Free Beam Tests and Friction Tests at Pond Inlet, N. W. T.

By Kari Airaksinen *

Abstract: The flexural strength and elasticity of the sea ice cover is determined by testing free beams extracted from various depths within the ice. The dependence on orientation and sample dimensions is investigated. The surface friction coefficient of ice against steel is measured with a small sledge. The influence of surface roughness and pressure is investigated.

Zusammenfassung: Biegefestigkeit und Elastizität des Meereises werden untersucht durch das Entnehmen von Eisbalken aus verschiedenen Eistiefen. Die Beziehung zwischen Festigkeit, Entnahmetiefe und Balkenabmessungen wird überprüft, der Reibungskoeffizient zwischen Eisoberfläche und Stahl mit einem kleinen Schlitten gemessen und der Einfluß der Rauheit der Oberfläche und des Andrucks festgestellt.

Introduction

A. G. "Weser" contracted with Wärtsilä Helsinki Shipyard to perform free beam tests and surface friction tests in connection with the EOS-72 routing study. The tests were made during May and June 1972 on the sea ice of Eclipse Sound outside Pond Inlet, N. W. T., as part of a joint Canadian — German expedition to investigate the sea ice conditions. The purpose of these tests was to measure the strength of the ice cover and the friction coefficient of the ice surface against steel in order to obtain information needed for the evaluation of the ships' resistance in ice.

To avoid the heavy equipment necessary for the cantilever beam tests in 1.8 m thick ice, it was decided that the subject of the tests would be medium-sized (1.5 m x 0.2 m x 0.2 m) free beams which were extracted from the ice cover with chain saws.

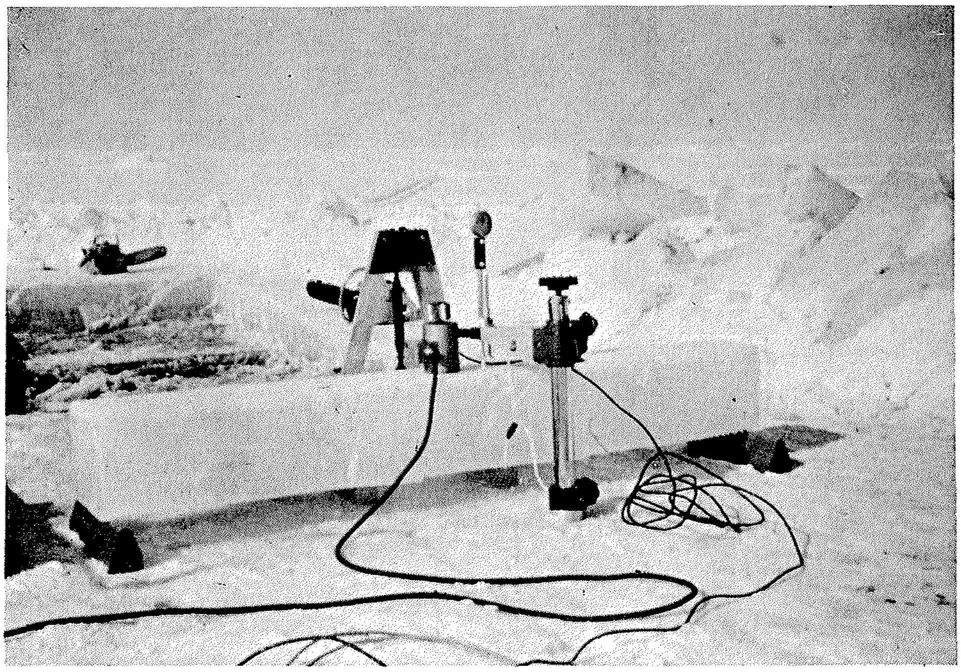

Fig. 1: The apparatus for breaking the beams.
Abb. 1: Zum Brechen der Eisbalken benutzte Anlage.

* Dipl.-Ing. Kari Airaksinen, Naval Architect, Wärtsilä Helsinki Shipyard, Helsinki, Finland.

The friction was determined with two types of steel surfaces. Surface 1 was sandblasted and unpainted thus corresponding to the hull of a new ship. Surface 2 represented an older ship having the surface corroded by sea water.

Beam tests

The testing apparatus consisted of an A-shaped rig (Fig. 1) anchored to the ice sheet with a chain going through a hole in the ice and attached to a small bar pressed against the bottom of the ice cover. This rig formed the pivoting point of the lever for breaking the beams.

