said and done, without traffic, most golf courses would go out of business. After all, the effects of foot and cart traffic on the turf are directly related to the amount of play. There is no free golf, and green fees, membership dues, and cart revenues support golf course operations. Excessive traffic, however, can have a detrimental effect on the quality of the playing surfaces.

Concentrated traffic is a multi-component stress to the turf. According to Beard (1973), traffic results in four problems: (1) turfgrass wear, (2) soil compaction, (3) soil displacement or ruts, and (4) turf removal or divots. The most apparent effects of traffic are ruts, divots, and direct wear injury to the turf plants. Compaction is often considered the *hidden effect* of traffic because it affects the underlying soil. Soil compaction may not be visible, but it often alters the soil physical properties in a manner that is detrimental to turf growth. This article discusses how compaction affects soil physical properties, turf growth, and the quality of playing conditions, along with various techniques for relieving or preventing compaction.

Deep-tine aeration can relieve compaction found beyond the reach of conventional core cultivation operations.

COMPACTION

Soil compaction is defined as the pressing together of soil particles, resulting in a more dense soil mass with less pore space (Carrow and Petrovic, 1992). Back in Soils 101 we learned that a typical silt loam soil capable of supporting healthy plant growth would be composed of 50% solids (45% mineral, 5% organic matter), 25% air-filled pore space, and 25% water-filled pore space. Apply pressure or compaction to this soil and the balance between solids, air, and moisture is altered. Soil aggregates break down and individual soil particles are squeezed and shift into closer alignment. The ratio between small water-holding pores and large air-filled pores increases. The soil becomes denser and holds more water due to the increase in small pores.

A little compaction may actually improve growing conditions for turf on a sandy loam soil by increasing the moisture-holding potential of an otherwise droughty soil. However, relatively few courses outside of Florida are built on sand or sandy loam soils. Most courses are built on soils that contain a significant amount of silt and clay. The texture of the soil is one factor that determines the potential for compaction. The higher the fraction of silt/clay in the soil, the greater the potential for compaction.

Other factors that influence the potential degree of compaction for a particular soil include:

- Particle size distribution — Soils that have a wide particle size distribution are more susceptible to compaction than soils that have a narrow particle size distribution. For example, when most of the particles of a sandy soil are about the same size, the root zone resists compaction because the individual sand particles touch each other and a bridging action prevents a shift in the pore size distribution.
- Soil moisture — Dry soils are more resistant to compaction than wet soils. The water acts as a lubricant, and soil particles shift under pressure and orient themselves in a manner that reduces large pore space. As a result, the ratio of small pore space to large pore space increases.
- Turf density and thatch — The amount of living or dead plant tissue that exists on the surface of the soil can buffer or cushion the effects of compacting forces. Weak, thin stands of turf are highly susceptible to compaction.

A comprehensive review of how compaction affects turfgrass growth can be found in Carrow and Petrovic (1992). Severe compaction affects turfgrass growth in the following ways:

- Altered root distribution and root dysfunction. Most turfgrass roots growing in heavily compacted soils are found near the surface. The mechanical impedance of compacted soils to root growth is partially to blame for the shallow rooting. Other potential causes of shallow root growth include the production of ethylene by roots subjected to compaction, resulting in the growth of shallow adventitious roots. Low oxygen levels in compacted soils also discourage deep rooting and limit root water uptake.
- In various studies of turfgrass growing in heavy soils, compaction has caused decreased shoot density, rhizome/stolon development, and clipping yield. In contrast, moderate compaction can increase topgrowth of turf growing in sandy soils.
- Nutrient uptake is altered in compacted sites probably due, in part, to the effects of compaction on root growth.
- Reduced water uptake can occur under compacted conditions.
- Turf growing on compacted soil can have reduced carbohydrate reserves and, in turn, have less ability to recover from stress.
- Compacted soil has a greater capacity to hold moisture. As a result, the soil takes longer to warm up during the spring, and the excessively moist rootzone inhibits root growth. Spring green-up can be delayed, and soft, soggy surfaces provide golfers inconsistent playing conditions.

From the golfer's viewpoint, a compacted soil equates to a less resilient playing surface. This may mean a little more roll in the fairways, but rock hard tees and greens. Golfers often complain that *the greens don't hold* when an inability to put backspin on the ball is to blame. On the other hand, severe compaction to a soil-based, push-up green can create an unfair surface that even a skilled player has difficulty holding.

MINIMIZING THE EFFECTS OF SEVERE COMPACTION

In general, two management strategies are employed to address the myriad of problems associated with growing turf on compacted soil:

- Alleviate the compaction that already exists through various cultivation techniques.
- Modify the soil physical properties and reduce or redistribute traffic to prevent further compaction from occurring.

Worst-case scenario . . . allowing golf carts to roam free on a soft, wet course.

