STYRELSEN FÖR

VINTERSJÖFARTSFORSKNING

WINTER NAVIGATION RESEARCH BOARD

Research Report No 137

Eetu Seppänen

ICEBREAKER’S BEAM IMPACT ON THE PERFORMANCE OF AN ASSISTED WIDE SHIP

Finnish Transport and Communications Agency
Finnish Transport Infrastructure Agency
Finland

Swedish Maritime Administration
Swedish Transport Agency
Sweden

Talvimerenkulun tutkimusraportit — Winter Navigation Research Reports
ISSN 2342-4303
ISBN 978-952-425-023-8

FOREWORD

In this report no 137, the Winter Navigation Research Board presents the results of IBeam - Icebreaker’s beam impact on the performance of an assisted wide ship. Project goal was to research the effects of different icebreaker beams on the assistance of wide ships.

The Winter Navigation Research Board warmly thanks the author for this report.

Helsinki

April 2026

Ville Häyrynen	Amund Lindberg
Finnish Transport and Communications Agency	Swedish Maritime Administration
Helena Orädd	Jonas Gustaffson
Finnish Transport Infrastructure Agency	Swedish Transport Agency

Aker Arctic

AKER ARCTIC TECHNOLOGY INC REPORT

ICEBREAKER'S BEAM IMPACT ON THE PERFORMANCE OF AN ASSISTED WIDE SHIP

FOR

FINNISH TRANSPORT AND COMMUNICATIONS AGENCY

Name of document:
Icebreaker’s beam impact on the performance of an assisted wide ship

Document Responsible: Eetu Seppänen	**Document Reviewer(s):** Riikka Matala
Document Approver: Teemu Heinonen	
Report number / Revision: A697 / A	**Status / Status Date:** Approved / 2025-11-27

Client:
Finnish Transport and Communications Agency / Ville Häyrynen

Revision remarks:
A: Initial revision

Summary:

A study was conducted for the Winter Navigation Research Board to evaluate the impact of icebreaker beam width on the performance of a 32-meter-wide assisted ship navigating through a heavy brash ice channel. The primary objective was to assess whether a moderate increase in the icebreaker's beam provides measurable decrease in the ice resistance of assisted ship. Three icebreakers with different beams were examined at two speeds. All tests were performed as towing tests using simplified hull forms without propulsion systems.

Icebreaker beams of 24 m, 27.42 m, and 32 m were tested at speeds of 6 and 8 knots. The 27.42 m beam resulted in the smallest resistances at both speeds, while the 24.0 m beam resulted highest resistances at 8 knots. At 6 knots, the widest and narrowest icebreaker beams resulted in similar ice resistance for the assisted ship.

Keywords:
Icebreaker assistance; Brash Ice

Client reference: W25-5 IBeam		**Project number:** 31082	**Language:** English
Pages, total: 23	**Attachments:** A	**Distribution list:**	**Confidentiality:** Public

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The beam of an assisting icebreaker influences the ice resistance encountered by the assisted ship in escort and towing operations. This study aims to provide support for decision making for the potential specifications of new Baltic icebreakers by studying a situation where an icebreaker escorts a 32-m-wide cargo ship in a heavy brash ice channel, see test set-up in Figure 1-1. Three icebreakers with different beams are tested at two speeds.

Assisting wide ships in heavy brash ice channels has been identified as a particularly demanding operation for Baltic icebreakers. There is a recognized gap in knowledge regarding how to evaluate the optimal beam for assisting icebreakers.

Figure 1-1: A 32-m wide icebreaker escorts a 32-m-wide cargo ship in a heavy brash ice channel in Test 3.1.

2 TEST ARRANGEMENT

The description of test arrangement is divided into three sections. The models used in testing are described in Chapter 2.1, tested ice condition is presented Chapter 2.2, and the test program is presented in Chapter 2.3.

2.1 SHIP MODELS

Ship models used in this test series are the assisted model M525A and the icebreaker model M555. Both models had a simplified hullform with symmetric bow and stern. The assisted model M525A had cylindrical bow representing a full-bodied slow steaming cargo ship such as a large bulk carrier. The icebreaker model M555 was built to have similar average hull angles as typical Baltic icebreakers could have. A turbulence stimulator (wire) was fitted to the bottom at the bow of M525. The icebreaker model had three different versions with different beams. The beam of the icebreaker was increased without adding length to the model meaning that the L/B ratio varied between the tested versions and the length of the parallel midbody decreased when beam was increased. Main particulars of the models are presented in Table 2-1 – Table 2-2 respectively for the assisted model and for the icebreaker models.

All tests were done as towing tests at the centerline of the channel. The distance between the models corresponded to 32 meters in full-scale. Ship models did not have propulsion. Towing force of the assisted model was measured together with the speeds of the models. Test arrangement can be seen from Figure 2-1 and Figure 2-2 below. Yaw, sway and surge of both models were restricted.

Figure 2-1: Test arrangement, icebreaker.

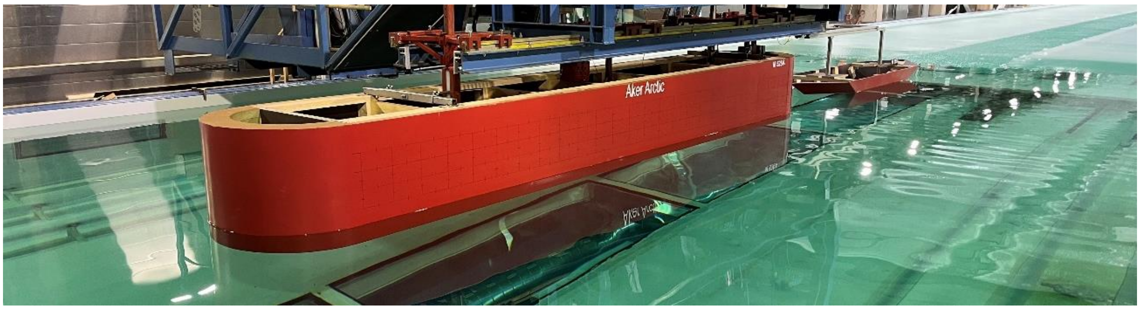

Figure 2-2: Test arrangement, assisted model.

Table 2-1: Main dimensions of the assisted model.

M525A, λ=32	Model scale	Full scale
Length at design waterline [m]	6.00	192.00
Beam at design waterline [m]	1.00	32.00
Draft [m]	0.30	9.60

Table 2-2: Main dimensions of the icebreakers.