Immediately after cutting the beam was placed on two wooden supports. The breaking force was measured with a force transducer (type HBM U1/1Mp) placed on the beam and connected via an amplifier to a U. V. recorder. The deflection was measured with an inductive displacement transducer (type S. E. 92/1000), also connected to the recorder. The beams were broken manually using an 1.5 m long bar for a lever. The loading time from the starting to the breaking varied between 2—5 seconds. After breaking the mean width and height were measured at the broken cross section.

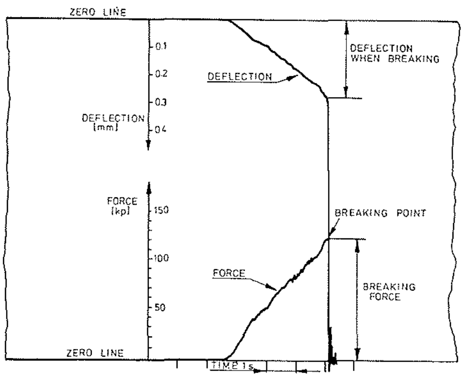

Fig. 2: An example of the recording.
Abb. 2: Ausschnitt aus einer Registrierung.

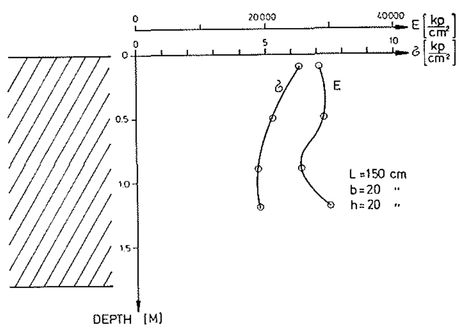

Fig. 3: The vertical variation of strength and elasticity in the ice cover.
Abb. 3: Veränderung der Festigkeit und des Elastizitätsmoduls im Eis mit der Tiefe.

Fig. 2 is an example of the recording on the oscillograph. The force and deflection were measured at the breaking point. The strength was calculated using the formula:

$$\sigma = \frac{(1.5F + 0.75G) \times L}{bh^2}$$

(F = loading force, G = weight of the beam, L = length between supports, b = width, h = height). When calculating the weight a density of 0.905 g/cm^3 was used.
The elasticity was calculated from the equation:

$$E = \frac{F \times L^3}{4\delta bh^3}$$

Here δ is the deflection due to force F at the breaking point.

To determine the vertical variation of strength and elasticity in the ice cover, beams were cut from different depths. The bottom of the deepest layer of beams was 1.3 m from the ice surface. Fig. 3 shows the results of this series. With increasing depth a slight decrease in the values is noted.

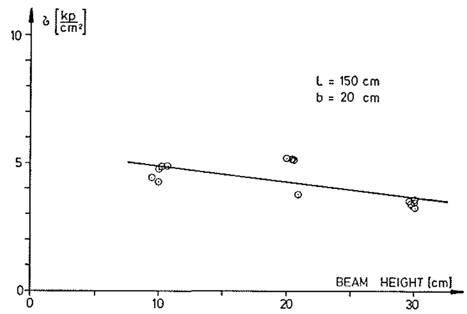

Fig. 4: Strength vs. beam height.
Abb. 4: Festigkeit in Abhängigkeit von der Balkenhöhe.

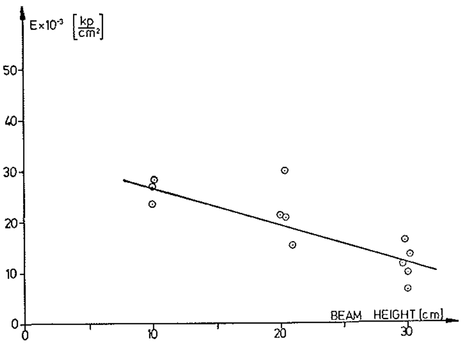

Fig. 5: Elasticity vs. beam height.
Abb. 5: Elastizitätsmodul in Abhängigkeit von der Balkenhöhe.

Earlier beam tests have indicated that the dimensions may influence the strength and elasticity considerably. Therefore a series of tests was carried out where the length, width, and height of the beams were systematically varied. Figs. 4 and 5 show the strong influence of beam height on strength and elasticity. The beam length has a small influence on the strength (Fig. 6), and a strong influence on the elasticity (Fig. 7). The beam width has practically no influence.

