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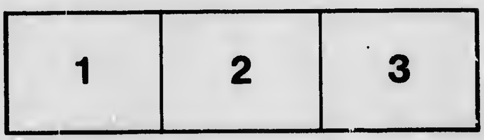

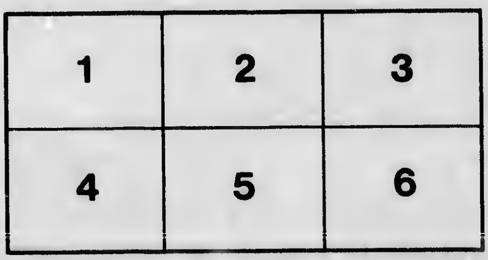

Canadian Society of Civil Engineers.

ESTABLISHED 1887.

TRANSACTIONS.

FRAZIL ICE.

ON ITS NATURE, AND THE PREVENTION OF ITS ACTION IN CAUSING FLOODS.

By Geo. W. Henshaw, M.C.S.C.E.

The subject of this paper is one destined, I believe, to become of increasing interest to Engineers in Northern countries, especially to those engaged in works liable to be affected by ice, whether through direct attack or through floods caused by the arrest of its movements. My object is to define the true nature of frazil, and to suggest a method of dealing with it, so as to prevent its more than suspected agency in producing floods.

Whether the vast masses of comminuted ice, which in places are found to underlie the surface ice, are composed of true subaqueously formed ice, or are made up largely of drifted snow, and the broken scales of surface ice carried down by the current, is yet to be positively determined; still, from the evidence which exists of enormous quantities of spongy looking ice seen rising from the bottom, it is reasonable to conclude that whatever may be the proportion of these substances true frazil is, really, their principal constituent.

Now, for an engineer to meet a difficulty with intelligence and success, it is almost essential to understand the actual character of the enemy against which he is to contend. To speculate on this brings us somewhat out of the sphere of the practical engineer and into that of physical science; but we are often compelled to this course when scientific men neglect the subject, or leave us in the dark.

That so little of the nature of frazil is known among engineers is not surprising, when we find that the haziest notions, if any, regarding it prevail among our highest scientific authorities.

At a meeting of the B.A.A.S., held in Montreal on the 1st September, 1884, in presenting a paper on the subject, the writer was confronted with a specimen prepared by Sir William Dawson, showing his idea of the formation of frazil ice. It was a piece of lead perforated or cut into deep flakes on its upper surface, by the action of a current of acid passing over it.

As explained by the President (Sir William Thompson), frazil was supposed, similarly, to be the product of currents of water passing over and disintegrating solid anchor ice, exposing, as he expressed it, its "bones," just as rock is worn into irregular forms by the removal of its softer parts. Now, it is difficult for me to conceive how anyone, practically familiar with the appearance of frazil, could attribute its minute, needle like fragments to a waterworn origin, or believe that a substance so developed could be produced in large quantities. We do indeed, in the spring, see ice disintegrated to its bones, and falling to pieces, but that is only when it is exposed to sun and air, and when the formation of frazil is already a thing of the past. This experience convinced me that science had as yet no information to give; and that up to the present the best authorities regarded frazil merely as a curious formation, of rare and limited occurrence.

I think many of us are hasty in assuming that all is known about the philosophy of ice formation. Tyndall, when he overthrew the theory of Rumford, did not, I think, exhaust the subject. We know that water can be brought above its boiling point without ebullition, and we know that it can be brought below its freezing point without congealing. We know that superheating requires pressure, but how much do we know of the conditions accompanying supercooling?

I believe that ice never forms in water without an independent nucleus; that when it appears free on the surface the nucleii are supplied by minute particles of vapor, which, becoming frozen in their ascent fall back upon the water, form perhaps, the very stars seen in a block of ice when melted through a lens by the sun's rays.

That frazil, like anchor ice, forms under water seems unquestionable. Mr. Frank Gilbert, engineer, contractor for deepening the channel through the Gallops Rapids, states that he has passed in a boat over great beds of it, covering the bottom in dense masses of a spongy appearance, through which his pole swept with scarcely perceptible impediment. He also observed it upon a wire rope extended beneath the water, between his vessels, looking like bunches of iron filings lifted up by a magnet. In this case he noticed the curious fact that parts of the rope were bare and others covered with the growth, which seemed to negative the idea that the cold had been conducted through the rope. Under the circumstances it is plain that the exposure of the ends of the rope had little or nothing to do with the formation of the ice.

The conclusion I have come to is, that frazil ice is formed in currents cold enough not only to preserve its crystals but to induce their formation.

But why should it grow luxuriantly on one spot, and yet refuse, as we have seen, to grow upon a closely adjacent spot of a character precisely similar?

Well, that is a question yet to be settled; but with your indulgence I will try to offer an explanation.

