CHAPTER 5

STRUCTURAL ANALYSIS OF ICE REMOVED FROM PUTTING GREENS

Introduction

A factor often discussed in association with damage to turf is the type of ice involved in the event. Solid, clear ice is often referred to as "black ice" and is considered more dense and less permeable than "white" or "opaque" ice (Beard, 1996). The structure of ice has been considered when the damage to alfalfa was evaluated (Freyman and Brink, 1967), but has not been evaluated for turf damage. Freyman and Brink also determined that both a solid ice sheet and an ice sheet with alfalfa stubble protruding through the ice were both impermeable to O_2 and CO_2 movement.

Ice structure has been associated with its permeability to gases (Rakitina, 1965), but only in a general sense and is unsubstantiated with research. The permeability of ice to O_2 and CO_2 was determined by Rakitina (1965) and reported as impermeable to both gasses. The objective of this research was to select visually different (i.e., solid vs. granular) ice samples from putting greens and compare their average mean grain sizes to their bulk densities.

Materials and Methods

In February of 1999, ice samples were removed from six putting greens. Samples were collected from three golf courses in State College, PA: Toftrees Resort; #14 and #15 greens at the Penn State Blue Course; and the Elks Golf Club. Samples were also collected from the Valentine Turfgrass Research Center in University Park, PA, and

Treesdale Golf Club in Pittsburgh, PA. I attempted to find ice samples that appeared to be visually different.

A concrete saw was used to cut approximately 30 by 30 cm sections of ice. The ice was pulled from the surface and placed in Zip-Loc® bags in portable coolers and stored in a -30 C freezer.

For bulk density measurements, samples were reduced in size with a band saw. Samples were trimmed to approximately 1.5 by 3.5 by 1.5 cm, and precise ice dimensions were determined using a micrometer. Sample weights were determined using an electronic balance, and bulk densities were calculated by dividing the sample weights by the sample volumes.

Samples were mounted on 10 by 10 cm glass plates using Pacer E-5 epoxy (Pacer Technology, Rancho Cucamonga, CA). Samples were mounted so that the ice which originally sat immediately above the turf was glued to the glass plate. Samples were transferred to the National Ice Core Lab in Denver, CO, to create thin-layer sections.

A microtome was used to shave the samples down to sub-millimeter thickness and they were photographed under cross polarized light. The cross polarized light caused each individual ice grain to emit a different color, making grain visualization relatively easy.

Image analysis of each ice sample was conducted using ArcView Version 4. One hundred individual ice grains of each thin layer sample were selected at random and outlined with the cursor using the hand digitizing function of ArcView. Average grain sizes of each sample were calculated using the area calculation function of ArcView.

Results and Discussion

All ice samples removed from the six putting greens had bulk densities of 0.82 g cc^{-1} or higher (Fig. 5.1). Bulk densities in this range are considered very dense and impermeable to air movement (Patterson, 1994; Rakitina, 1965).

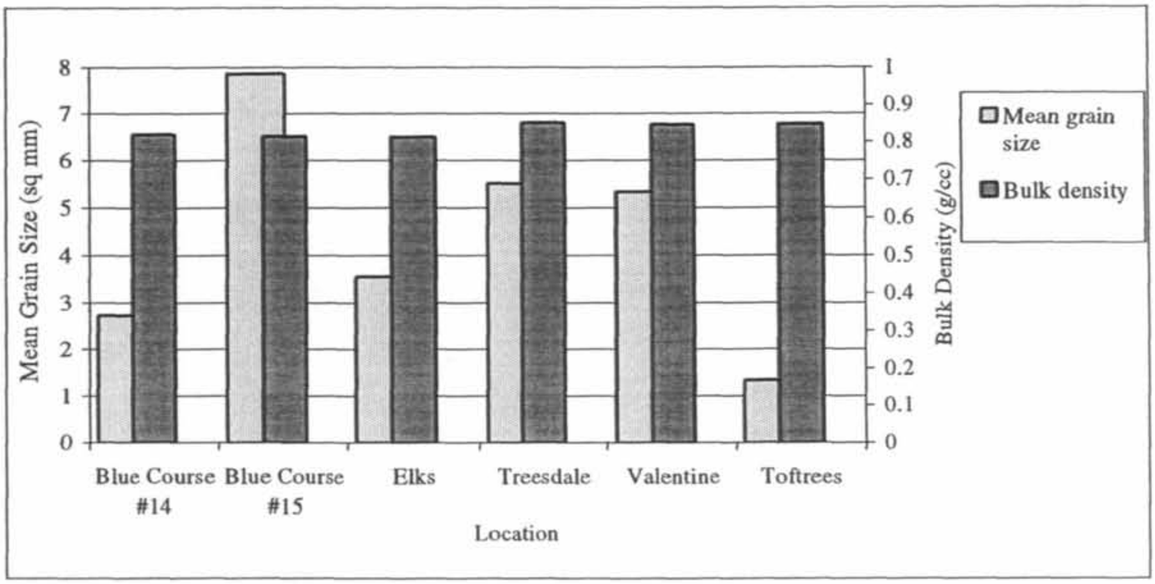

Fig 5.1. Comparison of ice mean grain sizes and bulk densities.

The sample areas were under ice cover for a minimum of two months. There were no signs of turf damage on any of these greens following spring greenup. All of the turf appeared to be unaffected by the prolonged ice cover.