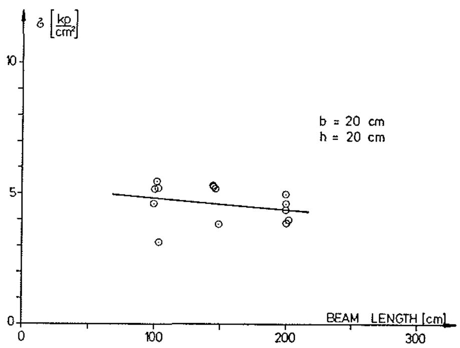

Fig. 6: Strength vs. beam length.
Abb. 6: Festigkeit in Abhängigkeit von der Balkenlänge.

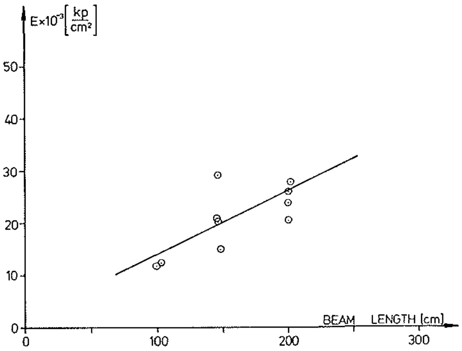

Fig. 7: Elasticity vs. beam length.
Abb. 7: Elastizitätsmodul in Abhängigkeit von der Balkenlänge.

Ice strength values are usually related to the brine volume. According to FRANKENSTEIN and GARNER the brine volume can be calculated with the formula:

$$\upsilon = S(45.917/T + 0.930)$$

(υ = brine volume ‰, S = salinity ‰, T = temperature °C)
The temperature and salinity profiles were measured by KOHNEN, WERNER, and WALTER. The strength versus brine volume is shown in Fig. 8. A comparison with DYKINS' results with simple supported beams shows good agreement.

Friction tests

The tests were carried out with a small sledge (Fig. 9) which was towed along the ice surface. The towing rope was attached to a force transducer (type HBM U1/1Mp). In addition, an accelerometer (type HBM B1M) which measured the acceleration in the fore and aft directions, was mounted on the sledge.

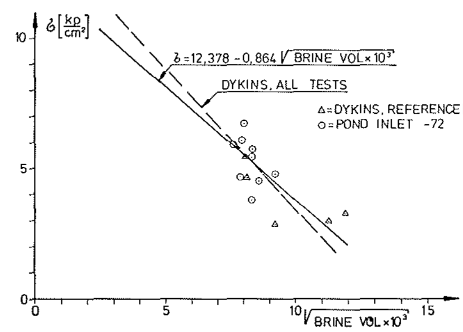

Fig. 8: Strength vs. brine volume.
Abb. 8: Festigkeit in Abhängigkeit vom Gehalt an Salzlösung.

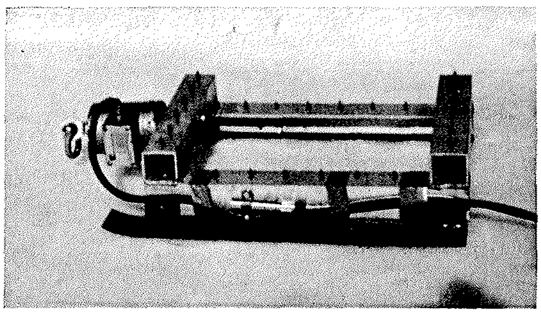

Fig. 9: The equipment for friction tests.
Abb. 9: Apparatur zur Durchführung des Reibungsversuchs.

The measuring instruments were connected with cables via amplifiers to a U. V. recorder. During the tests the cables were carried loosely in hand so that no additional force was imposed on the sledge.

The velocity was determined with a marker connected to the recorder. With this marker an impulse was given when the sledge passed the end points of a measured 10 m distance. From the timer marks on the recorder the average velocity could be calculated accurately.

