PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

ICE RIDGES IN A COASTAL AREA OF FINLAND

Erkki Palosuo Institute of Marine Research Helsinki, Finland

Synopsis

The coastal area of Finland is rather low and there are many islands where the ice can be attached. The following conditions seem to be necessary for the formation of an ice ridge in the coastal area:

- wind velocity must exceed a minimum value, which depends on the thickness of the ice and the distance between the islands
- most ridges will be formed from a rather even ice sheet by thrusting, i.e. pushing, the flaps of one sheet over or under the next sheet. The thickness of the ice must exceed 7 to 10 cm
- a part of an ice ridge is very often grounded or attached to an island
- in the floating part of a ridge the ice blocks close to the surface eventually froze together, although the degree of bonding between ice blocks at a depth of about 0.5 to 1.5 m below the free water level remains low.

Observations of ridge formation off Raahe in 1970

The formation of ice ridges in the coastal area of Finland has been observed for a long time (3). When an observer, such as a lighthousemaster, lives on a remote island, he is able to give a detailed description of the ridge formation. But very often the information has been rather superficial. A more detailed examination of the ice ridges was performed during the winter of 1970 off the sity of Raahe on the northern Gulf of Bothnia. From beginning winter to the end of the winter the harbour master made weekly measurements of the ice thickness on a line from the harbour to the Nahkiainen lighthouse, 15 nautical miles out. At the same time he observed the situation of ridges and possible changes in them (Fig. 1).

The first ridge of ice 7 to 10 cm thick, formed Dec. 26, was attached to the shoals in four or five places. The middle part of it was still floating. The second ridge formed January 4 was attached at both ends. The ice was already 10 to 12 cm thick. The third one was formed Jan. 26 along the ice breaker channel, when the ice north of the channel was broken and pushed southward. This ridge was attached to a shoal at its west end. The eastern end of it was connected to the second ridge. At the point of connection it reached the bottom at a depth of ten meters.

After Feb. 16, the ice in the inner part of the coastal area was immobile and new ridges were formed as far out as the Raahe lighthouse.

If we compare these observations with the results for earlier years it can be seen that 7 cm is the minimum thickness of ice forming a ridge. It is generally formed of ice 10 to 15 cm thick, although in this case the ridge is situated further out.

To get the surface profile, the ridges were photographed from an aeroplane on April 26 (4). Unfortunately there was a heavy snow cover in the area at that time and only the highest peaks of the ridge were clearly visible. At the same time a skindiver went down and drew the profile of the underwater part (Fig. 2). He also observed that the blocks on the surface were frozen together and a coherent sheet of ice about 40 cm thick was formed. Some vertical floes were frozen to this sheet at one end, although at a greater depth pieces were loose, so he was able to move them (1. 2). At the bottom the ice was very brittle, but he could not decide if the ice was eroded or if new crystals had formed and covered the ice floes.

The effect of wind on the formation of ice ridges

As seen before, the ice in the coastal area attaches itself to the islands and shoals. It seems obvious that there is a correlation between the ice thickness and the wind velocity necessary to break the ice (3). In Fig. 3 the observations during 10 years at Jaakonmatala off Raahe have been plotted.

The ice thickness was measured at the Isokraaseli pilot station once a week and was also often reported from the icebreaker on duty in the area. The wind velocities used are measured at Oulu airport. The critical factor of course, is the maximum local wind velocity, but this was not available.

The wind velocity needed for breaking up the ice cover showed an almost linear relationship with the thickness of the ice. This was valid when the ice was hard. All the cases where the ice had become rotten due to the warm weather, or when an extreme change of water level or a swell coming from storms on the open sea had broken the ice, have been discarded.

Similar comparisons of wind velocity and thickness of the ice have been made at successive points near the fairway to Raahe (Fig. 4). When the ice in the inner skerries has reached a certain thickness it does not break easily. But in the outer skerries it breaks even when it is rather thick. In the central part of the Gulf of Bothnia west of the Nahkiainen lighthouse the ice may move even when it is thick.

A short distance between the islands seems to be an important factor in preventing the ice from breaking up. Fig. 5 shows the results from fairways to Oulu, Vaasa and Turku. The difficulty is to define the density of the skerries. Not only are the islands very irregularly distributed, but it is difficult to decide which shoals shall be counted as islands. A study of "fast ice bridges" in the Kvark and in the Aaland Sea has already suggested that a submerged shoal functions as an island when a moving ridge has grounded on it (5).

