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SOME OBSERVATIONS ON THE EXPANSION AND CONTRACTION OF ICE ON CANADIAN WATERS.

By John H. Dumble.

To be read Thursday, 3rd December, 1891.

The movement of field ice on Canadian waters, by expansion and contraction, from change of temperature, is a matter of interest to the Civil Engineer, and one that he cannot safely disregard, when called upon to erect structures within its influence.

As Resident Engineer of the Cobourg and Peterborough Railway in 1860, I had a very painful experience of the force of ice on the Railway Bridge across Rice Lake. I subsequently experimented and practically tested the susceptibility to change of temperature, by expansion and contraction, of a floating piece of ice, on a pond near Cobourg, the result of which I will hereafter mention. The better way to illustrate the power of ice in motion will be to briefly describe the Rice Lake Railway Bridge.

The lake is a sheet of water over twenty miles in length and of an average width of two miles and one-half. The bridge crossed it at its widest part, and was nearly three miles in length. The depth of the water to the clay bottom (except in the channel) was less than twenty feet. A small island was crossed by the bridge within three-quarters of a mile of the south shore. The bridge, with the exception of half a mile of truss in the centre, was built on oak piles, vents were fourteen feet apart, with very heavy caps and stringers. The truss-bridge was very strong, with eighty feet spans resting on stout timber piers filled with stone. The whole structure was of the strongest and most substantial character of its kind.

And yet this bridge was wrecked in a few minutes, in the early part of December, by an ice shove, and, when the ice was comparatively thin. The pile work south of the island was inclined like a pack of cards to nearly an angle of forty-five degrees. An engine was caught on the bridge during the shove, much to the alarm and consternation of the driver. Subsequent shoves from all directions seriously affected the bridge, and twisted it into many curves and kinks. and, it was only saved from complete destruction by isolating it from the main field by cut-channels cut in the ice and constantly kept open on each side of the bridge for its entire length. The piers under the truss-bridge, including the larger ones under the swing, were toppled over, and I had to protect them by building larger piers around them, with a covering of timber at an incline on each side, like the roof of a cottage, against which the ice fractured and spent itself.

The railway was subsequently abandoned, owing to the neglect and destruction of the bridge, and a million of dollars spent in its construction was lost, not to speak of the disappointment to the town of Cobourg and vicinity. So much for ignorance of one of the forces of nature.

And now as to the ice itself. The formation of ice, as is well known, takes place at a certain fixed temperature (32° Fah.), and which remains constant during the process of solidification. A higher temperature causes ice to melt. Ice must, therefore, at formation, be at its greatest or maximum dimensions, and cover its largest area. The first movement of ice, after formation must necessarily be shrinkage or contraction. There is, however, a peculiarity about the contraction of ice which perplexed me very much for some time, as I could not see any tangible evidence of its contraction.

The ice field does not draw away from the shore during shrinkage, as might be expected, and leave open water to the extent of its contraction.

The expansion of a large field of ice is manifested by its encroachment on the shores of the lake. It fructures at the ripple mark and shoves on to the shore, and when the line of fracture occurs at a distance from the shore, it is evidenced by the appearance of a verticul ridge formed by the fractured ice. Such being the case it would naturally be expected that the ice field, during contruction, would recede from the fracture, whether on shore, or at a distance from it, or that fissures and cracks would be easily observed somewhere in the ice field of widths somewhat commensurate to previous shoves. Such evidence of the contraction of ice does rarely if ever exist. That contruction causes fissures however, is true, but so exceedingly small that they easily escape detection. It was sometime before I discovered this. As I crossed the lake one morning, after a cold snap, a very slight covering of snow lay on the ice, and showing innumerable cracks running in every direction, filled with water, and of widths from one-eighth of an inch to an inch in width. I counted over one hundred in the distance of a mile. The aggregate width of these fissures would fully equal the width of the greatest shove. This manner of contraction is, I think, readily accounted for. If the ice field were equally thick, dense and bare, which it is not, it would contruct uniformly towards its centre or centres, and draw away from the shore by the extent of its contraction.

