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TECHNICAL COMMUNICATIONS

Inlets, Entrances and Ice

Per Bruun

34 Baynard Cove Road
Hilton Head Island, SC 29928, U.S.A.

ABSTRACT

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This paper explains basic principles of ice interaction with shores comparing it to littoral drifts versus shores and drift barriers whether they function for ice or for sand or for both. A number of examples are given scematically outlining the two different modes of drifts and their influence on the selection of practical sites for harbours or terminals.

ADDITIONAL INDEX WORDS: *Ice, ice-drifts, ice versus shores, ice and littoral drifts.*

INTRODUCTION

Navigation and ice conditions in the Arctic are interrelated. This is the reason for the large icebreaker fleet stationed in Murmansk.

Through the years numerous tests on ice-breaking procedures, using a variety of vessels built and fitted for ice-breaking, have been undertaken. Proceedings from 12 POAC conferences since 1971 have produced about 90 papers on the subject referring almost entirely to open sea conditions, including breaking though ice ridges and pilings of various origins.

A ship's voyage has a starting and an ending point, where its commodity is unloaded/loaded at a quay or at a terminal. Such harbour facilities are almost always located in areas protected from heavy wave action, a bay, lagoon, fjord, behind an island or reef, or in a river mouth. While in some instances, protection against waves also means protection against ice; in others and perhaps in most cases, wave protection schemes could result in increased problems with ice, as ice masses contrary to water masses in currents and waves, stick together forming pile-ups, ridges, jams, etc. While any kind of hindrance to wave action will destroy, reflect, refract or diffract waves, ice is tougher in its interaction process with a structure. Ice is neither destroyed or visibly reflected. Ice "refraction" or "diffraction" is a very local affair (BRUUN, 1983). Certain similarities, however, exist in the interaction between currents and waves versus ice. Waves and currents propagating in the same direction flatten waves and spread the ice. Opposing currents increase the steepness of waves, and opposing ice movements, due to winds and/or currents, may cause ice ridges or ice jams. For people working with ice problems this is all very elementary. They instinctively try to avoid any kind of possibility for the concentration and packing of ice. In so doing they may stop or slow down the movement of ice towards the area they want to protect against ice and wave action. Therefore, they look for shores which have as little ice as possible.

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Site selection for harbours is usually dictated by protective criteria against wave, current and sediment transport actions. Land-dictated criteria, however, may sometimes override, wholly or in part, such natural maritime considerations. This could result in severe maintenance problems and create an economic problem for the project (BRUUN, 1990, Vol. 2).

Considerations regarding ice are usually based on experience with local conditions. Ice-jamming is less pronounced in certain areas and consequently these areas are best suited for fixed installations. In most cases, this is probably correct; but in others the fact that a structure placed in ice, by its mere presence, changes natural conditions and thereby increases danger of ice-packing was overlooked. Also, if the ice has first moved in and perhaps has grounded, it may be very difficult to get it out again, voluntarily or by force.

The following may sound elementary, but practical experiences have proven that it is sometimes important to return to or remind ourselves of important basic concepts. Certain general principles on protection against ice are outlined briefly in the following.

MAN-MADE STRUCTURES IN ICE

A harbour installation must not "catch" or "trap" ice. Where is has first formed, it many stay put or it may move under the influence of winds and/or currents. If the ice hits a substantial hindrance, it may be stopped or it may also bypass and continue its movement. In the case of the former,

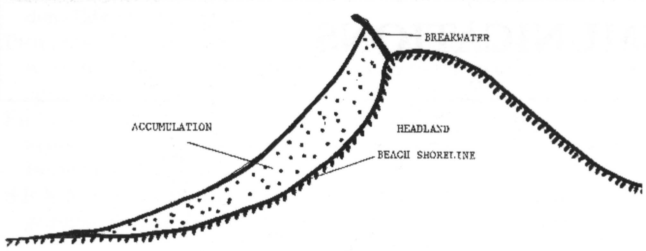

Figure 1. Reservoir for sand or ice at headland.

