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Riikka Matala

CHANNEL RESISTANCE IN FULL SCALE AND IN MODEL SCALE

Finnish Transport and Communications Agency
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Sweden

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FOREWORD

In this report no 107, the Winter Navigation Research Board presents the results of a research related to vessel channel resistance. The resistance was measured in full scale tests and the results were compared to model tests.

According to the results, the model tests overestimate the vessel resistance in brash ice channel. The results indicate that it is necessary to continue research and study to find out if the test result accuracy depends on hull shape or is the difference between full scale and model scale test results pronounced with new, EEDI-type bow shapes.

The Winter Navigation Research Board warmly thanks Mrs. Riikka Matala for this report.

Helsinki and Norrköping

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Lauri Kuuliala

Finnish Transport and Communications Agency

Anders Dahl

Swedish Maritime Administration

Markus Karjalainen

Finnish Transport Infrastructure Agency

Stefan Eriksson

Swedish Transport Agency

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CHANNEL RESISTANCE IN FULL SCALE AND IN MODEL SCALE

FOR

FINNISH TRANSPORT SAFETY AGENCY TRAFI

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Summary:

In 2018, the Winter Navigation Research Board funded a research related to vessel channel resistance (W18-8 FSC channel resistance).

A vessel resistance was measured in full scale, and the results were compared to model tests, which were conducted according to Finnish-Swedish ice class rules.

According to the test results, the model tests overestimate the vessel resistance in brash ice channel. It is necessary to continue research and study, if the test results accuracy depends on hull shape, or is the difference between full scale and model scale test results pronounced with new, EEDI-type bow shapes.

Keywords:
1A channel, brash ice channel, EEDI-tanker

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1 INTRODUCTION

The objectives of the research were to continue brash ice channel resistance and channel model test procedures research. The research was funded by Winter Navigation Research Board. The previous research is described in Aker Arctic report A-557.

The work, which is described in this report, is based on full scale measurements and observations. The work was divided into five parts:

1. Planning and preparation of full scale measurements
2. Full scale measurements
3. Comparing the results to model test results
4. Possibly conducting a model test in similar conditions that corresponds to full scale reference
5. Writing a report based on the measurements and observations in full scale and in model scale

The full scale measurements were conducted in February, 2018. The model tests were conducted later with three different model brash ice channels similar way to the tests, which are described in A-557 but with a perfect model of the vessel.

2 DESCRIPTION OF THE VESSEL

The vessel of interest was about 100 m long tanker with a vertical wedge-shaped bow. The vessel has ice class 1A. The model was built in scale c. 1:15.

3 TESTS

3.1 FULL SCALE

The full scale tests were conducted near Kemi Ajos on February 15th 2018. There is only one channel entering Ajos, and the channel was known to be operated frequently and rather regular and easy to reach from the shore. A satellite image of the channel is presented in *Figure 3-1*. The test area is marked in the image with a red circle. The ice channel thickness profile was measured at 8 locations (*Figure 3-2*).