CULTIVATION

In some respects, the constant process of root growth and dieback can be considered a passive, but important form of cultivation. Although compaction limits root growth, even a little root growth through a tight soil is a step in the right direction. When turf roots die and decay, the channels often retain their integrity and help reestablish large pore space. Microbes and the by-products of the plant decaying process are sources of the glue that bonds individual soil particles together to create relatively stable aggregates, creating more pore space.

The mechanical action of freezing and thawing also helps relieve soil compaction, if the playing surfaces are not continually subject to traffic associated with winter play. Natural processes like freeze/thaw cycles and root growth/death are most effective when the compacted site is left fallow — a condition that never occurs on golf courses. Consequently, more aggressive forms of cultivation are required to improve growing conditions on heavily compacted sites.

HOLLOW/SOLID-TINE CULTIVATION

Hollow or solid-tine cultivation is the universally recognized maintenance practice employed to loosen compacted soils. Most golfers are intimately familiar with this operation, and some respond with the familiar complaints regarding surface disruption. Practically all courses employ some form of hollow- or solid-tine aeration each season on greens and other areas.

Compaction caused by foot traffic, carts, or maintenance equipment on golf courses generally occurs within an inch of the surface. Compaction deeper into the soil profile can be caused by excessive earthmoving and grading operations with heavy equipment during the construction phase. However, surface compaction is, by far, a more common problem than deep compaction.

Standard punch-type coring units are designed to affect the upper 2 to 4 inches of the soil profile. The holes enhance the movement of water into the soil, and the holes encourage root growth. Removing aeration plugs and topdressing with sand provides an opportunity to modify the physical properties of the soil.

Removing a core of soil from a playing surface cannot help but reduce the bulk density of the underlying soil profile. Whether or not solid- or hollow-tine aeration actually relieves compaction is debatable, based on the conflicting results from various cultivation studies. Petrovic (1979) found a zone of compaction immediately surrounding a hole produced by hollow-tine cultivation. This cultivation-induced compaction was short lived and was generally found very close to the hole/soil interface. The greatest compaction occurred directly under the hole, and it persisted long after the sidewalls of the holes had collapsed. This explains how a thin zone of compaction can sometimes develop in greens that are cultivated to the same depth year after year, a phenomenon similar to the plow pan that can develop in agricultural soils.

Others have found core cultivation to increase water infiltration and root growth. Considering the inconsistent nature of the research results, varying the depth of cultivation penetration whenever possible is recommended. Standard hollow-tine cultivation of heavily trafficked playing surfaces has been and should remain a cornerstone of the foundation for any sound golf course maintenance program.

Vertidrain and deep-drilling cultivation makes the process of varying the depth of penetration as simple as changing a setting on the equipment. These operations can have a beneficial effect on deep zones of compacted soils that exist beyond the reach of standard cultivation equipment. Water injection also can be employed to relieve deep compaction and increase the infiltration rate of water into the soil without causing excessive disruption to the playing surface.

Course design can have a significant impact on traffic patterns. This greenside bunker funnels traffic across a narrow strip of turf, resulting in a narrow strip of dirt.

Various spiking units also are available to improve water infiltration without causing excessive disruption. The primary advantage of using a spiking unit across high-use turf is the speed at which the operation can be performed.

PREVENTING COMPACTION

COURSE DESIGN

One of the simplest ways to minimize the detrimental effects of concentrated traffic is to design the course in a manner that spreads the wear across as much surface area as possible. For example, large bunkers, mounding, or trees that block the entrances and exits to greens tend to concentrate traffic onto localized areas of the course.

CART PATHS

A well-designed network of paved paths provides an opportunity to use carts during wet weather without damaging the turf and compacting the soil. A number of articles can be found in past issues of the *Green Section Record* that describe in detail the benefits of cart paths.

MINIMIZING PLAY DURING AND IMMEDIATELY FOLLOWING WET WEATHER

As mentioned earlier, the susceptibility of heavy soils to compaction is directly related to the amount of moisture in the soil. Motorized carts are the primary culprits, but concentrated foot traffic across soft, wet soils can also cause compaction. Traffic needs to be redirected away from areas that have a history of sustaining damage during wet weather. A combination of signs and ropes/stakes helps protect these wet sites. Many courses need to be closed to motorized carts for an appropriate period of time after heavy rainfall events.

DRAINAGE

Wet soil is more vulnerable to compaction than dry soil. Consequently, improving surface and subsurface drainage, where necessary, will reduce the potential for compaction.

IRRIGATION

Controlling automatic irrigation carefully to eliminate wet areas is recommended. This may require the installation of new sprinklers, more efficient nozzles, and new controllers, and on some courses irrigation systems may need to be completely replaced. Non-uniform irrigation patterns and the resulting overwatering that occurs will create wet spots that are more susceptible to compaction.