M555A, λ=32	Model scale	Full scale
Length at design waterline [m]	3.04	97.28
Beam at design waterline [m]	0.75 / 0.86 / 1.00	24.00 / 27.42 / 32.00
Draft [m]	0.25	8.00

Figure 2-3: Stern of model M525.

Figure 2-4: Side of model M525.

Figure 2-5: Bow of model M525.

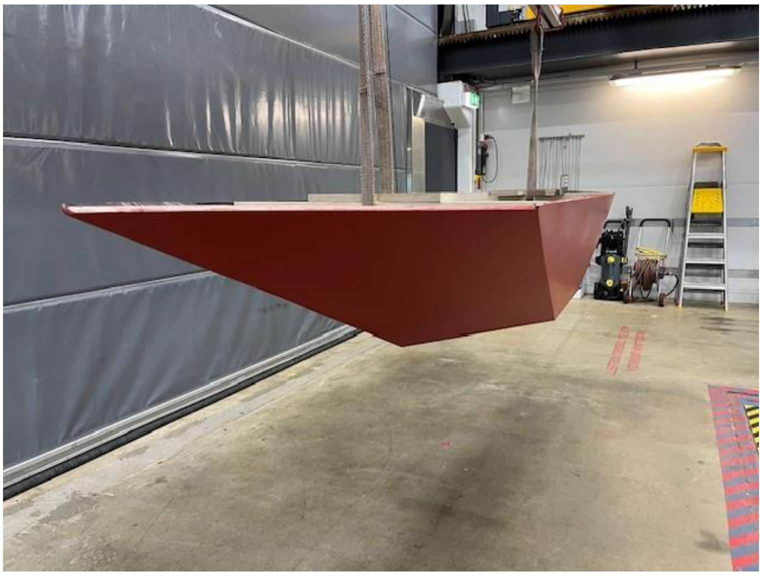

Figure 2-6: Stern of model M555 with 24.0 m beam.

Figure 2-7: Side of model M555 with 24.0 m beam.

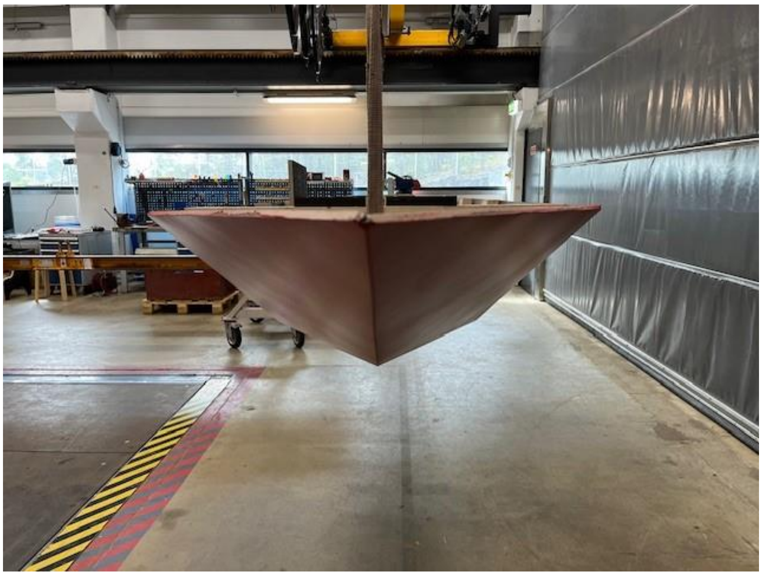

Figure 2-8: Bow of model M555 with 24.0 m beam.

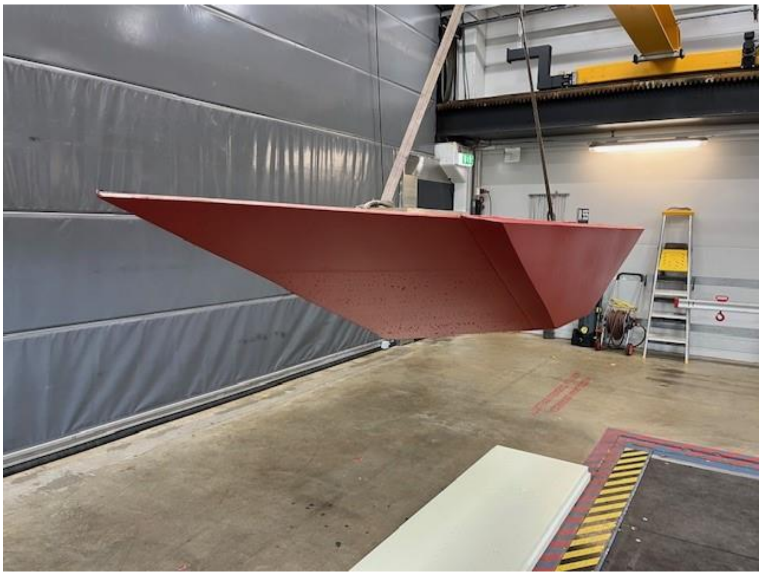

Figure 2-9: Stern of model M555 with 27.42 m beam.

Figure 2-10: Side of model M555 with 27.42 m beam.

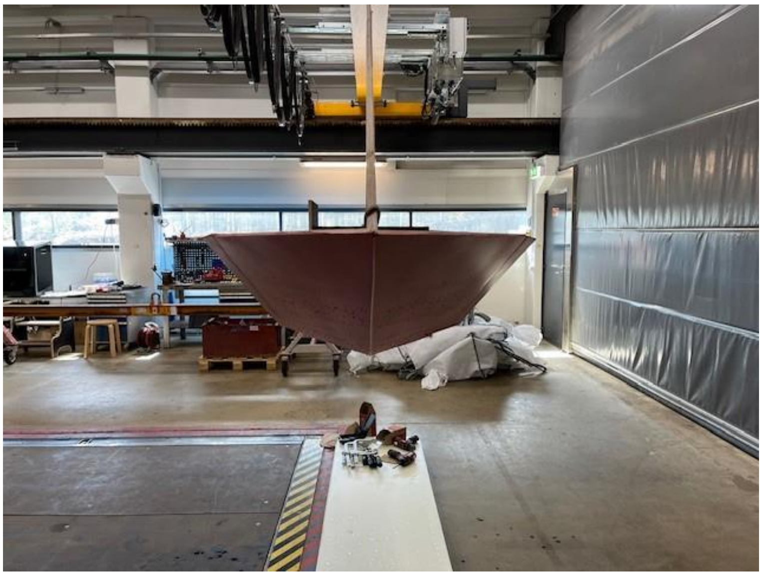

Figure 2-11: Bow of model M555 with 27.42 m beam.