Figure 3-1: Ice channels in a satellite image taken in early February 2018

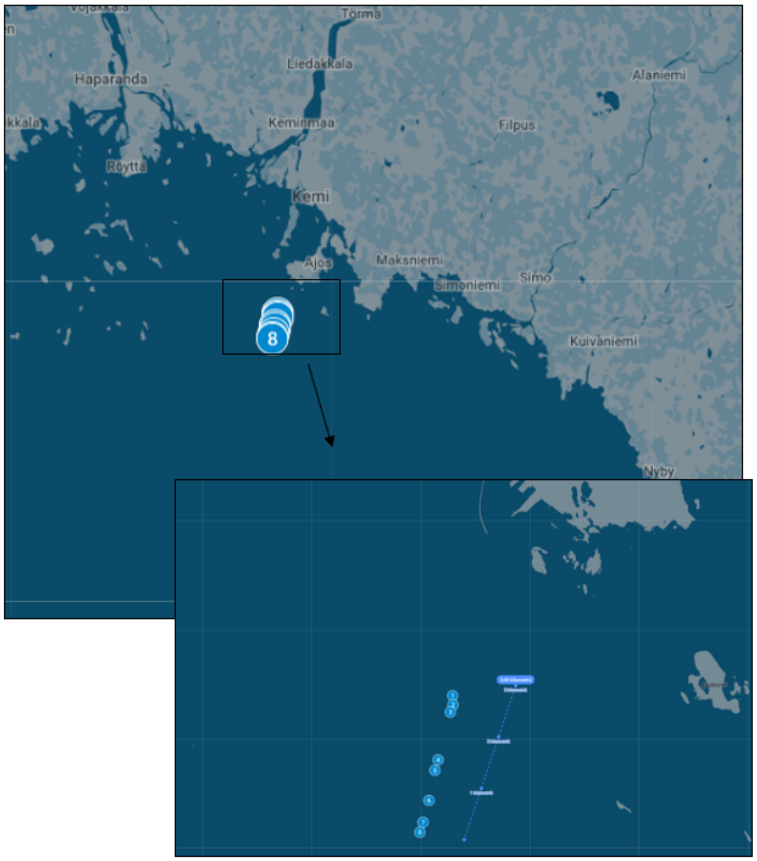

Figure 3-2: Channel profile measurement locations

The profile was measured by drilling through brash ice with 2 m intervals. The measurer moved over the channel with a small skiff, which was pushed forward with an oar and which could be pulled back to channel edge with a rope. One person was doing the measurement, while two persons stayed in the level ice edge and helped with moving the skiff, monitored the vessel traffic nearby and wrote down the measured values. This way, the measurement was safe to perform. The channel measurement equipment is shown in *Figure 3-3*.

Figure 3-3: Channel measurement

Ship measurements were recorded using vessel's own GPS logging system. Recorded data included:

- Date and time
- Latitude and longitude
- Vessel speed (knots)

Engine power of the vessel was recorded by recording engine control screen on video camera. Propulsion load was altered by adjusting controllable propeller pitch.

3.2 MODEL SCALE

The model tests were conducted with a model of the vessel, whose channel resistance was measured in full scale. The tests were conducted in three different brash ice types, and the channel was reconstructed twice after the first channel tests, so that the channel test was conducted three times in each brash ice type. The brash ice crushing strength was varied between the test days, but channel thickness and channel width remained the same. The test dates and ice types are presented in *Table 3-1: The test program*.

Table 3-1: The test program

Test day	Date	Ice type	Test
1	17.08.2018	Ice cubes	Channel 1
			Channel 2
			Channel 3
2	13.09.2018	FGX-ice, σ_c = 1000 kPa	Channel 1
			Channel 2
			Channel 3
3	20.09.2018	FGX-ice, σ_c = 500 kPa	Channel 1
			Channel 2
			Channel 3

The test was conducted at two different power levels in each channel. The ice test results were conducted according to Aker Arctic standard methods, and the test results were corrected to correspond to the channel thickness defined according to Finnish-Swedish Ice Class Rules and the same target friction coefficient.

Finnish-Swedish Ice Class Rules define exact channel profile but enables the use of average channel thickness H_{ave}, which is defined by equation [1]:

$$H_{ave} = H_m + 14.0 \cdot 10^{-3} \cdot B$$

where B is beam of the ship and H_m is 1.0 m for ice class 1A. Therefore, H_{ave} is 1.2 m in full scale. The width of the channel is also defined by the FSICR to be two times the vessel B.

The target friction coefficient between the model and ice is μ_{target} = 0.1.

The correction procedures are explained in Aker Arctic report A-557.

4 TEST RESULTS

4.1 FULL SCALE

The channel corresponded well to Finnish-Swedish Ice Class Rule 1A channel. According to the rules, the channel thickness in the middle of channel is 1 meter. The average thickness of 8 profiles center values was 1.03 m. The distance between first and last profile measurement was 2.7 km and according to the measurements and visual estimate, the channel was fairly even longitudinally. One measurement (profile 5) was measured from a channel intersection area, and that measurement diverged from other measurement, and the thickness in the channel center was 1.8 m. No speed test was conducted at that location, though. The profile measurements are presented in *Figure 4-1*.

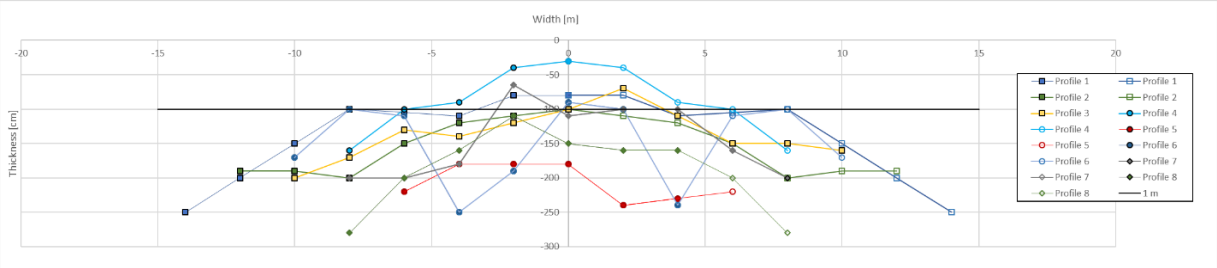

Figure 4-1: Channel thickness measurement results

The vessel speed was practically constant during all three tests. The vessel power was varied by adjusting the propeller pitch to desired level. The test results are presented in *Table 4-1* and *Figure 4-2*.