SOIL MODIFICATION

Heavy soil playing surfaces on greens, tees, and even fairways can be modified through an aggressive sand topdressing program. Routine core cultivation and core removal, followed by top-dressing to fill the holes, is one of the most wide-spread and effective maintenance practices used

TURF TIRES . . . THE REST OF THE STORY

Ever have an equipment vendor extol the virtue of his wares with statements such as: "The low-pressure, smooth-tread, balloon tires on this 300-gallon sprayer create a footprint no heavier than a pull cart loaded with a set of clubs"? The conclusion you are meant to draw is that the sprayer, or any other large, heavy item of equipment outfitted with similar turf-type tires, will cause less compaction and wear to the turf than a pull cart.

Something about that statement always bothered me, particularly the thought of how heavy that sprayer would be when filled with water. There is a temptation to begin a debate by challenging that statement with a test. We both lie down on the fairway. Someone pulls a cart with clubs across my body and someone drives a loaded sprayer over the vendor. I win.

The fact is that a large, heavy piece of equipment is still large and heavy regardless of tire design. Granted, a fairway mower equipped with balloon tires will cause less wear and compaction to the playing surface compared to the same unit equipped with narrow tires. The large, soft tires spread the weight across a greater surface area and they should be used on turf maintenance equipment. However, research indicates that a wide tire on a heavy unit causes deeper compaction than a narrow tire on a lighter unit, even though the footprints are equal (Blackwell and Soane, 1981). Furthermore, spreading the weight across a greater area does just that — it subjects more area of soil and more turf plants to traffic.

The *equal footprint* argument almost holds water under static conditions — no movement of the cart or the sprayer. Begin traveling across the turf and all bets are off. Stopping, starting, turning, and spinning the tires will create abrasion and bruising to the turf and impart shearing forces to the underlying soil.

Carrow and Johnson (1989) studied the effects of golf cart tires on turf and found that the amount of wear is significantly increased when you turn the cart because the weight shifts to the outside tires. The speeds at which you travel across the turf and the vibration from the engine influence the amount of compaction that is generated by the traffic. The final line in this reference speaks volumes: "According to our study, traffic distribution and the sharpness of turns is more important than type of golf car or tire design in minimizing wear to golf course turf."

Obviously, the more you travel over the same area, the more wear and compaction affect the turf. To distribute the weight across a greater area and create a light footprint, more tires are placed on heavy equipment. More tires means more passes across the same turf and more traffic effects.

The bottom line is that turf-type tires should be used on golf course maintenance equipment whenever possible. Tires, though, do not magically transform a heavy sprayer or mower into a pull cart. If you don't believe it . . . take the challenge!

Not sure how much wear carts cause to turf? A side-by-side comparison of no carts vs. heavy cart traffic leaves no doubt.

Cart paths should be well designed to encourage use by the golfers. This cart path is too narrow and located too far from the fairway.

on older push-up style soil greens to combat the detrimental effects of traffic. Similarly, high-quality greens often are topdressed with light, frequent applications of sand throughout the season. The intent is to develop a compaction-resistant rootzone and smooth the playing surface. Tees, too, are often placed on a similar cultivation and topdressing regimen.

An increasing number of courses are using sand to topdress heavy soil fairways. Specialized, high-capacity topdressing equipment is strongly recommended if substantial course acreage is targeted for soil modification.

SUMMARY

Soil compaction may be a hidden effect of excessive traffic, but the inability to see the problem does not lessen the detrimental effects of compaction on turf growth and development. Considering all the ways to prevent compaction described in this article, the one you can take to the bank is to limit traffic across the playing surfaces when the soil is wet. Cart revenues are important, but allowing carts access to a soft, wet golf course can cause short- and long-term damage to turf and soil far greater than the value of one day's worth of cart fees. A continuous cart path system is an excellent investment at courses where wet weather regularly would limit cart use.

How much traffic can you bare? Each course is different due to soil type, drainage, and many other factors. Keep the course dry, limit cart use during wet weather, alter traffic patterns wherever possible, and maintain an aggressive cultivation program to keep what you can't see, hidden compaction, from hurting you.

REFERENCES

Beard, J. B. 1973. Turfgrass: Science and Culture. Prentice-Hall, Englewood Cliffs, NJ. tgif link

Blackwell, P. S., and B. D. Soane. 1981. A method for predicting soil bulk density changes in field soils resulting from compaction by agricultural traffic. J. Soil Sci. 32:51-65.

Carrow, R. N., and B. J. Johnson. 1989. Turfgrass wear as affected by golf car tire design and traffic patterns. J. Amer. Soc. Hort. Sci. 114(2):240-246. tgif link

Carrow, R. N., and A. M. Petrovic. 1992. The effects of traffic on turfgrass. In: D. J. Waddington, R. N. Carrow, and R. C. Shearman, co-editors. Turfgrass. Agronomy. 32:285-330. tgif link

Petrovic, A. M. 1979. The effects of vertical operating hollow-tine (VOHT) cultivation on turfgrass soil structure. Ph.D. diss. Michigan State University, East Lansing. tgif link

BOB VAVREK, *agronomist for the North Central Region, wears a path to courses in Wisconsin, Michigan, and Minnesota with the intent of improving playing conditions for golfers.*