But ice forms in waters with currents, islands, headlands, and perhaps during snow storms. It is not, therefore, equally thick and pure and dense, and has many centres, and in shrinking to them pulls and opens fissures in all directions. These fissures fill with water and freeze, the ice field occupying its original area, but in a state of contraction. When a change to higher temperature occurs or the sun shines, expansion takes place and from a centre towards its circumference, the ice is shoved onto the shore to an extent equal to the width of the fissures.

These shoves sometimes exceed four or five feet in width, and occur on the shores, in the channels, or from headlund to headland, it being easier to fracture on the chord than the arc of the bay, and will always fracture on the line of least resistance.

It will be thus seen that the capacity of ice to expand and shove, and shove again, is only limited by its capacity to contract and recuperate. The repeated shoves have lodged ice on top of a high embankment over 30 feet in width and has lifted large boulders and pressed them against the abutments of the bridge. A very slight covering of snow acting as a non-conductor, prevents all movement of the ice from change of temperature, hence all damage from shoves occurs early in the season before the snow falls. The effects which I have endeavoured to describe occur on all Canadian waters in cold climates, but to some extent are governed by the size of the field ice.

Being much interested in the movements of ice from my experience at Rice Lake, I endeavoured one winter after my connection with the Cobourg Railway had ceased, to practically test by experiment the nature of ice movement. I regret that I had not the time or the skill to follow up and solve the question more satisfactorily. The result of the experiment, however, is interesting and somewhat instructive. I built a rough shed on the ice of a mill pond in Cobourg, and cut out the ice 110 feet long by 10 feet in width and allowed new ice to form. When it became an inch and a half thick I isolated a strip of ice 103 x 7 and kept it floating with an open channel eighteen inches in width all around it. I then inserted a small block of pine within 18 inches of each end which became frozen in and firmly embedded. To one of these blocks I attached and nailed the end of a seasoned pine rod three inches in width and 100 feet in length, and one and a quarter inch thick and firmly connected at the joints. To the other block was firmly attached a circular target with a scale, through which the graduated end of a rod moved freely. It was an American engineers' levelling rod and read accurately to the 1,000 part of a foot. Small rollers underneath caused it to move freely.

The floating piece of ice was kept isolated from the main field day and night with great care and precaution taken to ensure accuracy of result. I may add, that I visited the rod and registered it every few hours, day and night, during part of January and the whole of February, (I was young and enthusiastic then,) and the annexed tables show the hour, day, temperature, and the reading of the rod as taken and entered at the time. The accompanying diagram shows the movement of ice corresponding to the readings in the tables. The datum is the time, the upper profile or section shows the lineal contraction and expansion of a piece of ice 100 feet in length as read on the rod (to which should be added the expansion and contraction of the rod itself to give the actual movement). The section beneath represents the atmospheric changes as indicated by the themometer (Fah.)

The lower line exhibits the thickness of ice on the different days and times during the experiment. It will be observed on referring to the ice section that it exhibited no movement until it attained a thickness of three inches, notwithstanding various changes in temperature.

From that time, however, until it became five inches thick, it appeared most sensitive and responded quickly to every change of temperature, but its extent of expansion and contraction was much less than when it attained a greater thickness. Over five inches in thickness the ice was ever uniform and regular in its movement, and shews a contraction and expansion of .026 for 100-foot rod, over 32 degrees or from zero to 32°. I presume my reading of the thermometer at 34° should have been 32°, as it hung a little above the ice instead of being in it. This movement would indicate some sixteen inches to the mile, a much smaller movement than we know takes place, and which indicates that the expansion of the rod must be taken into consideration to give the actual figure. It will be observed from the tables that the contraction of the ice at zero on the 1st February was only .011 from formation at 32°. The same influence (the underlying water) which prevents movement up to three inches in thickness doubtless, continued to a certain extent as the ice had barely attained a thickness of five inches on the 1st February. The ice expanded to its original dimensions at 32° on the 8th and 9th February, and from that time forward was very uniform in movement, notwithstanding that it was subject to a high and wasting temperature at times, and even to the rays of a mid-day sun at 45° which I allowed to act upon it for several hours.