Figure 2-12: Stern of model M555 with 32.0 m beam.

Figure 2-13: Side of model M555 with 32.0 m beam.

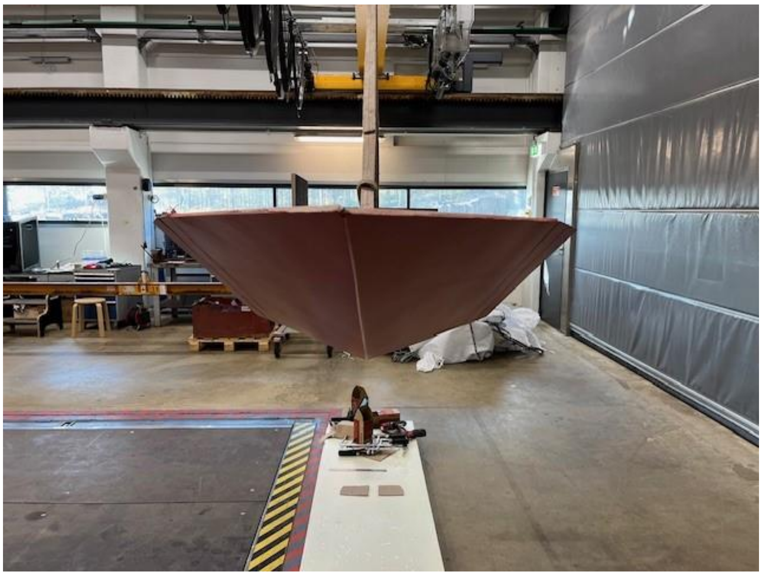

Figure 2-14: Bow of model M555 with 32.0 m beam.

2.2 ICE CONDITION

The tested ice condition represented a heavy brash ice channel which has thick side ridges or “cheeks” to restrict the lateral movement of the ice mass in the channel. Model ice was used to produce the surrounding level ice field for the brash ice channel. The level ice was produced by spraying water into the air at freezing temperatures. The sprayed water droplets froze into small ice crystals in the air, forming the FGX model ice layer. The target flexural strength of the level ice was 1120 kPa in full scale corresponding to 35 kPa in model scale. The target level ice thickness was 1.5 m in full scale. Hence, the corresponding level ice thickness was 47 mm in model scale.

The brash ice channel was constructed in two phases. First, a 48 m wide channel was cut to the level ice, and the broken FGX model ice was piled under the level ice to produce “cheeks” to the channel. The cheeks were piled against wooden T-shaped supports visible in Figure 2-16. It was assumed that the soft model ice forms a stable formation resembling the channel edge (cheek) in full scale. After that the channel was filled with solid fresh-water ice cubes to produce brash ice with target thickness of 1.5 m. According to Matala[1], the ice cubes model realistically all processes considered significant in ship’s ice resistance in an unconsolidated brash ice channel. Figure 2-15 presents the tested ice condition.

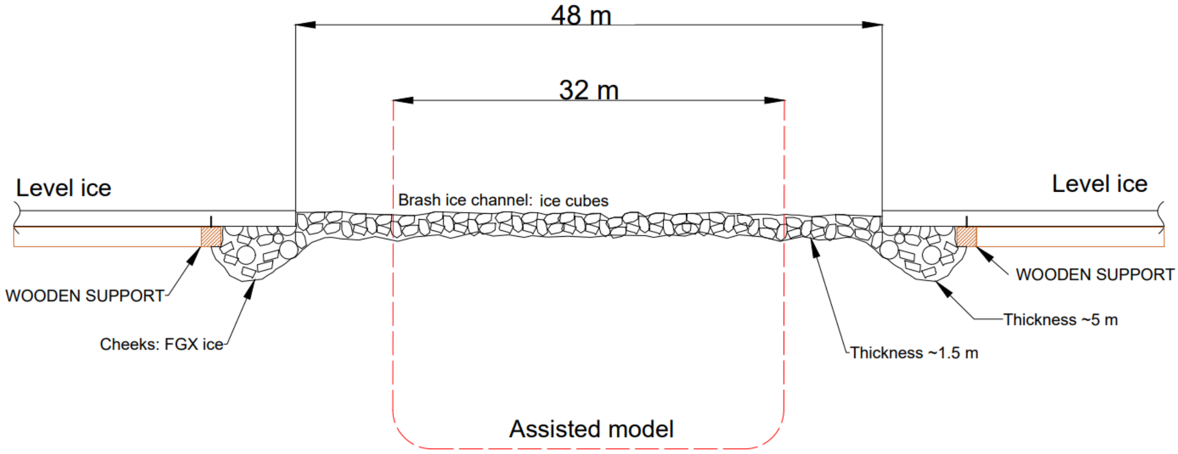

Figure 2-15: The tested ice condition.

---

[1] Matala, R., 2023. Verification of vessel resistance in old brash ice channels through model scale tests. Doctoral Thesis. Aalto University.

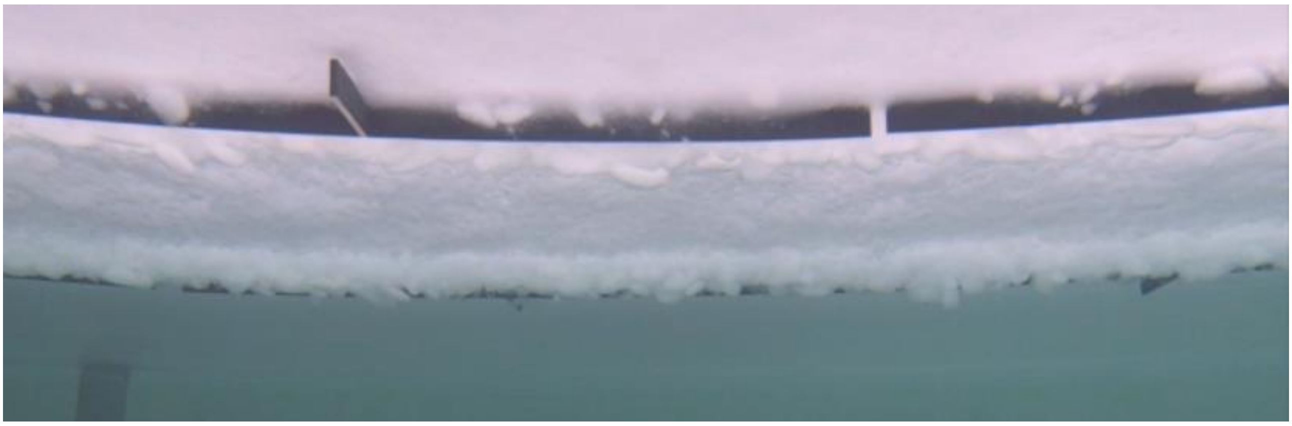

Figure 2-16: Wooden supports under the ice.