Table 4-1: The full scale test results

Pitch [%]	Speed [kn]	Speed [m/s]	Test distance [km]
100	10.2	5.2	1.0
80	8.6	4.4	0.7
56	5.8	3.0	1.2

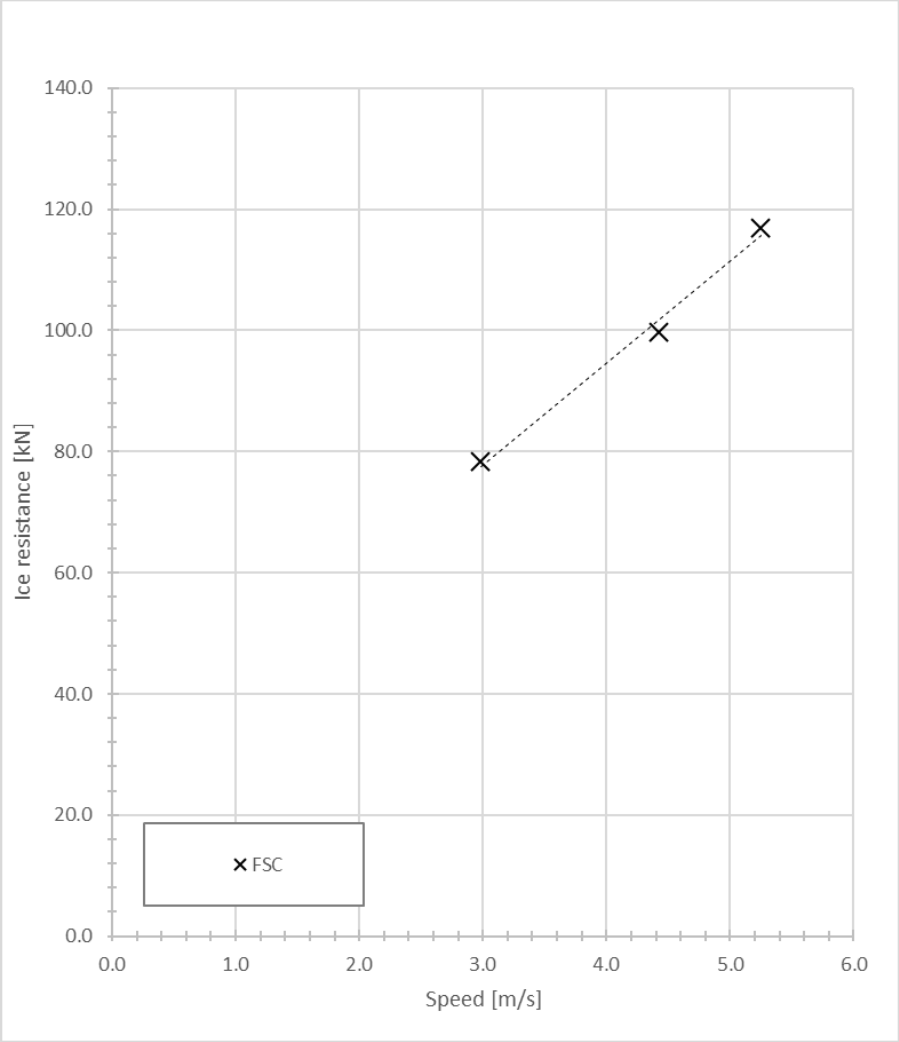

Figure 4-2: Vessel resistance in brash ice channel

4.2 MODEL SCALE

The test results without corrections are presented in *Figure 4-3*, with thickness correction in *Figure 4-4* and with thickness and friction correction in *Figure 4-5*.