References

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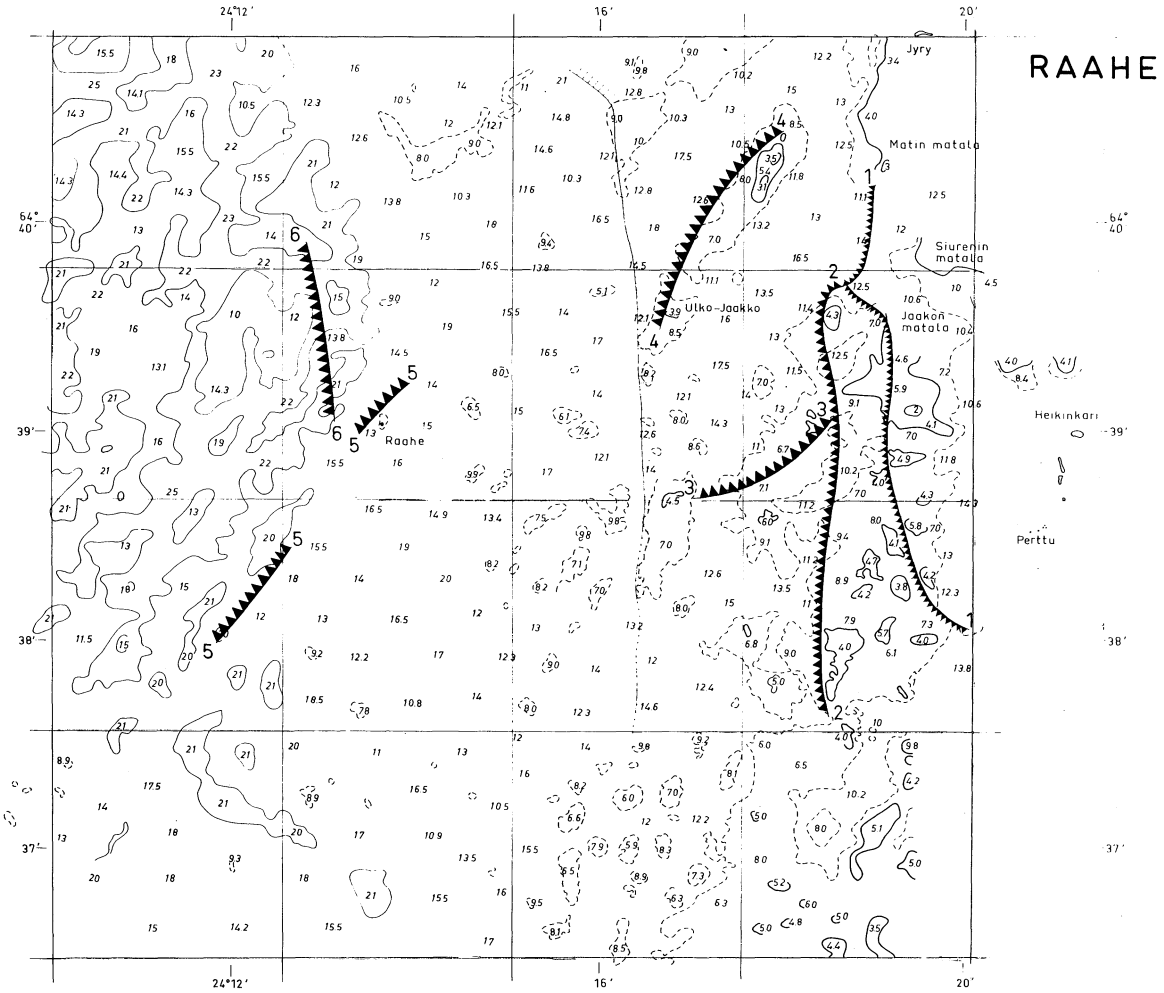

Fig. 1. Location of pressure ridges off Raahe in winter 1970/71. The ridges were formed as follows:

1.	Dec. 26, 1970	ice 7 to 10 cm	wind 12 m sec^{-1}
2.	Jan. 4, 1970	10 to 12	12
3-4.	Jan. 26, 1971	30	6
5.	March 7, 1971	35	12
6.	March 9, 1971	35	14