2.3 TEST PROGRAM

The test program is presented in Table 2-3.

Table 2-3: Test program.

Date	Test #	Speed [kn]	Beam, icebreaker [m]
13.8.-25	1.1	5	24
	1.2	8	
	1.3	6	
	2.1	6	27.42
	2.2	8	
14.8.-25	3.1	6	32
	3.2	8	

3 TEST RESULTS AND DISCUSSION

The measured ice resistances are presented in Figure 3-1. Open water resistance was subtracted from towing force to obtain the ice resistance. Ice resistance was scaled to full scale according to Froude scaling law.

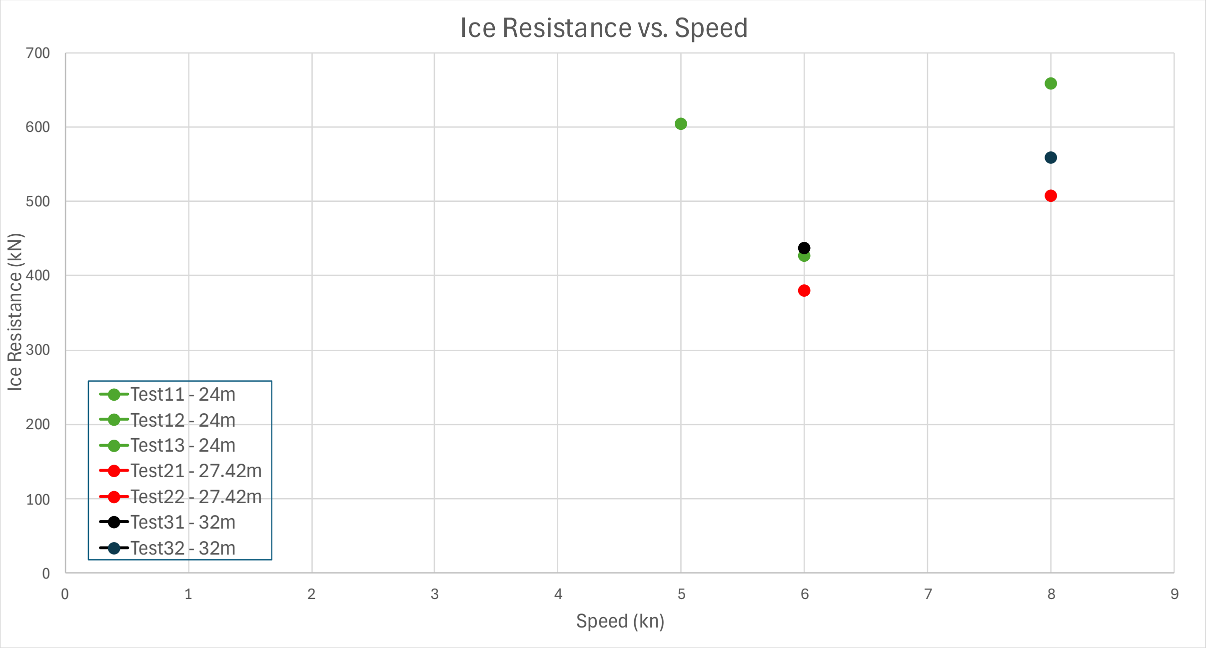

Figure 3-1: Ice resistance of the assisted ship.

The influence of icebreaker beam on the ice resistance of the assisted ship is demonstrated in Figure 3-2. In this comparison the measured ice resistance with 24.0 m beam is considered as 100 %.

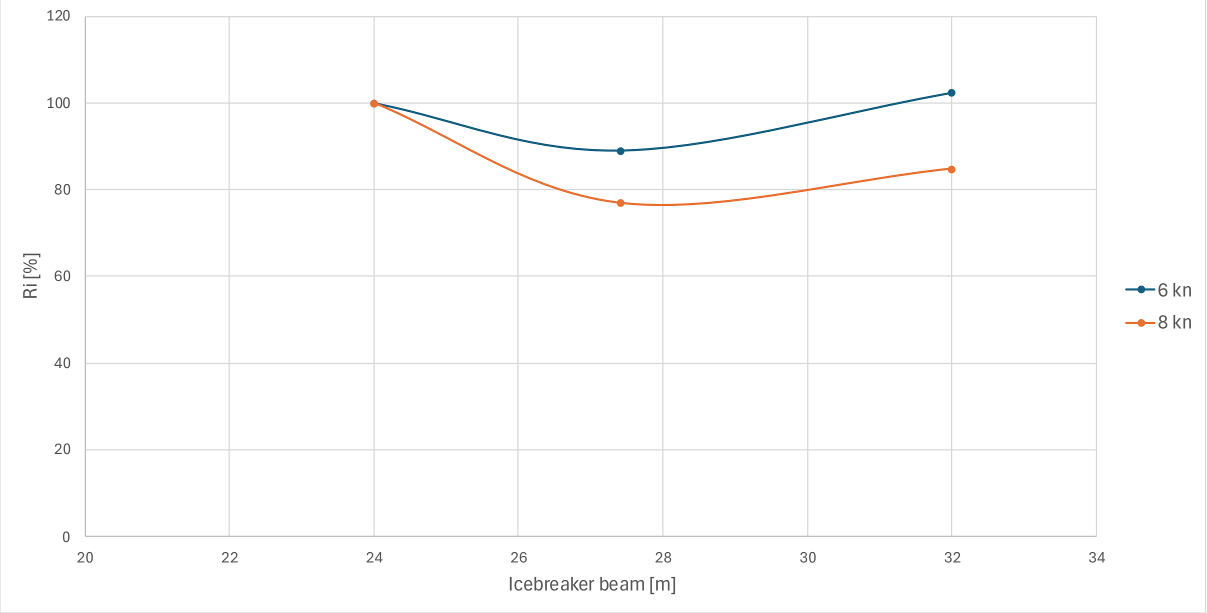

Figure 3-2: Relative ice resistance of the assisted ship as function of the icebreaker beam when 24 m = 100 %.