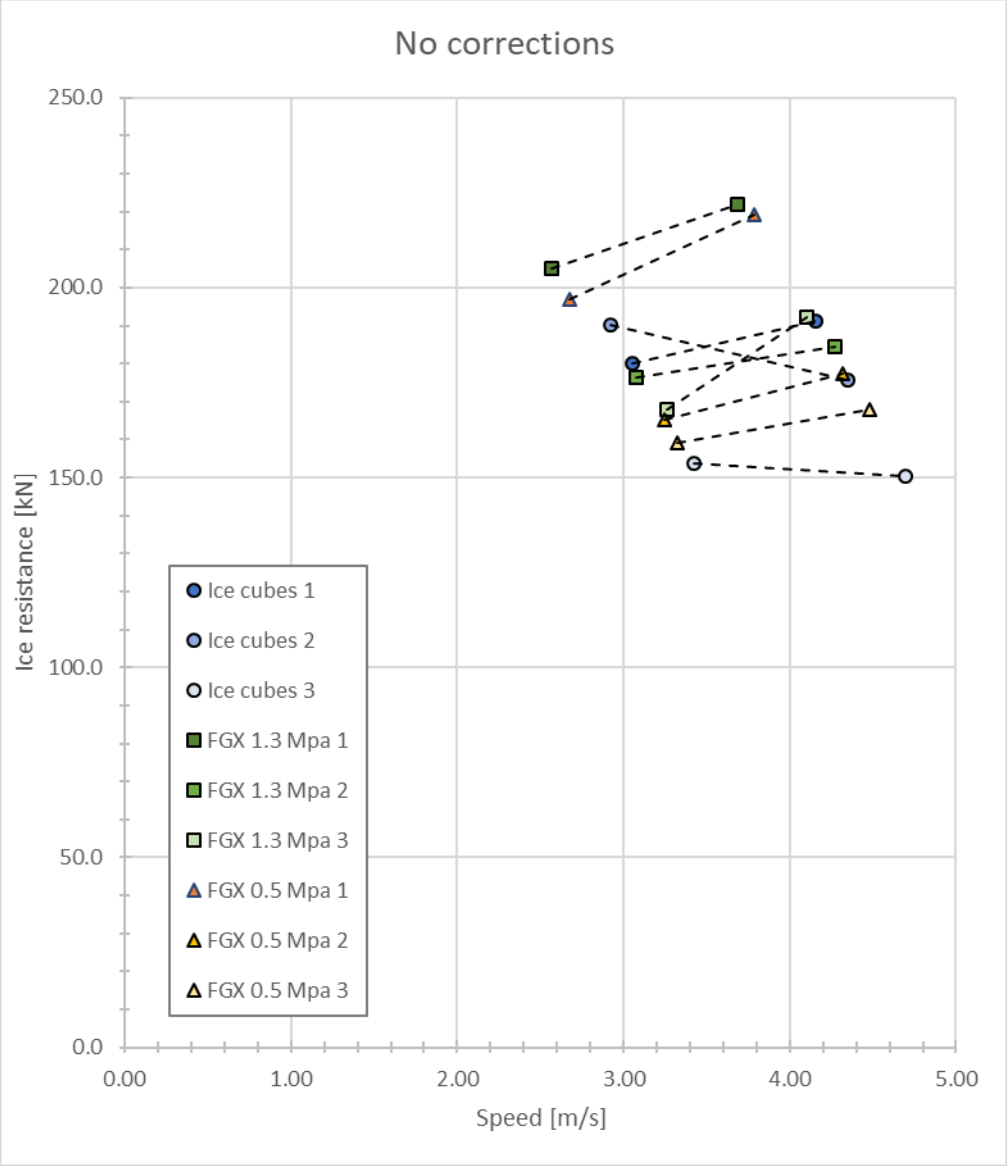

Figure 4-3: The test results without corrections

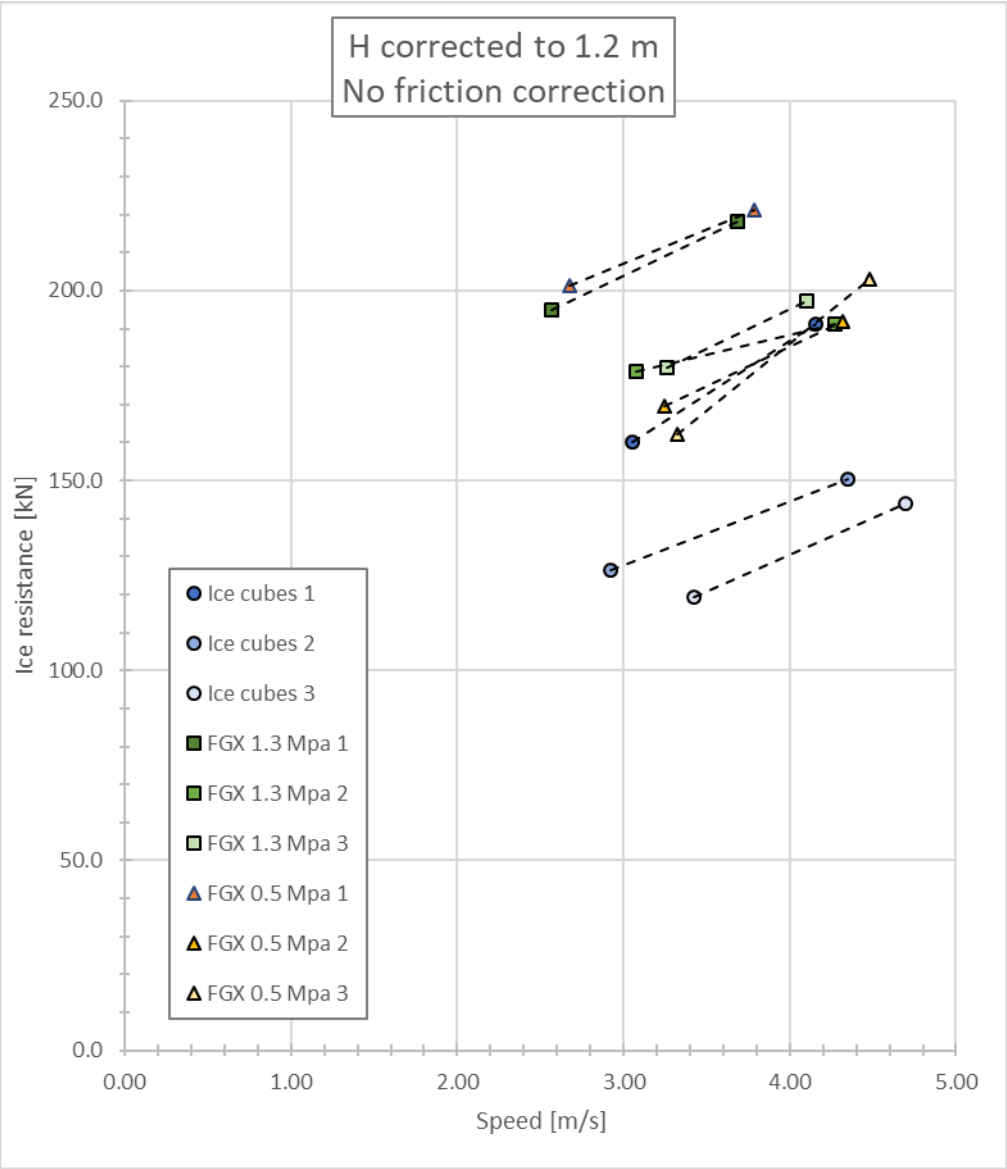

Figure 4-4: The test results corrected to target thickness of 1A channel according to FSICR