a reservoir of a proper size is needed. When the reservoir is filled, the ice may continue its movement which may generate new problems "downstream". The similarity to littoral drift conditions, therefore, is striking (BRUUN, 1990, Vol. 2). A reservoir of proper capacity and geometry is essential. in this respect, the similarity with littoral drift conditions is obvious. In littoral drift technology, we talk about "predominant drift". Its counterpart in ice technology is "the predominant ice drift", recognizing that the drift may come from either side. The standard technical solution to the littoral drift problem is breakwaters or jetties which protect against wave action and stop the littoral material drift. The ability of a jetty to do that depends upon its length and configuration. Jetties are usually built perpendicular to the shoreline, thereby increasing their capacity as reservoir structures. Their outer section may be curved downdrift to generate an outer harbour and to guide the material transport past the entrance, whether sand or ice (BRUUN, 1990, Vol. 2). For site selection, the two criteria, ample reservoir capacity and bypassing, are therefore mandatory. For example according to American experience, the sand trap installed on the updrift side of a littoral drift barrier shall have a minimum capacity of $\frac{1}{12}$ of the annual drift by sand from the updrift side.

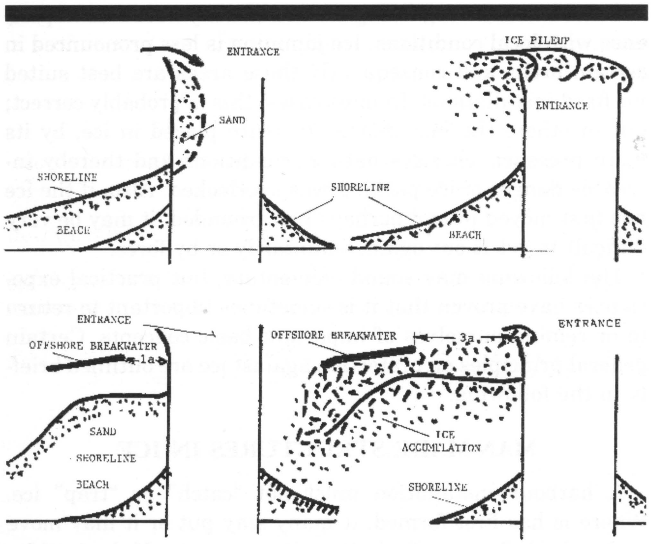

Figure 2. Accumulation of sand/ice at a jetty protected entrance and on the updrift side by a shore parallel offshore breakwater.

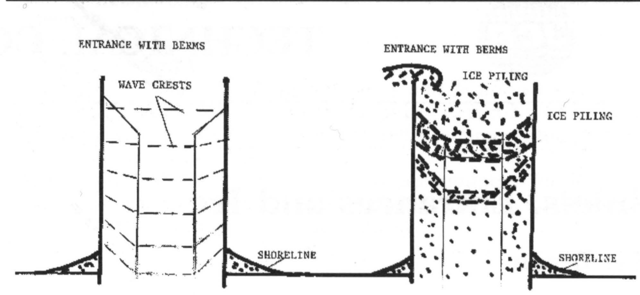

Figure 3. Wave and Ice-absorbing berms in an entrance.

The two criteria for sand and ice may, however, oppose each other. Reservoir capacity means a large updrift bay area, *e.g.,* generated by a headland (Figure 1). Bypassing by natural forces requires a stream-lined shore geometry without any hindrance to free movement.

Ultimately the reservoir may be filled with sand or by drifting ice, which then finally has to bypass or it has to be bypassed to avoid blocking of an entrance. Bypassing of sand beyond an entrance is a normal feature on littoral drift shores. Bypassing of ice is sometimes accomplished by using "ice-sluices" at hydraulic power plants built under arctic conditions, *e.g.,* in Iceland, Alaska, Canada, Norway and Russia. But quantities of ice are very modest and it is not possible to use the same technique on open sea shores. Ice may bypass by natural action due to currents, sometimes assisted by wave action. The principal question then becomes the site selection in relation to quantities and carrying capacities and how to use these without introducing adverse effects. If such effects occur, the problem is how to minimize them or eliminate them entirely.

Harbours on arctic shores are always located in fjords, in river entrances, or in estuaries. As such, they are facing the condition of ice-flows from either direction, caused by tidal currents.

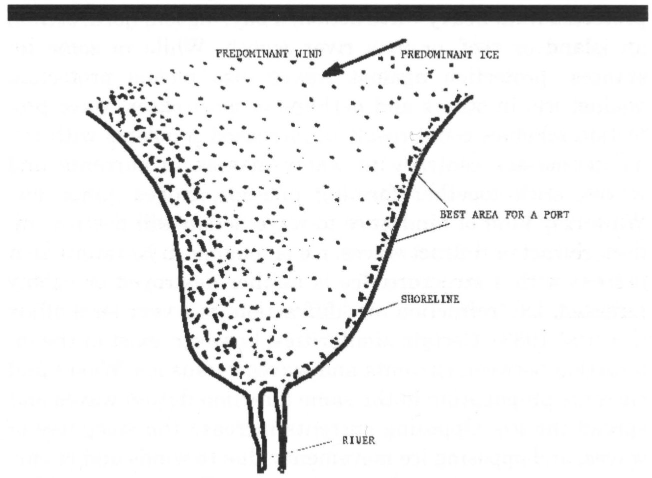

Figure 4. Location of harbour-facility in relation to predominant winds and/or predominant ice movement in an estuary or fjord.