The average channel widths encountered by the assisted ship as a function of the icebreaker beam are presented in Table 3-1 and Figure 3-3. The average widths are estimated based on visual footage as presented in Figure 3-7 and Figure 3-8. One interesting finding is that the channel does not widen in direct proportion to the increase in the icebreaker beam. A possible explanation for this relates to the displaced ice mass: when a wider icebreaker pushes the brash ice aside, the displaced ice volume is compacted into smaller space compared to a situation, in which a narrower icebreaker advances in a similar channel. The higher accumulation of piled-up ice collapses back into the channel behind the icebreaker with a higher force compared to lower pile. Another factor influencing the resulting channel width could be the shortening of the parallel midbody associated with increased beam. The lack of propulsion on the icebreaker model is also believed to ease the ice movement back to the channel impacting the experiment’s results.

The speed of the convoy influences the channel width and ice accumulation at the bow of the assisted ship. At lower speeds the assisted ship encounters more ice as the displaced ice has more time to move back to the middle of the channel. From the Figure 3-1 it can be noted that ice resistance of the assisted ship is excessively high at five knots when assisted by 24.0 m wide icebreaker. This is due to ice accumulation in front of the assisted model, which is visible from comparison Figure 3-4 to Figure 3-6 below. The lower tested speed was raised from five to six knots after the first test 1.1 because it was noticed that ice accumulation decreases when the speed is increased. The 5 knots speed was such a low speed that the ice mass displaced by the icebreaker hull reached to mid channel between the icebreaker and the assisted ship. The low flow velocity at the bow of the assisted model was not sufficient to accelerate and displace the ice pieces from the mid-channel to the sides resulting in accumulation of ice at the bow. The lack of propulsion on the icebreaker model is assumed to contribute also to the phenomenon.

Table 3-1: Channel width compared to icebreaker beam.

Icebreaker beam [m]	Channel width [m]	Icebreaker beam – channel width [m]	Channel width per icebreaker beam	Speed [kn]
24.0	22.4	1.6	0.93	6
24.0	22.6	1.4	0.94	8
27.42	23.8	3.6	0.87	6
27.42	25.1	2.3	0.92	8
32.0	26.7	5.3	0.83	6
32.0	26.0	6.0	0.81	8

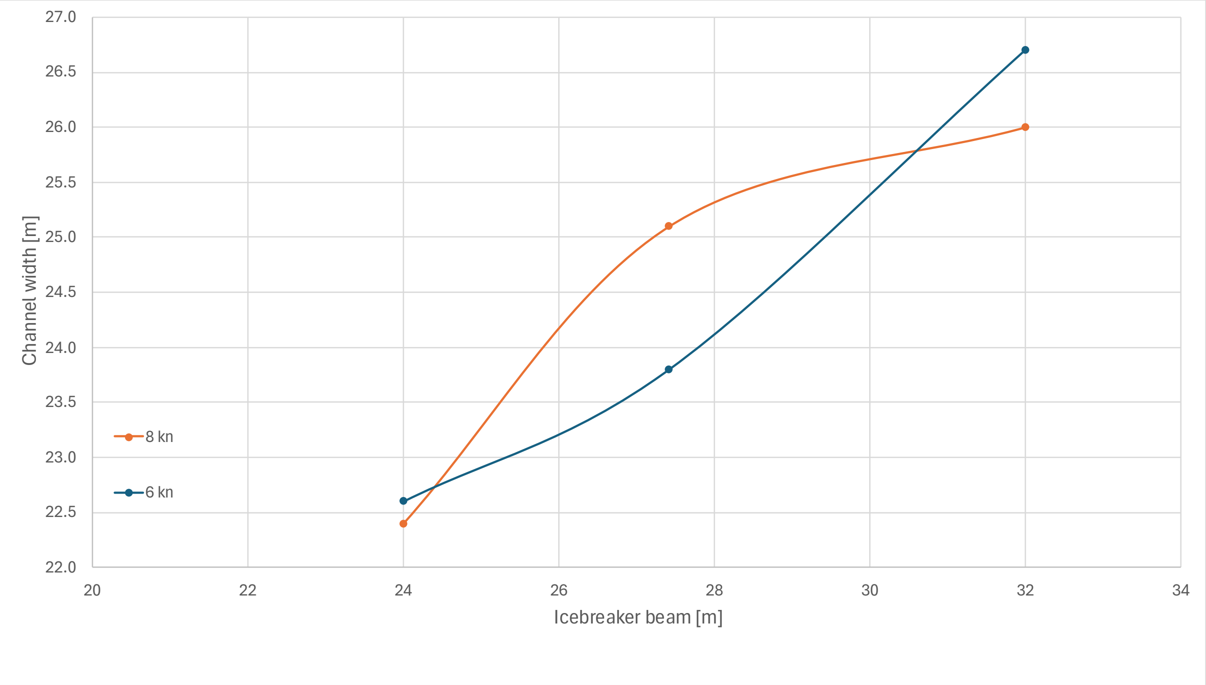

Figure 3-3: Channel width compared to icebreaker beam.

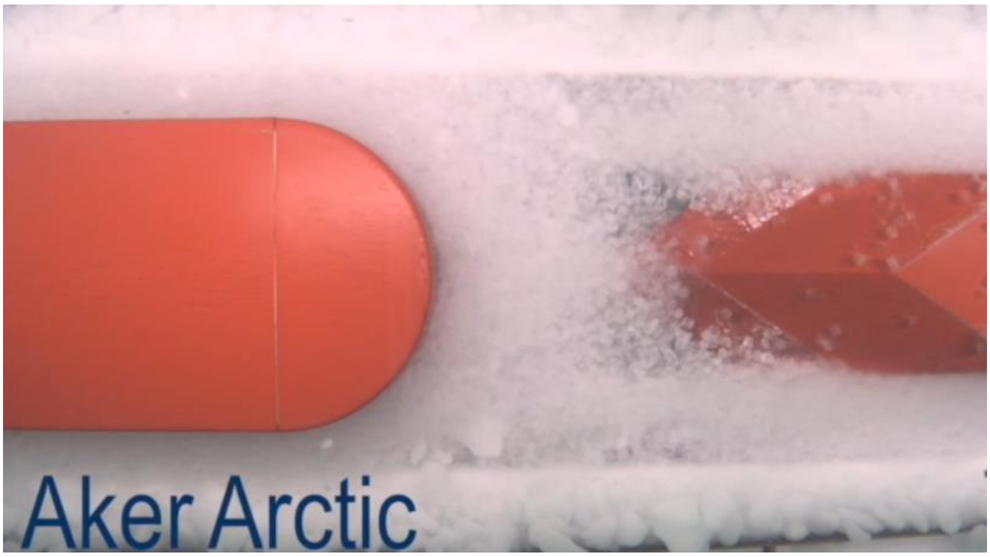

Figure 3-4: Ice accumulation between the models at 5 kn, 24.0 m icebreaker.