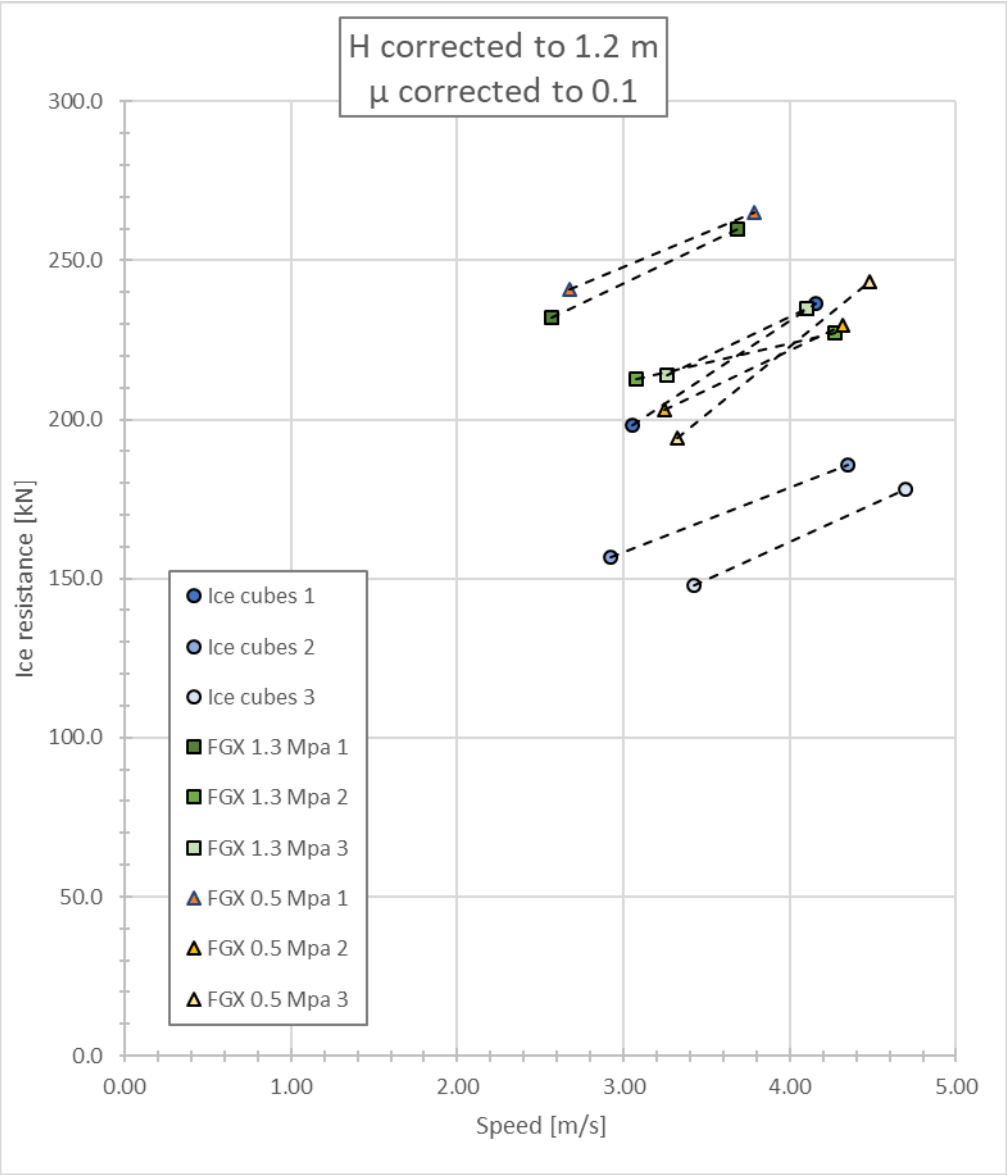

Figure 4-5: The test results corrected to target thickness of 1A channel and to target friction coefficient between model and ice, according to FSICR

4.3 FULL SCALE AND MODEL SCALE

The model test results and full scale results are presented together in *Figure 4-6* - *Figure 4-8*. In addition to FSICR