

CRREL

REPORT 78-9



Flexural strength of ice on temperate lakes

*Comparative tests of
large cantilever and simply supported beams*



Cover: Guiding large ice beam (just broken in cantilever test) into frame used for measuring flexural strength of simply supported beams.

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Flexural strength of ice on temperate lakes

Comparative tests of large cantilever and simply supported beams

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April 1978

Prepared for
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OFFICE, CHIEF OF ENGINEERS

By
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20. Abstract (cont'd)

strengths when the top surfaces are placed in tension. This behavior is attributed to differences in ice type; the fine-grained, crack-free top layer of snow-ice which constituted up to 50% of the ice cover in the current series of tests usually reacted more strongly in tension than the coarse-grained crack-prone bottom lake ice.

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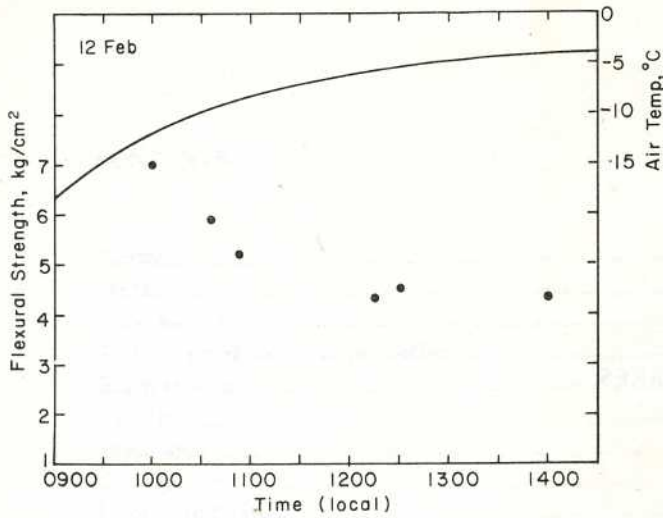
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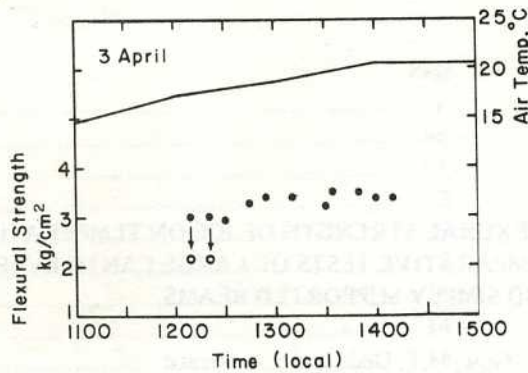
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a. Variation of flexural strength with temperature.



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Figure 1. Cantilever beam test data. On 3 April 1974, the top 6 cm of snow-ice had been reduced to an essentially strengthless condition, thereby reducing the effective thickness of the ice from 40 to 34 cm. Data denoted by open circles were computed on the basis of the absolute thickness (40 cm) of the ice cover (adapted from Gow and Langston 1975).

Comparative tests of in-place cantilever and simply supported beams by Butiagin (1966) do not seem to show any significant difference in failure strength that can be attributed to external stress concentrations. Frankenstein (1966) also believes that if a stress concentration exists at the butt end of the cantilever beam then the effect must be very small. However, Brown (1963) infers from tests made on plexiglass that the stress concentration factor for sea ice beams could be as high as 2.8.

In an attempt to resolve this problem, a test device was designed that permits the same beams used in cantilever tests to be tested with their ends freely supported, which should eliminate the effect of external stress concentrations.

It is the principal purpose of this report to present results of this second series of measurements involving parallel testing of in-place cantilever and simply supported beams. These tests were performed in conjunction with an ongoing program of studies of the growth characteristics, structure and mechanical properties of ice covers on temperate lakes and rivers.

