

on establishment of drainage for a wet green, be sure to locate the source of trouble in advance. Greens built near embankments or slopes may have especially tricky problems. Test diggings are helpful in establishing the drainage techniques.

Tile must be carefully installed at a depth of 24 to 36 inches. In some cases, one line in a green is adequate, while in others, they should be spaced at intervals as close as 10 to 15 feet. The grade of the tile may range from 0.5 to 5 feet per 100 linear feet. The grade and line must be established by instrument.

The tile should be laid on a true-line on a firm base of stone or trap rock. The joints should allow a space of 1/16 to 1/8 inch and they should be covered on the top with tar paper. The tile should then be covered with coarse stone or trap rock. The contour of the base soil after installation of the tile drains should have slight crowns that will lead water toward the drain opening.

In covering a coarse base or a tile drain covered with coarse material, add similar materials of slightly but increasingly finer texture up to the finest grades of gravel or trap rock to reach the level for start of topsoil installation. Twelve inches of loose topsoil material and the base soil above the coarse base or tile drain should total a minimum depth of two feet. When adding soil base before adding topsoil, make sure this material does not contain more clay than the topsoil. A material of this type could destroy all or part of the value of previous drainage work.

The soil that is used above the coarse base or tile drain should be very carefully selected. Details will not be given on the quantities of clay and sand as this will be covered in a subsequent paper. As the layers of topsoil and base soil are placed above the coarse base material or drains, use care to blend all layers. Also, all ingredients of the individual layers should be thoroughly mixed off the site before placement.

Quite often, use of drainage procedures as described will raise the level of the green above the natural surface soil. This is commonly very helpful in enabling soil water to move out of the drainage system. This more exposed elevation permits the wind and air to circulate more freely over the surface of the green. Usually this feature is considered very desirable.

The drainage system should not be developed without the sound guidance of someone who has thorough knowledge and actual experience. This applies especially with tile drainage. Also, actual attainment of the proper soil materials and the desired blending is far more likely to occur with experienced guidance.

Some of the details suggested to insure drainage give the task an appearance of being too much trouble. Every effort required for soundness of the drainage system will be repaid. A lack of drainage cannot be corrected easily after the green is finished, and without good drainage, putting green maintenance becomes undesirable business. In some cases, the quality of the greens will always be inferior regardless of the amount of maintenance effort.

Soils

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Soils upon which turf is to be established deserve considerable attention whenever rebuilding or remodeling is contemplated. Putting green soils are so often the source of turf trouble that the USGA Green Section began about 10 years ago to sponsor research dealing with the physical relationship of soils. This work has been done at Beltsville, at Oklahoma State University, at UCLA, and more recently at Texas A. & M. College.

There are four primary functions of a soil. It provides support, nutrients, water, and air (oxygen). In addition to these primary functions, the soil used in a putting green must fulfill other peculiar requirements. (1) It must resist compaction under traffic and during all kinds of weather conditions. (2) It must hold a properly played golf shot, yet be firm enough to resist the pitting caused by golf balls played with a high trajectory.

(3) The soil must provide the primary requirements to a plant handicapped by the attrition of traffic and constant close mowing.

Soil is not an inert material but is rather a complex chemical, physical, and biological system in which all factors must be considered in their relationship one to another. Thus, among the functions that a soil performs, there are numerous interactions. A few examples will serve to demonstrate this fact. (1) Air in the soil affects the plant's ability to take up water and nutrients and to use them in its growth. (2) Air affects the depth and distribution of roots and in turn influences support as well as nutrient "foraging" ability. (3) Water and air in the soil vary in inverse proportion.

The discussion of air and water content of a soil leads to a consideration of pore space characteristics. We have evidence that a good agricultural soil is composed of about 50 per cent solids and about 50 per cent pore space. The pore space in turn is divided about equally between capillary pore space, which may be thought of as the space which holds water, and non-capillary pore space, which may be considered air space in a well drained soil.

The above description of a good productive soil will fit a well-tilled loam. This is where the imposition of putting green requirements begins to intrude upon accepted thought. A putting green cannot be tilled, and the preponderance of relatively small particles which, when wet, are crushed and are pressed together by foot traffic, causes the larger pore spaces (air spaces) to be excluded from the soil. Consequently there is an imbalance between non-capillary and capillary pore space.

The use of a higher percentage of sand will tend to balance the relationship between large and small pores but this addition of a high percentage of larger particles brings about a reduction in total pore space. Thus, it appears that 34 to 38 per cent is the maximum total pore space obtainable in a good putting green soil. This appears adequate, however, if the amounts of large and small pore spaces are about equal.

The considerations of pore space are important as they affect drainage and

aeration of a soil. These soil characteristics are closely related. Both are affected by underlying strata. A layer near the surface may impede the movement of water, creating a false water table and causing roots to be shallow. On the other hand, layers of gravel at depths of as much as 12 inches may be desirable because a false water table at this depth may prevent "drouthiness" in a sandy soil.

The synthesis of a suitable soil for putting green use can be accomplished quite effectively by the use of appropriate laboratory measurements. These measurements are (1) mechanical analysis, (2) pore space amount and distribution of sizes, (3) permeability (measured as inches per hour with a .25 inch hydraulic head), and (4) moisture retention. The use of these measurements upon compacted trial mixtures of soil together with careful interpretation will permit the making of a putting green soil that will maintain its suitability over a long period.

The actual putting green construction procedure should conform to the following outline:

1. Lay tile in a suitable pattern after the subgrade has been established. The contours of the subgrade should correspond to the planned contours of the finished green.
2. A gravel blanket, $\frac{1}{4}$ to $\frac{1}{2}$ inch aggregate, should be placed over the tile lines and over the entire surface. Minimum thickness for this layer should be 4 inches.
3. Because of the tendency of soil to migrate downward into gravel, a layer of coarse sand $1\frac{1}{2}$ inches in thickness may be used over the gravel blanket. This is particularly desirable if the underlying gravel is coarse. If fine gravel is used, the sand may not be necessary.
4. Mix soil off the putting green site. Place carefully on the prepared base.
5. Save an ample supply of the soil for future topdressing.
6. Sterilize putting green after soil is in place by the use of methyl bromide or other suitable sterilant.
7. Firm the soil, rake it smooth, and firm it again until the surface is smooth and uniformly firm.
8. The green is now ready for planting.