requirements, the model test results were corrected to correspond to thickness of 1.0 m, which is the 1A channel thickness in the middle of the channel.

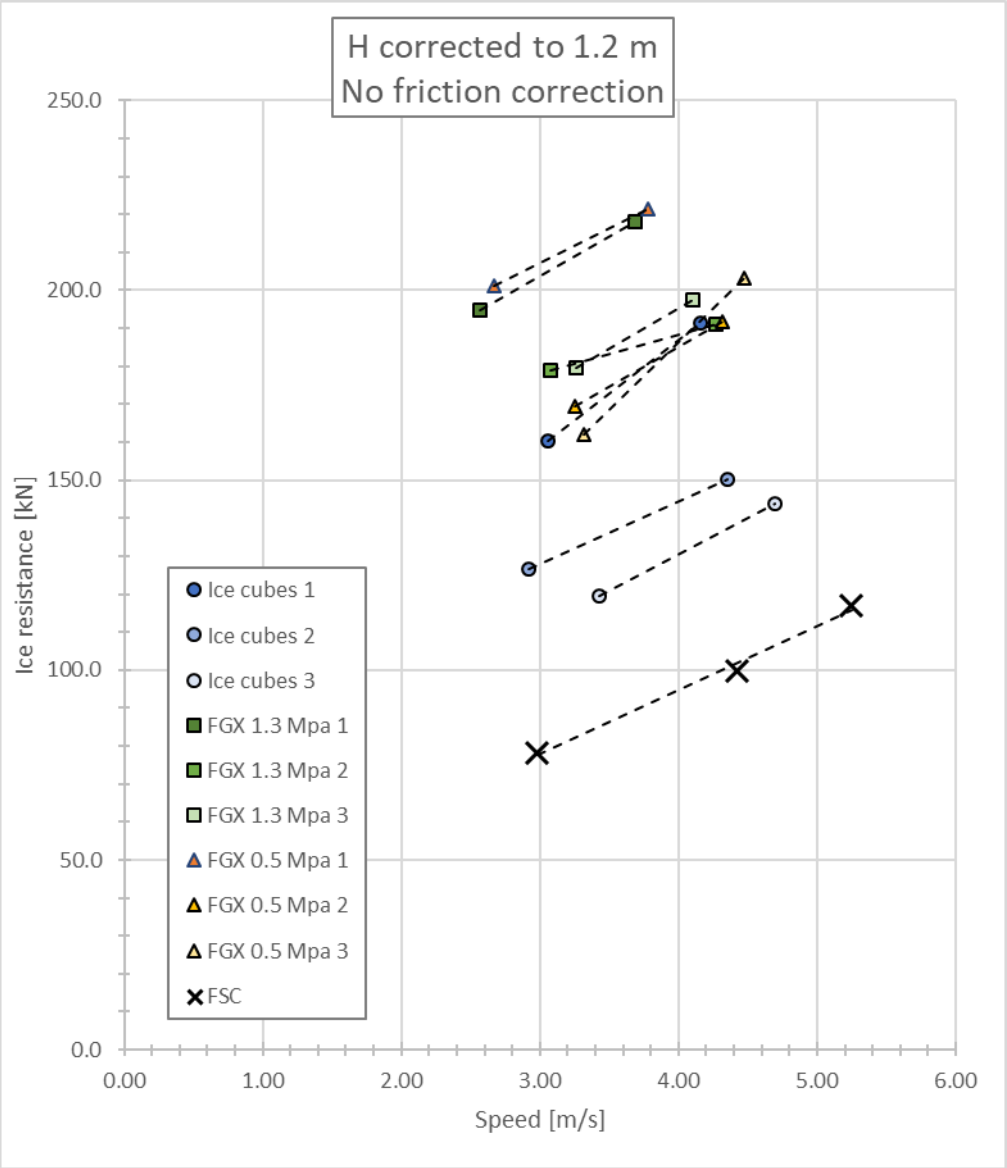

Figure 4-6: Full scale and model scale test results, model test brash ice thickness corrected to correspond to 1A channel according to the FSICR

