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ABSTRACT

EVALUATING FRAZIL ICE ACCUMULATION IN RIVERS AND STREAMS: A CASE STUDY

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The primary operational water intake for a paper plant was to be located in the Menominee River at a site below about 2 km of rapids and falls. Unaware of a potential frazil icing problem and assured by the wedge-wire intake screen manufacturer that there would be no icing problem, the company had designed the intake, purchased the screens, and considerable progress was made toward the installation of their intake system. The engineering staff discussed the matter with the author and joined in a site inspection in late January 1982. Significant frazil was found, construction on the intake system was suspended, and a field data collection effort was initiated to characterize the icing conditions. This paper reports the findings of that work.

In mid-February impulse radar profiles of the ice thickness and riverbed were made at 100-ft intervals down 3500 feet from the head of the ice cover (below the rapids). A shear vane was used to obtain a strength indication in the frazil ice. The thickness of the accumulation, its density, and the river depth were measured at selected locations for ground truth. Velocity profiles were taken

beneath the ice at locations which seemed to typify various accumulation conditions. The ice cover, trees and banks were inspected for several kilometers downstream for signs of ice action and/or flooding. Historical meteorologic and hydraulic data were obtained.

The radar provided continuous cross-section profiles of sheet ice thickness, frazil ice accumulation, flow channels beneath the frazil, and the river bottom and sub-bottom; revealing significant densification of the frazil in the lower portion of the accumulation. Shear vane data went from about 700 Pa (when significant thermal weakening had occurred) to about 8.8 kPa in the densified regions.

The frazil undersurface shear imparted by the water was typically below 150 Pa, but extended up as high as 760 Pa.

The site FDDs varied from about 665 to 1000 °C-days. Prior to the field work, about 835 FDDs had accumulated.

The average open water in the rapids and falls reach was estimated to be 56,000 m^2.

The winter flow of the river is about 30 m^3/sec, and its average cross-section at the site is about 280 m^2.

Porosity of the frazil accumulation was 45 and 78 per cent ice by volume. The permeability of the accumulation was between that of a fine gravel and a coarse sand.

An important property of the accumulation was the densification of its lower boundary. This has been observed in the field on other occasions by the author, reported in intake model studies as a component in an "accumulation-deformation" cycle, and considered to be a revealing characteristic of the regime: The hydraulic stress on the undersurface of the deposited frazil was responsible for the deformation of the interface region of the accumulation. Such densification increases the channel cross-section, smoothes the interface and reduces the hydraulic pressure on the accumulation. After some critical dimension is attained at a cross-section, it appears that any additional frazil entering the section will be transported downstream.

The radar cross-sections allowed us to follow the meander of the flow channels in the winter, and to evaluate the effect of the ice accumulation on the transport of bed material.

Under extreme conditions, the quantity of frazil ice in the water column at the site is less than 2% by volume. An intake design using a conventional small-aperature screen would have no hope of surviving such icing conditions.