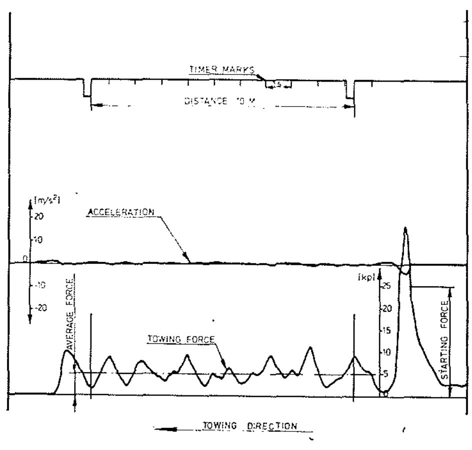

Fig. 10: An example of the recording in friction tests.
Abb. 10: Ausschnitt aus einer Registrierung im Reibungsversuch.

Fig. 10 shows an example of the recording. The friction coefficient is defined by the equation:

$$\mu = F/N$$

(F = towing force, N = normal force)

The dynamic friction coefficient versus surface pressure is presented in Fig. 11. A decrease in the friction coefficient with increasing pressure is noted. The results also clearly demonstrate the influence of surface smoothness.

The static friction coefficient versus surface pressure is shown in Fig. 12. The difference between the surfaces is not so pronounced. The relatively large scatter in the points is mainly due to the time dependent adhesion of steel to ice. The static friction coefficient is not so strongly dependent on the surface pressure.

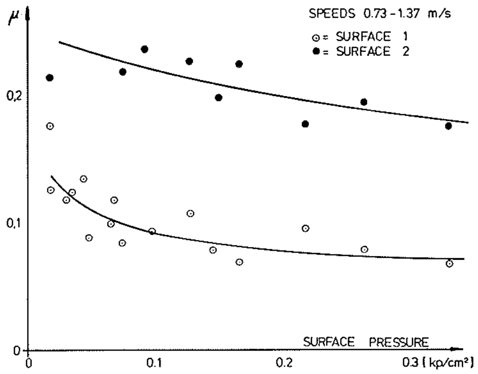

Fig. 11: Dynamic friction coefficient vs. surface pressure.

Abb. 11: Der dynamische Reibungskoeffizient in Abhängigkeit vom Aufdruck.

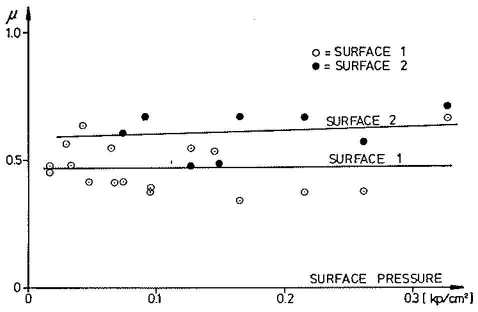

Fig. 12: Static friction coefficient vs. surface pressure.

Abb. 12: Der statische Reibungskoeffizient in Abhängigkeit vom Aufdruck.

Summary

Medium-sized beams were extracted from various depths of the ice cover. The strength and elasticity of the beams were determined. Tests with beams of different sizes showed that the results may be considerably influenced by the beam dimensions.

Friction tests were performed with two steel surfaces against ice. The dynamic friction coefficient is strongly dependent on the roughness of the test surface. The difference in the static friction coefficient is not so pronounced. An increase of the surface pressure decreases the dynamic friction coefficient.

Literature

Dykins, J. E.: Tensile and Flexure Properties of Saline Ice. Proceedings of the International Symposium on Physics of Ice, Munich / Germany, September 9—14, 1968, pp. 251—270.

Frankenstein, G. and G. Garner: Equations for Determining the Brine Volume of Sea Ice from — 0.5° C to — 22,9° C. Journal of Glaciology, Vol. 6, No. 48, 1967, pp. 943—944.

Kohnen, H.: Seismic and Ultrasonic Measurements on the Sea Ice of Eclipse Sound near Pond Inlet, N. W. T., on Northern Baffin Island. Polarforschung, 42. Jg., Nr. 2, 1972, pp. 66—74.

Walter, R. und K. Blewett: Strukturkartierung und Profilaufnahme im Meereis des Eclipse Sound (Baffin Island). Polarforschung, 42. Jg., Nr. 2, 1972, pp. 97—101.

Werner, J., Schreiner, B. T. and E. Treude: Meteorologisch-geländeklimatologische Untersuchungen bei Pond Inlet, N. W. T. (Baffin Island). Polarforschung, 42. Jg., Nr. 2, 1972, pp. 102—109.