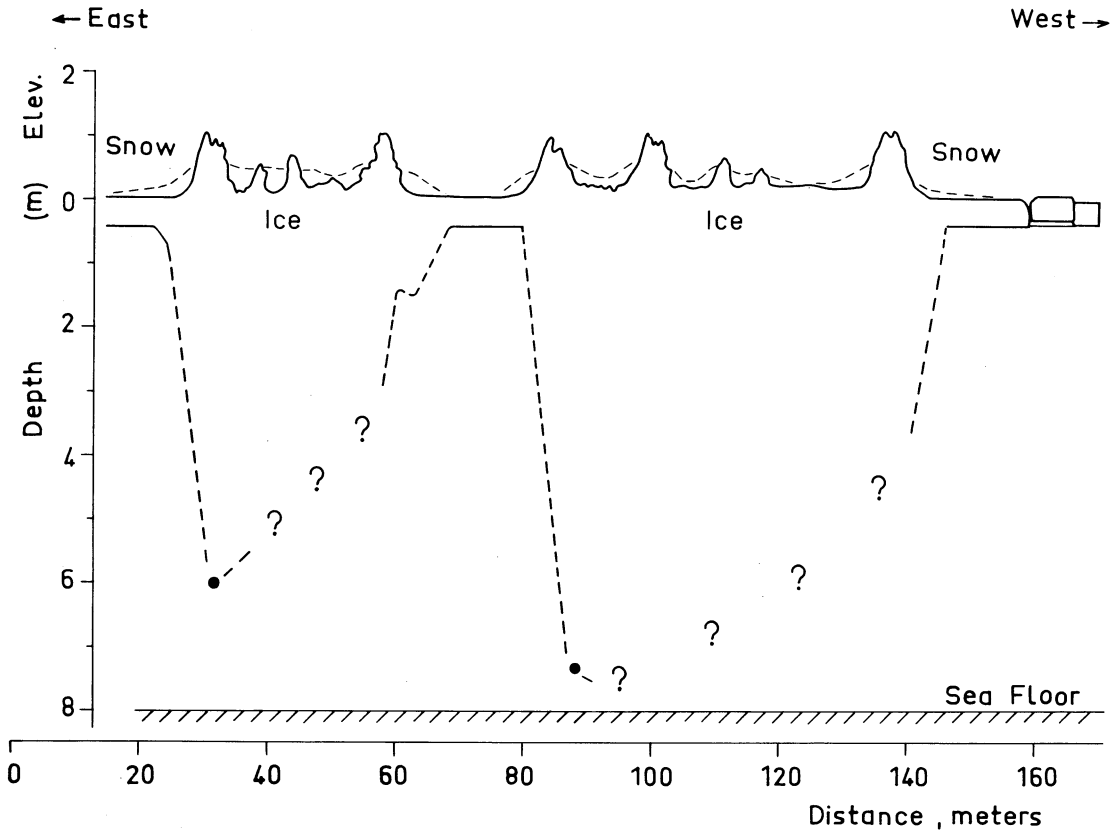

Fig. 2. Tranverse cross-section of Ridges 1 and 2 off Raahe. The profile of the upper surface is determined by air photos, the depth of the ridges is measured by a skin diver.

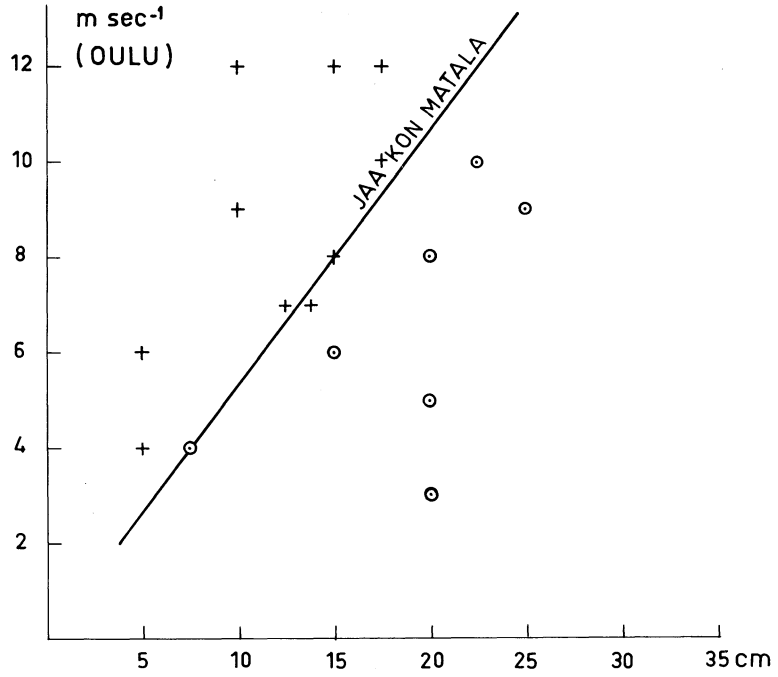

Fig. 3. The interdependence of the thickness of the ice cover and the one-day-mean wind velocity at the break-up of the ice on the Heikinkari - Jaakonmatala section of the Raahe fairway. The circles indicate that the ice did not break; the crosses, when it broke up.