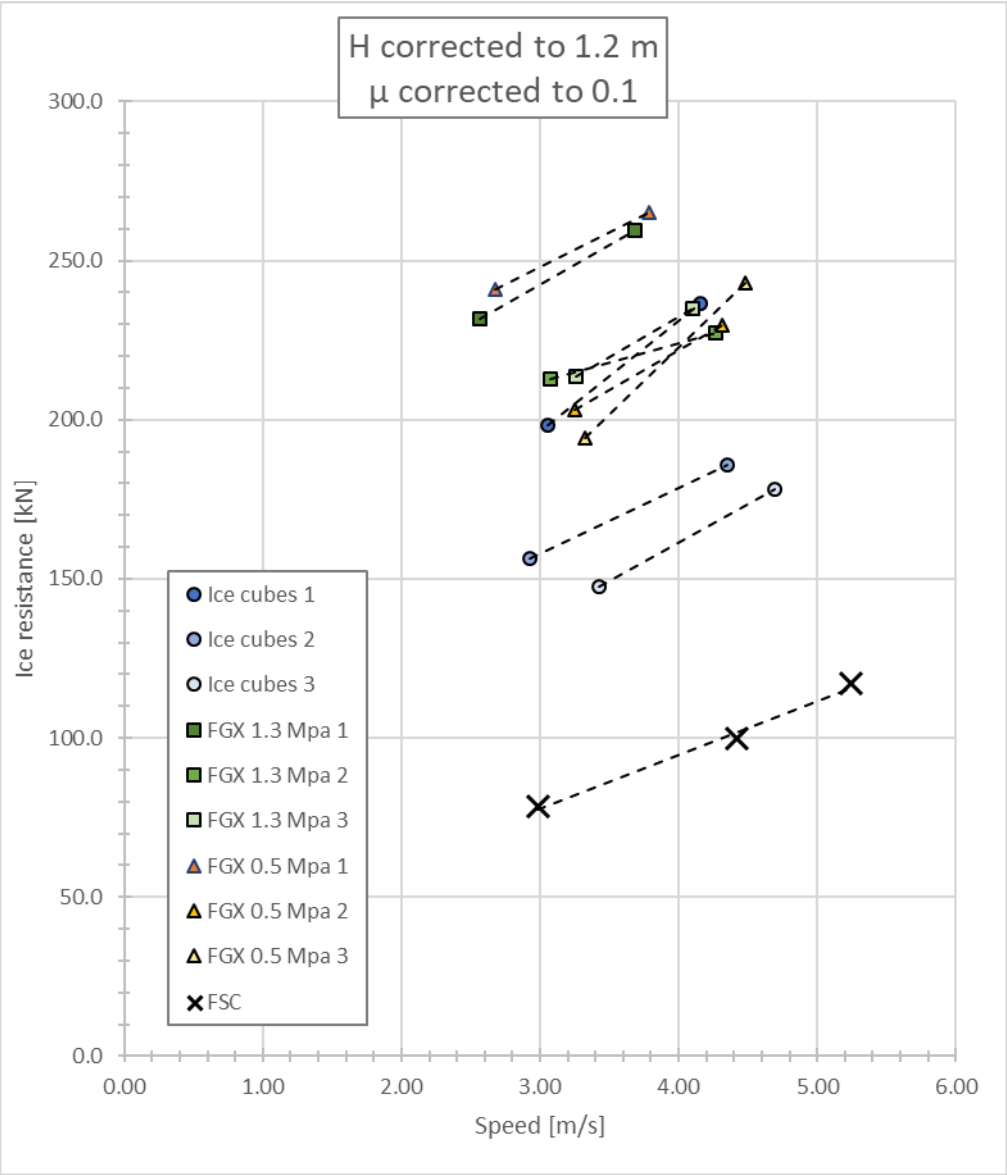

Figure 4-7: Full scale and model scale test results, model test brash ice thickness corrected to correspond to 1A channel and model test friction coefficient corrected to target value 0.1 according to the FSICR