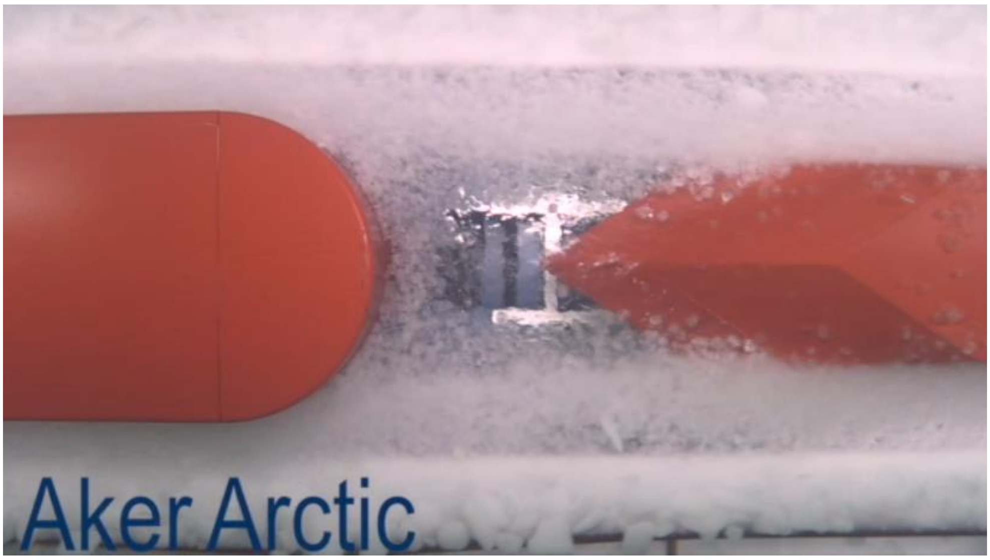

Figure 3-5: Ice accumulation between the models at 6 kn, 24.0 m icebreaker.

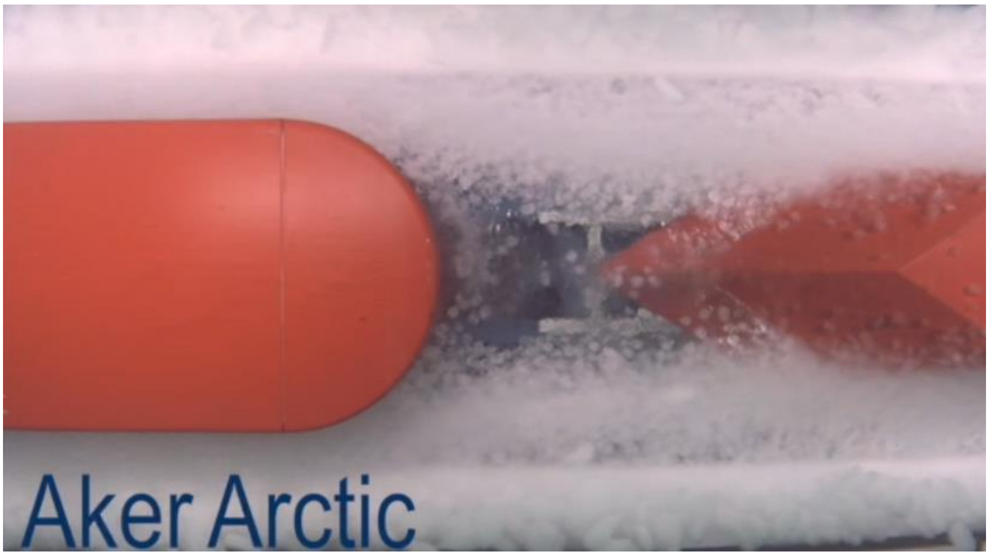

Figure 3-6: Ice accumulation between the models at 8 kn, 24.0 m icebreaker.