All who have observed the action of fine drifting snow, when driven by the wind over a plane surface, such as a roof or a railway platform, will have noticed that it does not sweep along in clouds, or rolling volumes, but in long rifts or streaks with bare spaces between. With every lull of the wind these streaks rest for a moment, to be swept away by a succeeding blast into new combinations of a similar form, according to the variations, in force and direction, of the wind.

Now it is evident that these rifts are produced by the small inequalities of the surface of the plane. That the bare places are where the wind is least obstructed; and that the snowy streaks are the eddies where its force is partially obstructed. Now if this is admitted, we are brought to the important conclusion, that if the obstructions on the plane remain unaltered, and the direction, volume, and force of the wind continue unchanged, the streaks of snow with the spaces between will always occupy precisely the same position upon the plane.

If we now apply these observations to the flow of a river, we shall find a close approximation to such supposed conditions. For taking the case of a stream with a rocky bed, we have the more or less permanent obstructions on the bottom; while, unlike the air, the volume, speed, and direction of the water are but little affected by superficial influences.

The bottom of such a river presents a confused succession of irregular obstructions, around, over and between which the water rushes in every direction possible at once, and at every variety of speed. Along its main channel, greater freedom gives the river current its highest velocity, so raising its volume at the stiller reaches that backward currents or eddies are formed at its edges.

Looking at the troubled tumbled surface such a river sometimes presents, one is tempted to believe it a hopelessly involved chaos of complicated motion; but there is no chaos there. Every movement is made under as strict a law as governs the piston of an engine. Every bulge or swirl that we notice at some particular spot comes from the self-same sunken rock or cranny, and each would repeat itself precisely, were it not for molecular variations, which we will not here take account of further than to note that they modify, in a minor way, the results of which I am about to speak.

Bearing these facts in mind let us take a horizontal or plano section of the river.

Here we have in the currents so intersected, instead of the long streaks seen in our snow drift, an irregular network with meshes of every size and threads of every thickness. The threads represent the currents, and the meshes the comparatively still spaces enclosed. If we wish to represent the molecular effects alluded to, they may be shown as a sort of fringe of eddies along the sides of the threads.

As in the case supposed the general plan and position of the network is permanent, and as we know that water is a bad conductor of heat, it is plain that a sudden cooling of the water up stream would cause the threads of the network to became colder than the enclosed meshes; while the reverse would be the case on the water above becoming warmer, so that objects placed, the one in mesh and the other in the thread, would be affected differently as to temperature.

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Now for the formation of frazil.

The river is cooled down nearly to congelation; there is, we know, a very small margin to go upon at freezing point. The thermometer goes down to zero or below. The river in its efforts to part with its remaining heat steams, but its current is too rapid to freeze over; and so a supercooled current is borne down through the network.

The result is obvious, objects that present suitable nucleii in the threads are covered with a growth of frazil, while similar objects in the meshes remain bare. Similarly, on a sudden change to a warmer temperature the masses of frazil are thawed from their frail anchorage, rise, and are carried down by the stream. A phenomenon noticed by many observers. This theory also explains why frazil does not form on sandy or fine gravelly bottoms; for wherever there is any shifting of the obstructions on the bottom there will also be changes in the threads and meshes preventing that continuous contact with the cold current which is necessary to the formation of frazil, or so mixing thread and mesh as to bring the whole above the required temperature. I claim for this theory if not absolute demonstration, at least the merit of accounting for all known facts in connection with the nature and action of frazil.

Frazil, as we know, appears in the form of a mass of frail particles, with very little cohesive power. It is plain then that in small quantities, or with anything like a free passage, it would pass away harmlessly seaward. It could not under such circumstances become sufficiently dense to stop even its own passage, except in eddies, wedge spaces, or "culs de sac."

Unfortunately in the St. Lawrence there are too many of all these. Every shoal or batture affords such asylums, into which the frazil gradually packs. Fragments of ice are thrust into the mass affording new crannies for accumulation, until the flow of the stream is confined to the deeper or more direct channels. In their turn these channels will be most choked at their bends, especially where shoals or low lying islands exist on the outer side of the curve of the current and receive its centrifugal impact.

Now when we consider that the volume of a river like the St. Lawrence is not greater in winter than in summer but rather less, and that at certain points there are floods one year, and none the next, we naturally conclude that the floods are caused by more than usual obstruction below, and not by increased volume. The trouble is, therefore, local and may be removed without injuriously affecting other parts of the river.

I revert once more to the nature of frazil, in order to clearly point out the difference between it and surface formed ice when in motion and floating down stream.

