The Application of CT Technology to the Experimental Study of Highway Icing

M. Q. Edens and E. E. Adams

1. ABSTRACT

The applicability of CT technology to the study of highway icing and its use in studying an ice adhesion enhancing mechanism referred to as “keying” were investigated. An understanding of the relationships between the texture of a roadway's surface and the adhesion ice and its control may be greatly furthered if experimental investigations can be made at the scale of the surface and surface connected voids. The ability to examine one sample, in various states (dry, wet, ice covered etc.) along a particular cross-section is particularly desirable for observations at the surface level. Cross-section images obtained via x-ray CT were found to provide acceptable resolution and be of sufficient quality for use in observing and measuring several surface connected void parameters. Observation of the infiltration patterns and the extent of infiltration of several materials, water, ice and anti-icer, may be of interest in icing studies. Because the density of bitumen is the same as water and very close to that of ice and anti-icers a clear distinction between the materials in a CT image can be difficult or impossible. Clear observation was found to be possible if a dry state reference cross-section was subtracted from the identical cross-section image of the same specimen when water, ice, or anti-icer were present.

An mechanical mechanism that may enhance the adhesion of ice to pavement, “keying”, was studied for three pavement types, super pave, grade b, and chip sealed. Grade b was found to have the smallest key width (0.39mm) of the three pavements (1.78 mm for chip sealed and 1.34 mm for super pave). Grade b also had the smallest ratio of total keyway width to pavement length of the three, 0.109, 0.146, and 0.503 respectively. In terms of the force required to lift ice from the surface of each, in the absence of all other adhesion mechanisms and friction grade b would require the least force. The widths of the surface opening (shear line) into the keying voids was also measured. Grade b had the smallest average length of 1.03 mm vs. 4.43 mm for super pave and 5.27 mm of chip sealed. The ratio of the total shear line length to pavement length was largest in the chip sealed, 0.57, followed by grade b at 0.13 and super pave at 0.09. The shear lines are related to the force required to shear the ice “keys” at the pavement surface.

2. Introduction

During the winter, maintenance activities by Transportation Departments are often concerned with the persistence of ice and snow on roadways. Actions taken to control snow and ice are typically plowing, sanding, and application of anti-icing and deicing chemicals. Anti-icing and deic-

* Civil Engineering Department, Montana State University, Bozeman MT 59717

ing chemicals are freezing point depressants. The terminology refers to the time of application, that is, prior to an anticipated icing event or after the fact [1].

Basically there are two ways in which roadway icing occurs. One results when liquid water present on a road surface subsequently freezes. The other arises due to vehicular compaction of road snow cover. The mechanisms responsible for the ice to pavement bond determine the strength of that bond. Ultimately chemical application aims to reduce the strength of the ice-pavement bond [2] for effective ice and snow removal.

Bonding of ice to pavement is partly due to surface adhesion. It may be enhanced through a mechanism called “keying”. Water, in the liquid or solid state, can key by flowing into cavities at the pavement surface. The cavities function like keyways into which a key fits. Keying of snow is likely to occur primarily through compaction and perhaps temperature related viscous flow.

Experimental verification of keying is problematic. To make the observations it is necessary to examine the interface of a layer of bonded ice or snow to pavement. One of the ways in which such an observation might be made requires that a sample be sliced into two parts to expose a cross-section of the ice-pavement interface. Cutting pavement generates considerable heat [3] which will alter the insitu ice morphology.

An experimental investigation was conducted which aimed to verify the existence of “keying” using a non-destructive imaging technique, namely x-ray CT (x-ray Computed Tomography). The investigation was carried out in two parts. The first dealt primarily with issues concerning an ability to observe a pavement’s surface structure. In addition the technique was applied to water, ice, and anti-icers at the pavement’s surface and within its surface connected voids by using cross-section images produced via x-ray CT. The second part, which was dependent upon results of the first, was aimed at verifying the presence of a “keying” mechanism and provide some preliminary

measurements of size and frequency of occurrence in three different pavements types, grade b, super pave, and chip sealed.

For CT imaging of pavement to be useful as an investigative tool which can be used in place of traditional section and polish techniques it must, at the least, provide access to the same information. Section and polish techniques provide access to the internal geometric state, i.e. arrangement of aggregate, air voids, and bitumen. Observations of water within voids or ice cover attachment at a pavements surface are not feasible with traditional methods since the process of sectioning usually requires application of water to cool the cutting blade. A tool that allows imaging of a wet, dry, with ice cover, etc. pavement samples, in such a way that the state is not altered during the imaging procedure, is of considerable interest. One of the major goals of this project was to determine if x-ray Computed Tomography would be such a tool.

Experimental investigations requiring observations of a material's internal structure have traditionally relied upon physical sectioning techniques. A major disadvantage of physical sectioning is that it destroys the sample and may even modify the structure along the sectioning plane. A non-destructive approach to observing a material's internal structure is X-Ray CT, which will be referred to in the report as CT. Its capabilities and limitations as a tool for investigating highway icing are currently undocumented. In this study interest is centered on observing pavement surface and surface connected voids as well as the penetration of liquid water, ice/snow, and anti-icers into these voids.

3. A Brief Description of X-Ray CT

CT is a tool that can be used to non-destructively inspect the internal structure of a material. In CT, radiographs, i.e. x-ray pictures, are digitally recorded. To produce a digital cross-section of