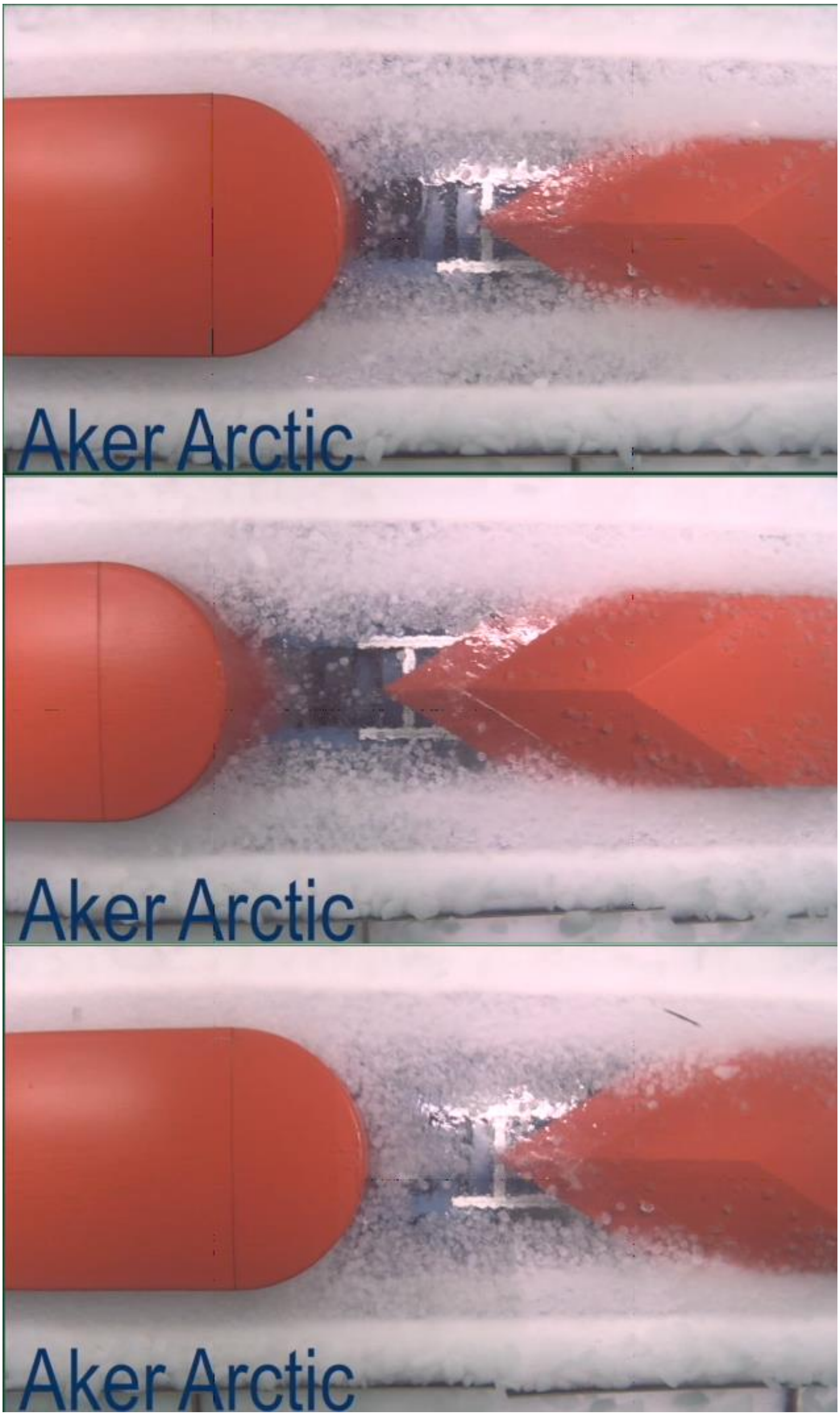

Figure 3-7: Channel between the models at 6 kn. 24.0 m, 27.42 m and 32.0 m starting from top.

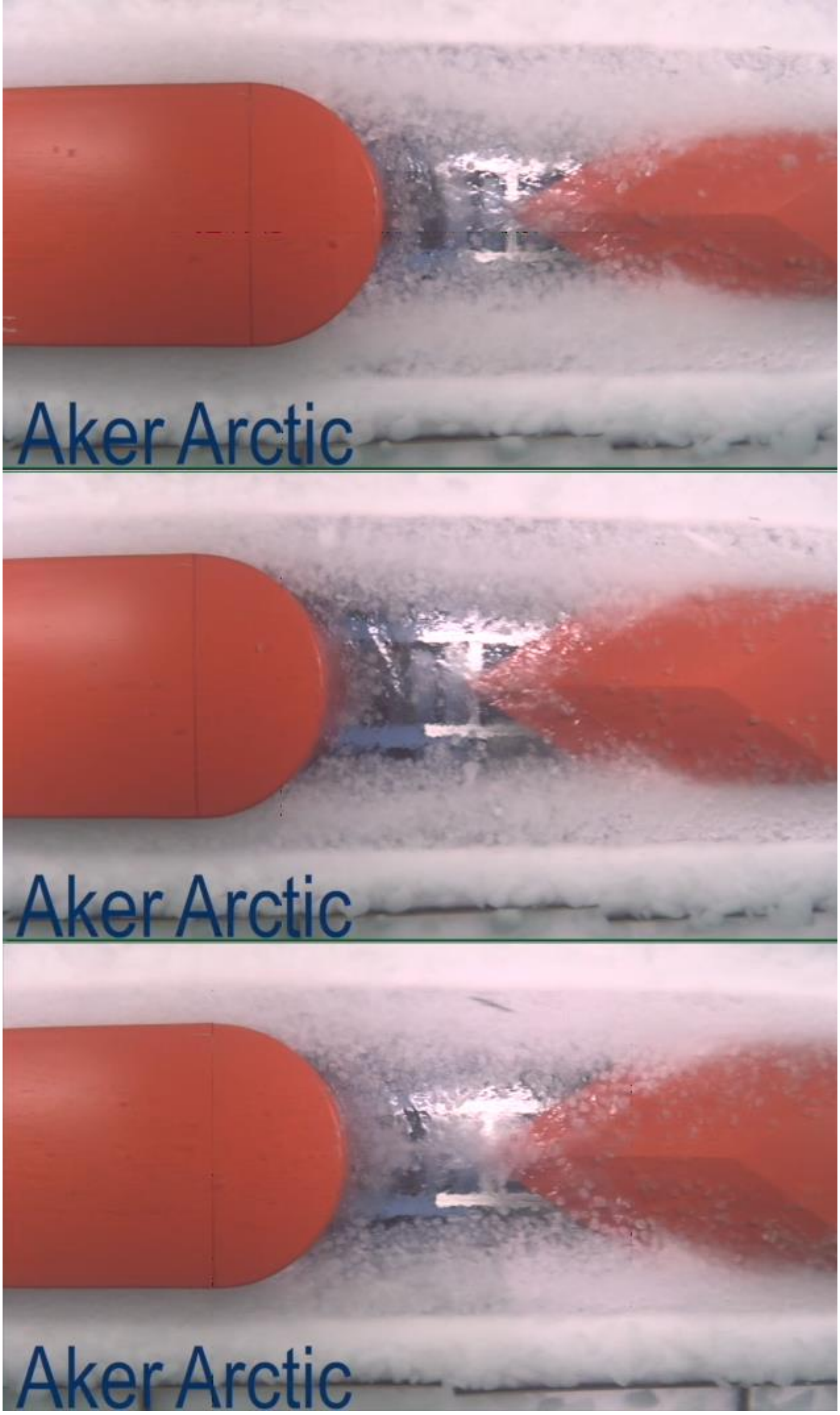

Figure 3-8: Channel between the models at 8 kn. 24.0 m, 27.42 m and 32.0 m starting from top.

The measured ice resistances show that the lowest ice resistance for the assisted ship is reached when the icebreaker beam is 27.42 meters at both 6 and 8 knots. With 24.0 m beam compared to 32.0 m the results are more complex; at 6 kn resistance is almost the same but at 8 kn the larger beam of icebreaker results in a smaller ice resistance for the assisted ship. Combination of three different phenomena is identified as possible reasons for the results:

- Thickness and compactness of the displaced ice
- Position at assisted ship's bow in which the displaced ice hits
- Collapse of the displaced ice back to the channel / Ice accumulation at the bow of the assisted ship

Ice resistance of the assisted ship at 8 knots is smallest with the 27.42 m wide icebreaker and highest with the 24.0 m wide icebreaker. Ice resistance consists of breaking the ice, displacing and submerging the ice pieces as well as friction and speed effect. In the brash ice channel, there is no breaking component, and the submersion component is rather small due to bow shape of the assisted ship.

Visual analysis of the test video shows that the height of the ice mass displaced by the assisted ship is different between tests 1.2 (24.0 m), 2.2 (27.42 m) and 3.2 (32.0 m); during test 2.2 the height of the mass is smallest and during tests 1.2 and 3.2 almost the same, maybe a bit higher in test 1.2. This is visible in Figure 3-9 where a green rectangle is added on top to visualize the height of the ice mass. Frictional resistance comes from friction coefficient times contact area times contact pressure. Among these factors, only the contact area varies, which results in higher frictional resistance observed in tests 1.2 and 3.2 compared to test 2.2. It is possible that in test 1.2 the assisted ship plows the thick mass on the sides due to contact angle being large and in test 3.2 the wide icebreaker produces thicker mass to the sides of the channel already before the assisted ship.