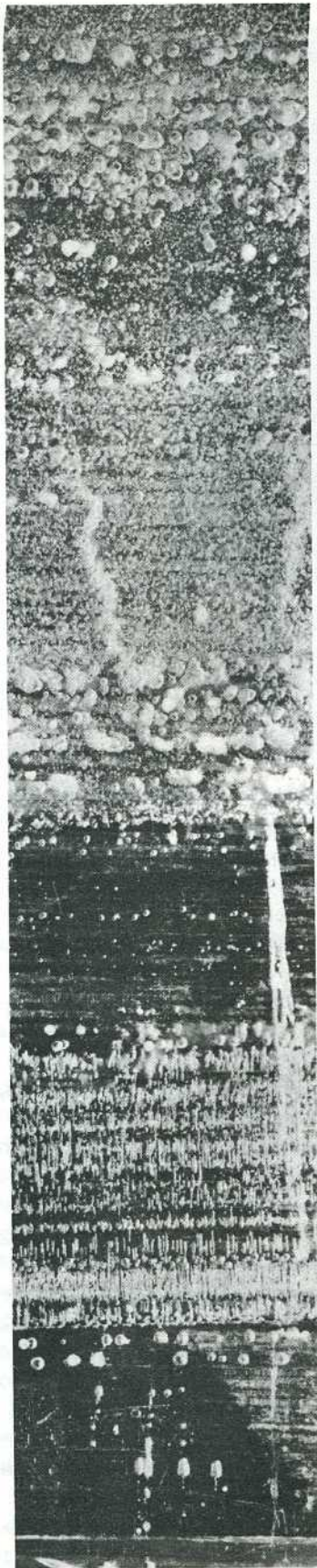
TEST SITES AND ICE COVER PROPERTIES

The majority of tests were performed on Post Pond, located near Lyme, New Hampshire. Additional tests were also performed on Canaan Street Lake situated

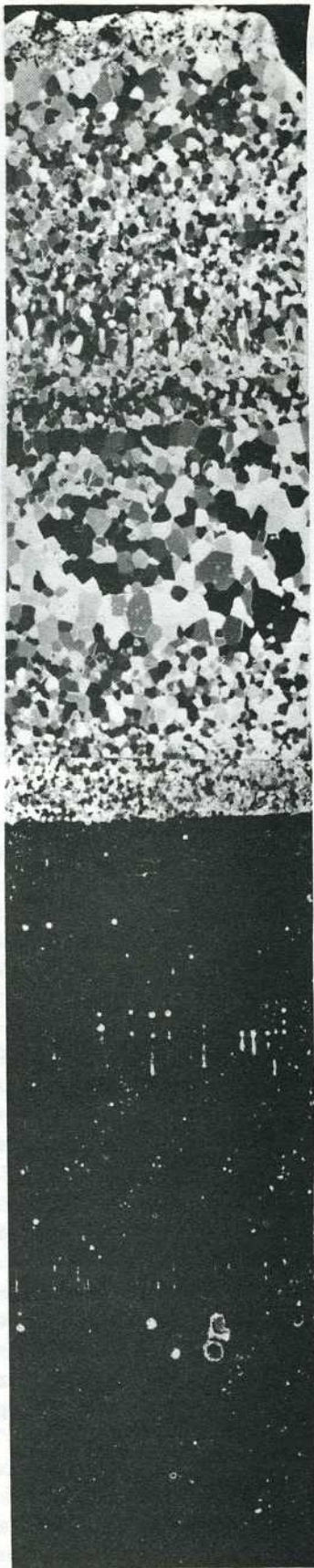
near the town of Canaan, New Hampshire. Combined tests of in-situ cantilever and simply supported beams were initiated in March 1975 and completed the following winter in March 1976.

The ice cover on both lakes was composed typically of two major ice components: true lake ice, formed by the freezing of lake water, and snow-ice that overlies the lake ice and is formed by the freezing of water saturated snow.

Vertical sections of ice sheet stratigraphy and structure from Canaan Street Lake are presented in Figure 2. Structure, as photographed in an ice beam from Canaan Street Lake, is illustrated in Figure 3. In both sections of ice in Figure 2, the lake ice component can be distinguished easily from the overlying snow-ice. Crystals in the structural section (Fig. 2b) are all oriented with their c-axes vertical. Occasionally crystals with subhorizontal c-axes occur in the top or earliest-formed ice but such crystals are soon eliminated in favor of crystals with vertical c-axes. The transition to fine-grained, equigranular snow-ice is especially well marked in the structural section. Both Post Pond and Canaan Street Lake developed vertical c-axis structure during the 1974-75 winter and essentially identical structure was observed in the winter ice cover of 1975-76. The formation of a c-axis vertical structure was invariably associated with the growth of very large crystals. At some test sites, the ice texture approached that of a single crystal and in all cases the sizes of crystals



a.



b.

Figure 2. Vertical sections illustrating stratigraphic (a) and structural (b) characteristics of a lake ice sheet, Canaan Street Lake, New Hampshire. Transition from snow-ice to lake ice is especially well marked. In this instance, the lake ice is composed entirely of crystals with vertical c-axes. Ice thickness is 43 cm.