It has been observed on Rice Lake that thick ice did not move with the same alacrity as thin ice. It is well understood that the most violent shoves occur when the ice is between five and twelve inches in thickness. My experiment confirmed this, and it appeared that the rapidity of ice movement is inversely as its thickness. This lagging behind of ice and not responding readily to rapid changes of temperature is well shown on the diagram of observations — 55, 62, 65, 73, 84, 92, 96, 100, 120 and 158. The temperature during my experiment did not fall below minus 4°, but uniformity of movement throughout was ever observed.

From these brief observations and somewhat crude experiment may we not summarize as follows:—

That ice, like all other bodies, is subject to expand and contract by change of temperature.

That ice forming at a temperature of 32° is at its greatest or maximum dimensions.

Its first movement must, therefore, be contraction. That the underlying water prevents movement in ice under three inches in thickness from change of temperature.

That up to five inches in thickness the ice is affected from the same cause, and, although its movement is uniform, its capacity to contract is reduced from what it afterwards attains.

The rapidity of ice movement is inversely as its thickness.

The capacity of ice to expand and shove on to the shores and to repeat the operation is due to the peculiar manner in which it contracts.

A slight covering of snow (as non-conductor) prevents all ice movement.

That the ice field expands from a centre or centres and fractures on the line of least resistance.

That Railway Bridges or other structures crossing extensive waters, if not constructed in a *massive manner*, will need protection from the ice field, which is most effectually done by isolation and cut side channels, otherwise an inclined surface must be presented to the ice, on which it may run up, fracture, and spend its force and shield the piers.

NOTE.—Blue Section on Diagram is Ice. Black, Thermometer.

Table of Observations (on 100 feet of Ice), Jan. and Feb., 1860.