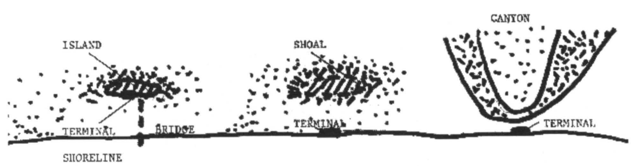

Figure 5. Island, reef, shoal or canyon as wave or ice protective structures.

Large reservoirs can only be generated by natural headlands. Headlands usually generate concentrations of currents. In either case, concentrated drifts by sand and ice may result, and the problem is how to get the material past the headland and its structures in the least difficult manner after the reservoir capacity has been exhausted.

In this respect, sand and ice demonstrate behavioural similarities as well as differences, making a direct transfer of technology difficult or impossible. Figure 2 shows behavior as well as behavioral differences of sand and ice action at a harbour or inlet entrance to a bay, lagoon, or basin. It is assumed, based on numerous practical experiences, that some sand or ice enters between the jetties. In this respect, the detailed pattern of sand and ice movements differ and so do the technical measures against the sand or the ice (Figure 2). Note that an updrift offshore breakwater must be placed further away from the entrance than the littoral drift breakwater to deter ice in the entrance area.

Figure 3 shows a rather narrow entrance to a harbour, like Nome, Alaska (SACKINGER *et al.,* 1983). This type entrance will clog with sand or ice easily. Wave action will concentrate in the middle of the entrance due to diffraction; ice will cling to the side. In either case, shallow water berms (Figure 3) will, by refraction or in the case of ice by "a similarity to refraction", improve conditions for wave as well as ice action in the entrance channel.

As mentioned above, most harbour installations in arctic waters are placed in protected areas like fjords, bays, lagoons and river mouths. Obviously, if the choice of shores framing an entrance is free, facilities should be placed on the leeside where wave and ice action are least (Figure 4). Analyses of sea ice drift in coastal zones, therefore, are important (*e.g.,* SMITH, 1989).

If one is faced with placement of a harbour or a terminal on the open coast, the existence of islands, reefs, shoals or canyons may be taken advantage of as indicated in Figure 5.

As river ice during the spring and early summer continues to flow towards the entrance for a longer period of time, great care should be demonstrated in selecting the proper site on the shore. As shown in Figure 6, a flood channel is preferable for an ebb channel carrying more ice.

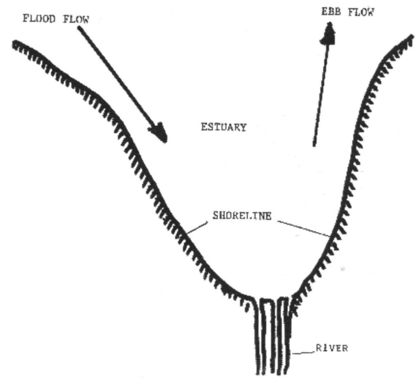

Figure 6. Location of facility is best in a flood channel.

DISCUSSION

It seems obvious that some definite similarities exist between the behaviour of littoral drifts and ice drifts, versus structures, and that similar measures against these drifts are possible. The difference in behavior is because: (a) Sand travels mainly along the bottom, while ice floats in water or in ice. (b) Water is of higher viscosity, ice, and in particular broken ice, has a highly variable "viscosity" much lower than sand-filled water. (c) While sand may or will settle down, ice keeps floating in water or in ice masses. Sand, therefore, is easier to catch and handle than ice in all its varieties. Measures against the adverse effects of the two materials and their modes of drift, therefore, differ quantitatively, but not much qualitatively.

Perhaps the days are close at hand when, during certain circumstances at entrances, it may be practical to dredge ice ridges and barriers by using hydraulic equipment, including cutterheads, and to transfer the mass; thus, discharging it, and reducing the nuisance to a minimum or eliminating it altogether.

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