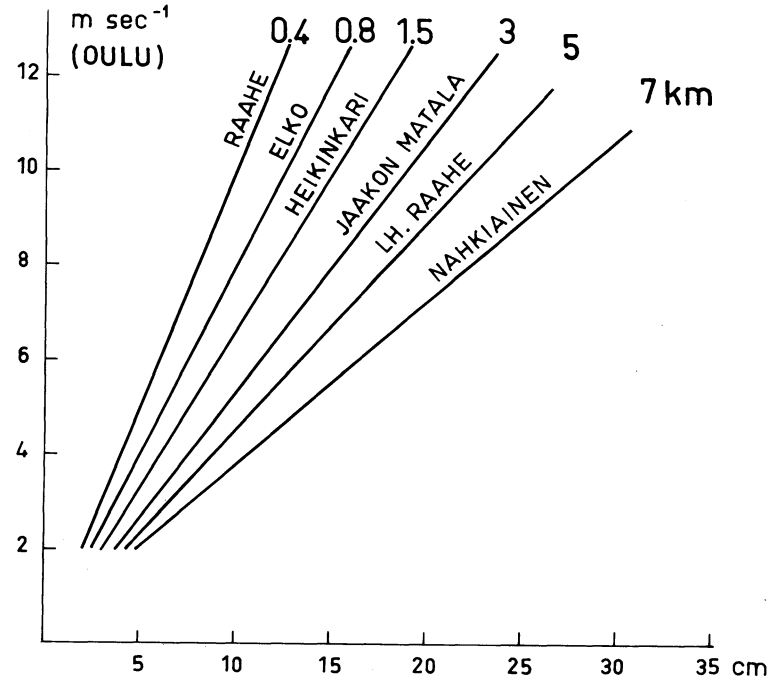

Fig. 4. The interdependence of the thickness of the ice cover and the mean wind velocity at break-up on the different sections of the Raahe fairway. The main distance between the islands and shoals are given in kilometers.

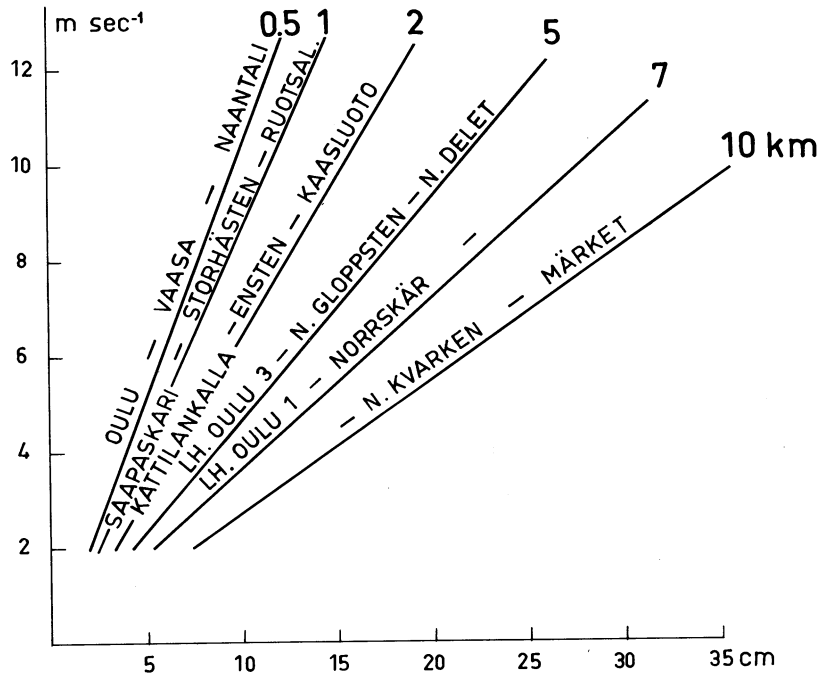

Fig. 5. The interdependence of the thickness of the ice cover and the mean wind velocity at break-up on the different sections of the Oulu, Vaasa and Naantali fairways. The main distance between the islands and shoals are given in kilometers.