No.	Date.	Hour.	Tempra-ture.	Thickness Ice.	Graduated Rod.	Remarks.
1	Jan. 29	1 p.m.	32°	3 ″	·011	Wind, N. W.
2	29	6 "	34	3	·012	W.
3	29	10 "	34	3	·012	W.
4	30	9 a.m.	27	3½	·009	N. W.
5	30	12 "	26	3½	·008	W., clear.
6	30	2 p.m.	28	3½	·009	W.
7	30	3 "	31	3½	·010	W.
8	30	5 "	33	3½	·010	W.
9	30	6 "	34	3½	·011	W., strong wind.
10	31	12 "	22	3½	·007	N.
11	31	12.30 "	19	3½	·006	N.
12	31	2 "	17	3½	·006	N., blowing a gale.
13	31	4 "	14	3½	·005	N. E., snowing.
14	31	9 a.m.	9	4	·003	"
15	31	12 "	9	4	·003	N. E., light wind.
16	31	2 p.m.	9	4	·003	N. F.
17	31	4 "	8	4	·003	N. F.
18	31	5 "	6	4	·002	N.
19	31	7.30 "	6	4	·001	E., clear.
20	Feb. 1	1 a.m.	Zero.	5	·000	N.
21	1	6 "	4°	5	000	N. E.
22	1	9 "	10	5	·001	N. E.
23	1	11 "	14	5	·005	E.
24	1	3 p.m.	10	5	·006	E.
25	1	5 "	13	5	·005	E.
26	1	11 "	12	5	·006	E.
27	2	4 a.m.	10	5	·003	N.
28	2	9 "	14	5	·004	N. E
29	2	10 "	16	5	·004	N. E.
30	2	10.30 "	18	5½	·005	E.
31	2	1.30 "	23	5½	·007	E.
32	2	3 p.m.	22	5½	·007	W.
33	2	5 "	19	5½	·006	N.
34	2	9.30 "	10	5½	·004	Calm.
35	2	11 "	12	5½	·002	"
36	3	3.30 a.m.	18	6	·004	"
37	3	8 "	18	6	·004	....
38	3	1 p.m.	22	6	·006	S.
39	3	4 "	20	6	·005	S.
40	4	12 "	24	6	·007	W.
41	4	1 a.m.	22	6	·007	S. E., snowing.
42	4	7 "	22	6	·007	....
43	4	11 "	26	6	·008	Calm.
44	4	12 "	28	6	·009	....
45	4	1 p.m.	30	6	·010	Ther. 60° in sun.
46	4	5 "	30	6	·010	....
47	4	6 "	28	6	·010	....
48	4	7 "	24	6	·008	S.
49	4	9 "	26	6	·008	S.
50	5	2 a.m.	26½	6	·008	E.
51	5	7 "	24	7	·007	S., snowing.
52	5	10 "	32	[illegible]	·011	S. E.
53	5	1 p.m.	34	7	·012	S E.
54	5	5 "	34	7	·012	S. E.
55	5	7 "	33	7	·011	....
56	5	8 "	36	7	·011	Water on ice.
57	6	2 a.m.	37	7	·011	W.
58	6	7 "	33	7	·011	W.
59	6	11 "	32	7	·011	W.
60	6	3 p.m.	30	7	·011	N. W.
61	6	5 "	28	7	·010	N. W.
62	6	9 "	24	7	·007	S. W.
63	7	12 "	28	7	·007	S. W.
64	7	2 a.m.	24	7	·007	S. W.
65	7	4 "	22	7	·005	....
66	7	8 "	28	7	·005	S. W.
67	7	9 "	32	7	·009	S. W.
68	7	12 "	32	7	·011	S. W.
69	7	1 p.m.	34	7	·012	S. W.
70	7	3 "	35	7	·012	S. W.
71	7	5 "	36	7	·013	Ice dry.
72	7	9 "	28	7	·010	Calm.
73	8	12 "	28	7	·009	S. W.
74	8	9 a.m.	32	7	·011	Ice dry.
75	8	11 "	38	7	·012	Ice wet.
70	8	11.30 "	39	7	·012	S. W., ice melting.
77	8	12 "	37	7	·012	S. W.
78	8	3 p.m.	34	7	·012	W.
79	8	4 "	34	7	·012	W.
80	8	7 "	32	7	·012	....
81	8	8 "	32	7	·012	N. W.
82	8	9 "	17	7	·006	N. W., surface water freezing.
83	8	11 "	13	7	·015	N. W.
84	9	12 "	8	7	·004	....
85	9	3 a.m.	6	7	—·009	Blowing a gale.
86	9	6 "	Zero.	8	—·014	N.

Contraction and Expansion of Ice.—*Continued.*

Table of Observations (on 100 feet of Ice), Jan. and Feb. 1860.