When the beam of the icebreaker increases, the assisted ship has to displace less ice pieces resulting in smaller resistance. Frictional resistance combined with resistance due to displacing the ice pieces results that the ice resistance is highest with 24 m icebreaker, because both displacing the ice pieces and high frictional resistance. From the three tested beams 27.42 m seems to be the functional compromise.

Figure 3-7 and Figure 3-8 show that ice accumulation in front of the assisted model varies between the tests. There seems to be more ice accumulation with 32.0 m wide icebreaker than with 27.42 m wide icebreaker. The ice accumulation most likely has some effect on the ice resistance, although the measurements did not indicate a clear correlation between the resistance and amount of accumulated ice during the tests. This phenomenon would have probably been different if the icebreaker model was equipped with propulsion and the length would have been increased together with the beam.

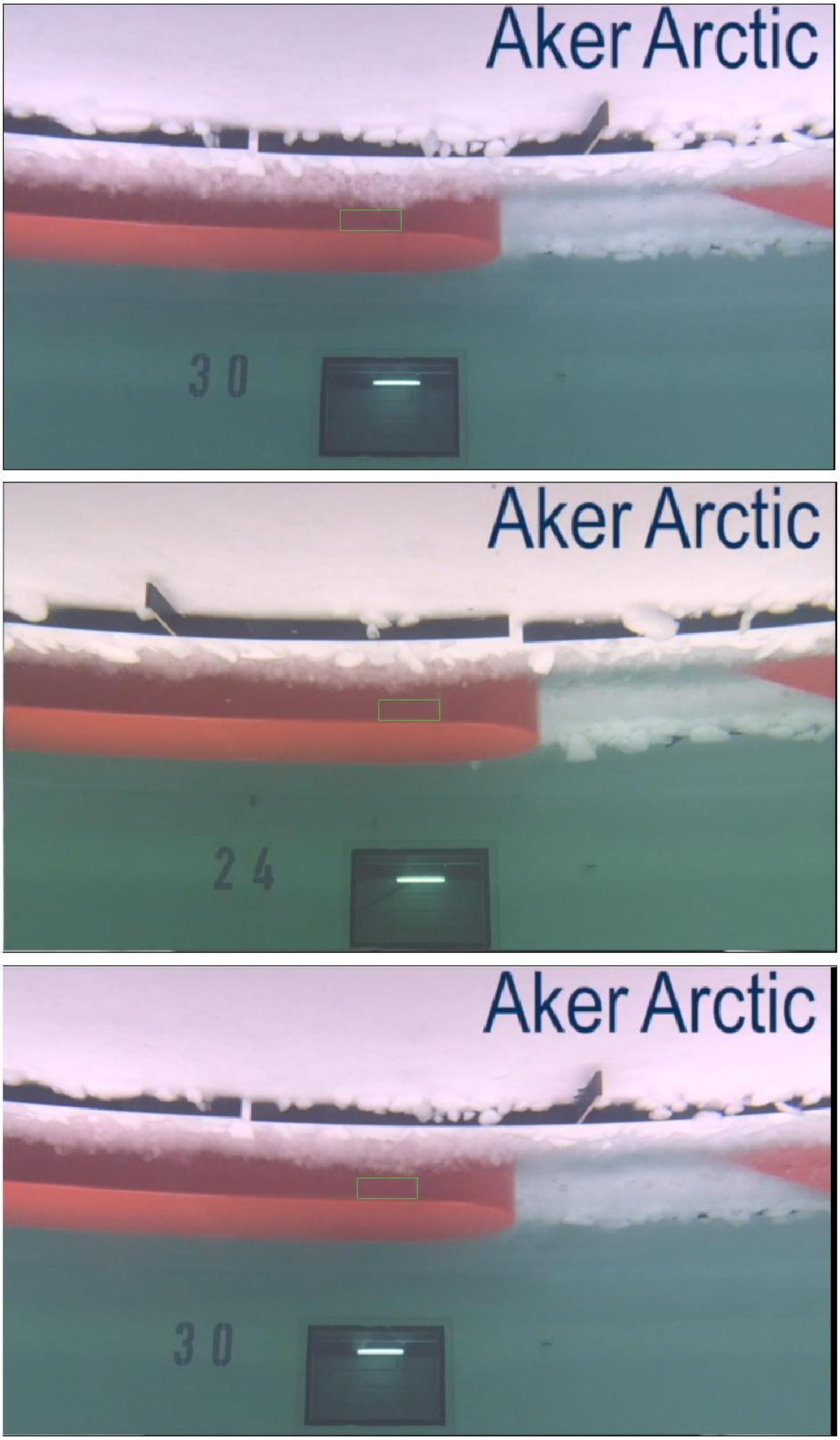

Figure 3-9: Comparison of brash ice thickness, 24.0 m, 27.42 m and 32.0 m starting from the top. 8 kn speed.

The test arrangement was simplified to maximize repeatability of the tests between different icebreaker beams. It is possible that slightly different results would have been obtained with more complex testing arrangement in which propulsion is added, and the length of the icebreaker is varied. This testing method did not consider consolidation either except around the cheeks, which is one relevant factor in real-life situations. Typically, the channel would consist of partly consolidated sections as well as loose brash ice mass around more frequently used areas.

4 SUMMARY AND CONCLUSIONS

The impact of icebreaker beam on the performance of an assisted ship was investigated in this research with simplified models. Three different icebreaker beams were tested: 24.0 m, 27.32 m, and 32.0 m. The results indicated that the lowest ice resistances are obtained with the 27.42 m wide icebreaker in all cases. At higher speeds the 32.0 m beam resulted lower resistances than the 24.0 m beam while at lower speeds their resistances were almost the same. The result from the higher speed can be prioritized due to the expected assistance operations in full scale. According to operational experiences from full scale the average assisting speeds settle around 10 knots. The results indicate that in confined conditions the width of the channel made by wide icebreaker will reduce more than with narrow icebreaker. This is due that the ice is displaced into smaller space, and it will return to the channel behind the icebreaker. It is to be noted that tests were not tested in consolidated conditions in which the wide icebreaker is estimated to have the biggest benefits for the assisted ship.

It is recommended that in future tests, propulsion is added to the icebreaker model as well the length would be also varied.