Surface ice may be seen in process of formation on the open channel, shooting out their lances from floating nucleii, or, more frequently, projecting itself from the shore ice under the lee of salient points. It forms thin sheets through which the oars of passing boats crash like brittle glass. All along the open channel fragments are broken off by the action of wind and wave, and float down until stopped by some obstacle. In cold weather these are either cemented together on their way or quickly consolidated when they arrive at a barrier, and thus, as a rule, is formed the surface crust over the open channel. Where the water is still or the current sluggish the opening closes smoothly by the extension of the ice from either side.

A channel closed by packing is always more or less rough, and it would be quite possible, by critical examination, to determine the relative force of the current at different places, at the time of its taking, from the degree of roughness in which it was left.

There is no evidence to show that floating ice is carried beneath the fixed ice to any great extent, except in a strong current. Even then the tendency to rise in packing seems nearly to balance the downward movement. Huge hummocks are formed in such places, and the obstruction caused by them is due chiefly to broken sheets caught vertically, or at an angle with the surface.

The character and action of frazil is totally different. Rising in masses from the bottom, its buoyancy is so small that it floats to a considerable distance below the surface; while so little is its cohesion that when the mass becomes compacted enough to elevate its upper face above the water, it falls apart and spreads over the surface. It often attaches itself to floating ice or forms a nucleus for a new sheet of ice; and should severe cold sufficiently consolidate the whole, the surface ice would be swept beneath the barrier ice, in the train of the frazil to which it was attached.

The Caughnawaga indians, who in winter daily transport the mails to and from Lachine, state that frazil or slush ice runs only in the early part of the winter; and that when it ceases to come down, they know that the channel is closed at the upper end of the lake. If this is so, it shows either that the frazil formed below the cascade rapids remains fixed to the bottom as anchor ice, or, what is more likely, that being arrested by the friction of the overlying ice, it is thrust aside and jammed between the ice and the bottom, over the battures or shoals. At any rate, it goes to prove, than without an open channel, frazil is not carried down to any great extent from lake St.-Louis. As a factor in Montreal floods, therefore, we need seek it no further up than the foot of the Lachine rapids.

By keeping the channel open from these rapids down to the foot of Montreal Island it would seem that the frazil would be carried past without serious lodgment; but as there appears as yet no means of effecting this object, our natural recourse must be to so prepare the bottom of the river so as to give as free a passage to the frazil ice as we possibly can.

As will readily be inferred, I am strongly of the opinion that the disastrous spring floods from which the City of Montreal has suffered, are caused primarily by the choking of the river during winter, by which the area of the waterway is so reduced as to be unable to carry away the increased volume produced by the melting of the snow. Of course this is aggravated by the down flow of ice from the lakes above.

This latter difficulty it has been proposed to prevent by placing ice breakers, or rather ice arresting piers in Lake St. Louis, intended to keep it back until the barrier below has broken away.

Curiously enough, this contrivance, though one of the oldest known, has of late been received by some with so much enthusiasm, that disputes have arisen as to who had the honor of first suggesting it; not among engineers, however. It has been used in various beneficial ways, chiefly in securing an ice bridge at some dangerous spot. The latest case of the kind, known to me, was for the purpose of making a road upon which to haul stone and other material for the repair of the Carillon dam; a part of which had been undermined and carried away the previous year. The attempt, which was entirely successful, was made under the direction of Mr. Stark, superintending engineer of the Ottawa River Canals.

No doubt such a plan applied to Lake St. Louis would ameliorate spring floods at Montreal if we were sure that it would entail no other consequences. But there remains a serious question; whether in so doing, the ice would not pack so heavily above, as to flood the upper country, and the water obtain so great a head as to carry piers and everything else before it, and bring a worse disaster upon the city.

From the foregoing considerations it seems reasonable to conclude that the direction of any effective operations for the prevention of floods, should be in the following lines:

1st. Straightening the channels; or where this cannot be done enlarging them at their bends, by cutting away the inner sides.

2nd. Clearing away boulders and other elevations, on the shoals outside the bends, wherever the thrust of the stream tends to carry ice and frazil into wedge places and culs de sac. Giving the bottom a downward grade of the stream to give free egress to ice entering from above.

3rd. Removing over the whole area of the part of the river affected, all boulders, ledges and other projections of the bottom. Thorough cutting all sub channels, so as to give them a free discharge at the outlet; and benching such shallow slopes along the shoals as in combination with the surface ice afford the natural traps in which the frazil is caught.

Since writing the above a recommendation of the Government Commission on Floods has been partially put into effect, namely, an attempt to keep open the river channel between Three Rivers and Sorel, by means of vessels fitted to break up the ice.

While very doubtful of its success as a means of preventing floods at Montreal, I nevertheless heartily endorse the experiment. In such a difficult question the experience gained in an effort of this kind must greatly help on a solution, and may lead to other discoveries of benefit to the country, which otherwise would remain unknown.

Montreal, 14th Dec., 1886.