No.	Date.	Hour.	Temperature.	Thickness Ice.	Graduated Rod.	Remarks.
87	Feb. 9	8 a.m.	4°	8	—·011	N.
88	9	9.30 "	6	8	—·010	N.
89	9	11 "	9	8	—·009	N.
90	9	12 "	10	8	—·006	....
91	9	2 p.m.	12	8	—·005	N.
92	9	9 "	7	8	—·005	N.
93	10	1 a.m.	10	8	—·005	Calm
94	10	5 "	10	8	—·004	E.
95	10	8 p.m.	11	8	—·004	E.
96	11	10 a.m.	12	8	—·004	E.
97	11	1 p.m.	20	8	+·001	....
98	11	3 "	24	8	+·005	N.
99	11	8 "	17	8	+·002	N.
100	11	10 "	16	8	+·001	N.
101	12	12 "	13	8	—·002	N.
102	12	2 a.m.	10	8	—·004	N.
103	12	6 "	9	9	—·008	N.
104	12	9 "	13	9	—·006	N.
105	12	11 "	19	9	—·001	N.
106	12	1 p.m.	23	9	+·003	N.
107	12	3 "	24	9	+·005	W.
108	12	6 "	24	9	+·006	S. W.
109	13	8 a.m.	26	9	+·005	E.
110	13	12 "	34	9	+·012	W.
111	13	2 p.m.	34	9	+·012	E.
112	13	8 "	30	9	+·012	....
113	14	4 a.m.	26	9	+·008	....
114	14	8 "	26	9	+·006	N. E.
115	14	12 "	26	9	+·006	N. E.
116	14	1 p.m.	27	9	+·006	N. E.
117	14	3.30 "	28	9	+·008	N. E.
118	14	10 "	15	9	—·002	Clear night.
119	15	4 a.m.	12	9	—·005	N. W.
120	15	12 "	20	9	—·000	N. W.
121	15	2 p.m.	20	9	+·001	N. W.
122	15	5 "	22	9	+·003	S. E.
123	15	10 "	29	9	+·009	S. E.
124	16	9 a.m.	18	9	+·002	S. E.
125	16	11 "	18	10	+·001	N. E.
126	16	2 p.m.	18	10	+·001	N. E.
127	16	3 "	16	10	+·000	N. W.
128	16	6 "	14	10	+·000	W.
129	16	9 "	8	10	—·008	W.
130	17	6 a.m.	8	10	—·014	....
131	17	8 "	— 4	10	—·017	N.
132	17	5 p.m.	+14	10	—·004	N. E.
133	17	8 "	6	10	—·009	N. E.
134	17	10 "	4	11	—·011	N E.
135	18	8 a.m.	12	11	—·009	....
136	18	10 "	12	11	—·009	Snow drifting through roof.
137	18	12 "	18	11	—·006	N. E.
138	18	2 p.m.	18	11	—·004	N. E.
139	18	6 "	16	11	—·001	N. E.
140	19	9 a.m.	10	11	—·008	N. E.
141	19	5 p.m.	16	11	—·003	N E.
142	19	9.30 "	10	11	—·006	E.
143	20	8 a.m.	26	11	+·003	E.
144	20	9.30 "	27	11	+·005	W., moves slowly.
145	20	12 30 "	30	11	+·007	E.
146	20	2 30p.m.	32	11	+·010	W.
147	20	6 "	34	11	+·012	W.
148	21	3 a.m.	20	12	+·001	E.
149	21	12 "	34	12	+·012	E.
150	21	2 p.m.	38	12	+·012	E.
151	11	4 "	37	12	+·014	E.
152	22	12 "	37	12	+·012	E.
153	22	12 "	32	12	+·011	E.
154	24	12 "	30	12	+·010	E.
155	25	12 "	24	12	+·000	E.
156	25	5 "	24	12	+·000	E.
157	25	10 "	17	12	+·000	E.
158	26	8 a.m.	12	12	—·007	N. E.
159	26	9.30 "	22	12	—·006	N. E.
160	26	5 p.m.	30	12	+·007	....
161	27	8 a.m.	34	12	+·012	N. E.
162	27	12 "	45	12	+·012	S. W., exposed ice to sun.
163	28	12 "	34	12	+·012	S. W.

TRANSACTIONS CAN. SOC. C. E.
VOL. V. PLATE

SKETCH SHEWING METHOD OF OBSERVING
CONTRACTION AND EXPANSION OF ICE
—— COBOURG C.W. 1860 ——

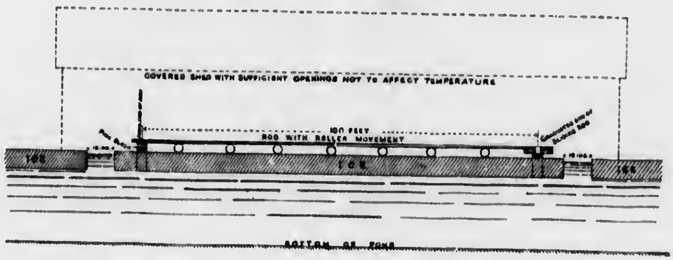

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DIAGRAM
SHEWING EXPANSION AND CONTRACTION OF ICE 100 FEET IN LENGTH,
ALSO THERMOMETRICAL SECTION CORRESPONDING TO THE ICE MOVEMENTS