These ice samples were selected because of their visible differences in structure (Fig. 5.2-5.7). The samples from Toftrees and the 14th green at the Blue Course appeared to be very clear, similar to ice made from freezing water. The ice from the 15th green at the Blue Course and Treesdale appeared to be very cloudy and coarse and made from freezing sleet or slush.

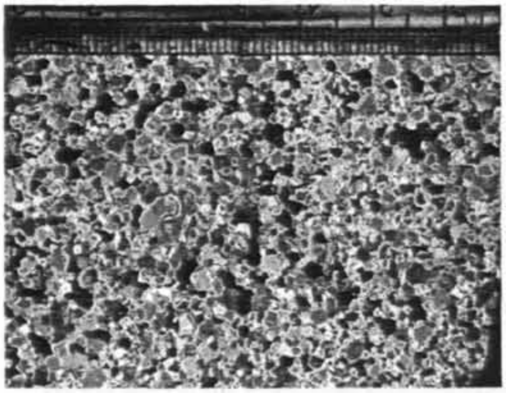

Fig. 5.2 Thin layer image of Blue Course #14 ice sample.

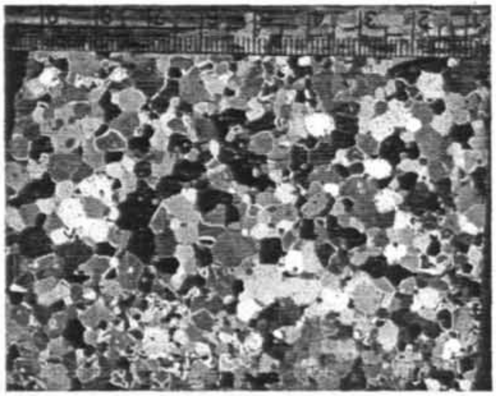

Fig. 5.3 Thin layer image of Blue Course #15 ice sample.

Fig. 5.4 Thin layer image of Elks ice sample.

Fig. 5.5 Thin layer image of Treesdale ice sample.

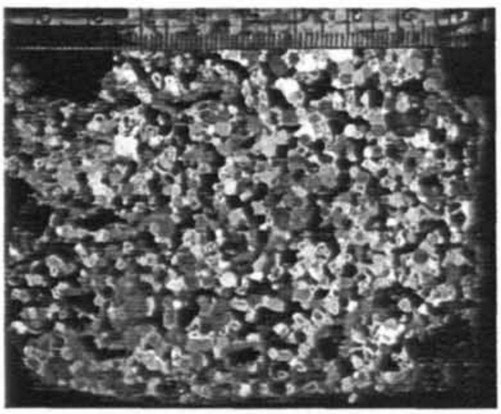

Fig. 5.6 Thin layer image of Valentine ice sample.

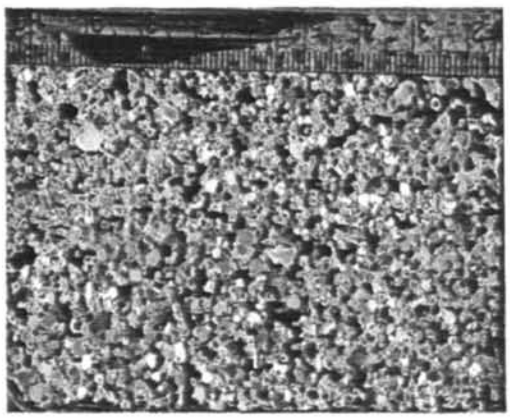

Fig. 5.7 Thin layer image of Toftrees ice sample.

These observations were confirmed by analyzing the mean grain sizes (Fig 5.1). The ice that appeared to be clear had mean grain sizes of 1 to 3 sq mm, and the coarse ice had mean grain sizes greater than 5 sq mm.

Even though the ice samples grain sizes and visual appearances were different, their bulk densities were similar. This suggested that grain size and appearance may not be an adequate determination of the ice's density or permeability. These ice samples had mean grain sizes ranging from 1 to 7.9 sq mm, and yet, all bulk densities were between 0.82 and 0.88 g/cc.

Conclusions

The term "black ice" has been used in many articles about turfgrass winter kill. This term is used to characterize a very solid and dense type of ice sheet and described as impermeable, as compared to the white or "granular" ice (Beard, 1996). My data suggests that even though ice may appear to be porous or semi-permeable, appearance is not a valid parameter to gauge density or permeability. The ice selected for this study had a wide range of appearances, but bulk densities were similar.

It is logical to assume that ice created from freezing water would have a very high bulk density (> 0.8 g/cc). Therefore, weather events that involve rain or meltwater will result in high density ice on turf areas where the liquid is concentrated in low lying and poorly drained areas. These types of areas typically experience turf loss more often than sloping or well-drained areas. Hence, the type of ice may not be as much of a factor as has been suggested (Beard, 1996).

It may be more important how quickly the ice was created and what temperature changes the turf transpired during ice development. These are two important factors that have been reported to be significant in ice coverage damage of small grains (Andrews and Pomeroy, 1975). Further research needs to be conducted to quantify temperature changes that plants are exposed to during ice development. The degree and rate of temperature drop associated with ice formation may have impacted plant survival more than the physical properties of the resulting ice layer.