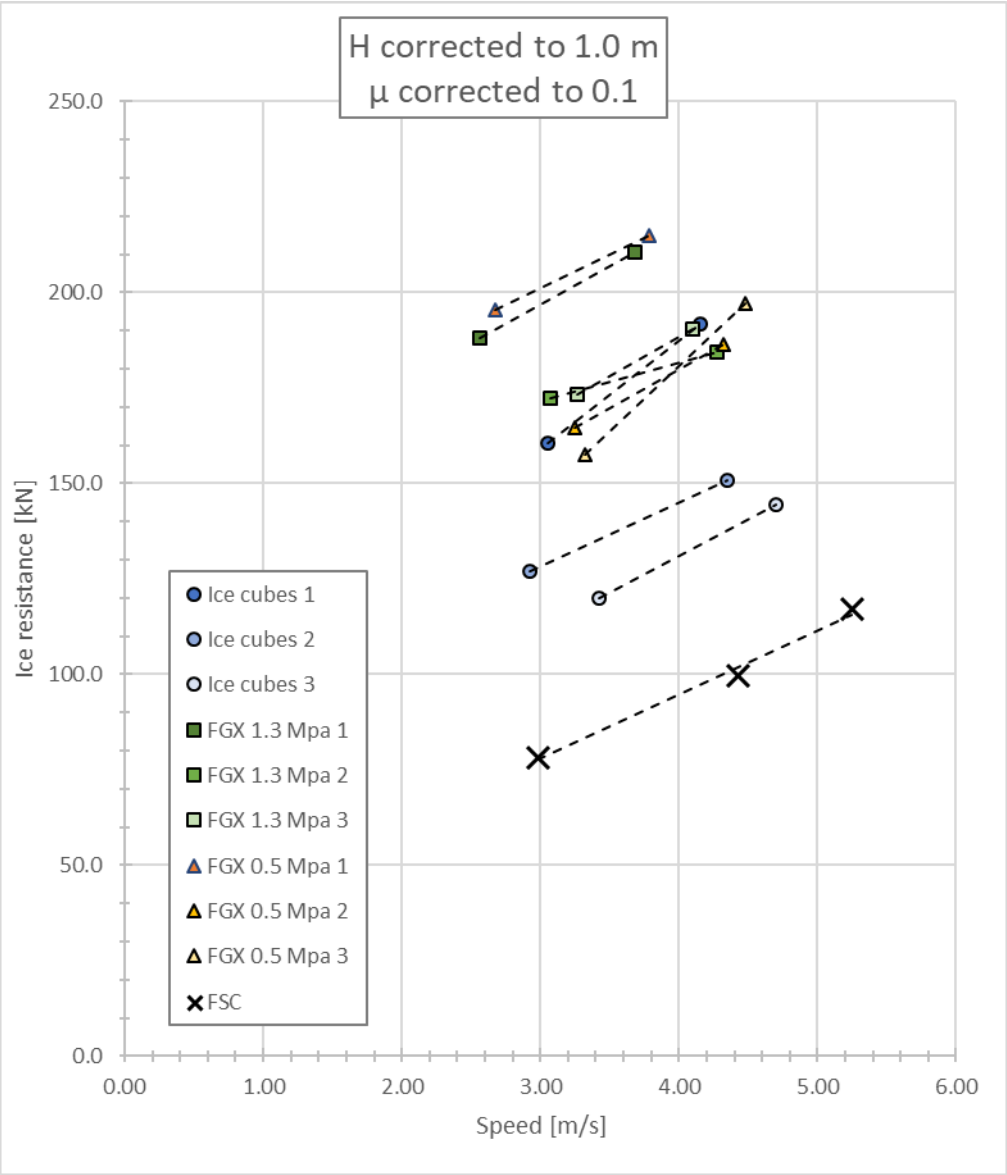

Figure 4-8: Full scale and model scale test results, model test brash ice thickness corrected to correspond to 1.0 m (channel thickness in the middle of an 1A channel) and model test friction coefficient corrected to target value 0.1 according to the FSICR

5 CONCLUSION AND DISCUSSION

The measured channel in Kemi corresponded well to the condition required for 1A vessels, since the average thickness of profile middle points was 103 cm.

When comparing the ice resistance measured in model scale to the full scale measurement results, it is evident that the model tests overestimate the channel resistance, at least with the tested hull shape. None of the tests in different brash ice types corresponded directly to the full scale resistance, but the ice cubes (practically infinite crushing strength and no particles transformation during the test) generated the smallest resistance and the results, which were closest to the full scale measurements.

The topic requires additional research. At first, the tests must be repeated with a different vessel with a similar hull shape to confirm the results. Secondly, the tests must be conducted with a different hull shape to enable evaluation of hull shape effect on current model test functionality in more traditional hull shapes.