Double-ended ferry tested in ice

Saaremaa and Hiiumaa are two large islands off the Estonian coast with daily connections between them by sea. The double-ended ferry *Soela* began operation in 2017 and was tested in ice last year.

Soela is one of the three double-ended Ro-Ro and passenger ferries built by Baltic Workboats for the Estonian Maritime Administration between 2015–2017. She operates daily between Saaremaa and Hiiumaa islands throughout the year, using an ice channel in the winter. The ice trials were performed in her normal operational area.

Trial Results

The objective of the full-scale ice trials was to verify that the vessel fulfils its design requirement, 2 knots in 45 cm thick level ice with a flexural strength of 500 kPa. Before the ferries were built, their ice-going capability had been evaluated with model tests at Aker Arctic's ice laboratory in 2013.

The average ice thickness in the area was measured to be 30 cm based on 38 measurements. The flexural strength was on average 578 kPa based on ice sample temperature profile and salinity. *Soela* performed well in this ice thickness and also in a 50 cm thick ice channel. Through calculations and comparisons to model test results, the full-scale ice trials verified that the Estonian double-ended ferries *Kihnu Virve*, *Ormso* and *Soela* fulfil their design requirements.

Technical details	
Length	45 m
Breadth	12,48 m
Capacity	200 persons, 32 cars or two trucks

Full-scale tests for Swedish ferry

Yxlan is a commuter ferry in the Swedish archipelago.

On the shores of Stockholm, the capital of Sweden, lies a network of islands where people live year-round. Instead of taking the bus to work or school, the inhabitants jump on a ferry which transports them to the mainland, regardless of season or weather.

There are several ferries commuting in the Stockholm archipelago year-round as part of the public transport system. Last year, a new ferry named *Yxlan* was built by Baltic Workboats in Estonia and joined the Waxholmsbolaget fleet in Sweden.

Testing in ice

Aker Arctic performed the ice model tests for *Yxlan* two years ago to support the design work. The full-scale ice trials were performed this spring, confirming the design target of 2 knots speed in 25 cm thick level ice.

The main focus of the ice trials was to conduct tests in level ice.

"The ice outside Stockholm was not thick enough for the test, therefore the location chosen for the test was in the Ångerman River, about 500 km north," says Topi Leiviskä, Head of Research and Testing.

Measurement methods

Ice thickness was measured by drilling holes into the ice along the ship track and measuring the thickness with an L-shaped rod. Altogether 47 measurements were done which had an average ice thickness of 38 cm.

Flexural strength was defined using the three-point bending method. For this method, 500 mm long ice beams were cut out from the ice with a chain saw. The beams were then shaped to have a final thickness of 50 to 70 mm. A purpose-built device was then used to load the ice beams and the breaking force was measured. A total of nine measurements were made with an average flexural strength of 406 kPa.

"The easier method of measuring flexural strength is using the water's salinity and temperature," Development Engineer Jukka-Pekka Sallinen explains. "However, river water has no salinity, therefore the more complex method needed to be used."

The ice measurements were then converted to reflect sea ice conditions and used to analyse the results from the full-scale tests.

"The results showed that the vessel clearly surpassed the design targets, reaching double the speed in 25 cm level ice," adds Leiviskä.

The client and the owner also performed operational tests during the same trials.

Technical details	
Length	27 m
Breadth	8 m
Capacity	150 persons

Ice thickness was measured by drilling holes into the ice along the ship track and measuring the thickness with an L-shaped rod.

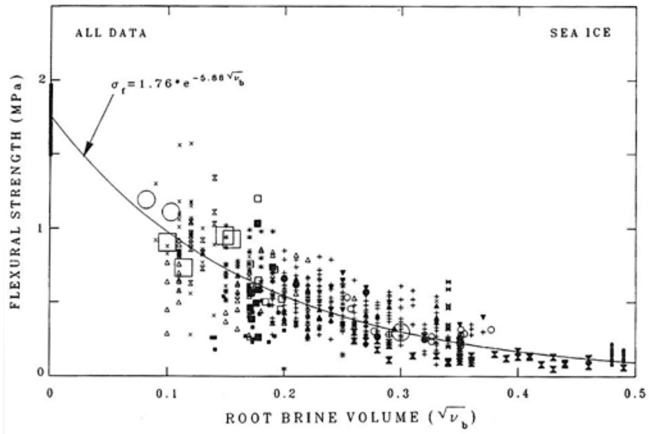
Full scale ice measurements

Flexural strength

The flexural strength of ice can be measured using three different methods: a cantilever beam test, a simply-supported beam test or with brine volume measurements.

The cantilever beam test is done by cutting a beam into the sea ice while keeping one end of the beam connected to the ice sheet, similar to the method used in model tests. The free end of the beam is loaded until it breaks. Cantilever beam tests are very laborious to do and, therefore, are very seldom used in full-scale measurements.

In simply-supported beam tests, the ice beams are cut from a larger block of sea ice. A beam is simply supported from both ends in an A-frame and vertically loaded in the middle until it breaks (picture 1).



Picture 2. Flexural strength versus the square root of the brine volume for first-year sea ice (Timco and O'Brien, 1994)

Thickness

Level ice thickness can be measured with an L-shaped stick from drilled holes. In brash ice and ice ridges, the thickness can be measured using a mechanical drill when the drill length is known.

Picture 1. A-frame with ice beam.

Picture 3. A hydraulic press is used for compression strength measurement.

The breaking force is measured with a force transducer and the flexural strength can be calculated from the measured force according to Euler-Bernoulli beam theory.

Flexural strength can also be defined by measuring the salinity and the temperature of the sea ice. Ice samples are collected with a core drill specifically made for this purpose. The drilled core is divided into samples to obtain both a salinity and a temperature profile.

The ice salinity can be measured by melting an ice sample and measuring its salinity with a salinometer. The temperature of the ice core is measured with a digital thermometer immediately after drilling.

The flexural strength of the sea ice can then be estimated by using the brine volume calculated from the ice temperature and the salinity according to picture 2.

Ice compressive strength, uniaxial unconfined

The compressive strength of sea ice is determined from ice cores drilled from the level ice. The cores are cut to a specific length with perpendicular ends and inserted into a hydraulic press. The hydraulic press includes a strong frame and a cylinder which crushes the ice core. The compressive strength is defined from the pressure required to crush the ice core.

Ice density measurements

Ice density can be measured by defining the weight needed to submerge a freely floating ice sample. The weight is measured with a small digital scale. The ice density can be calculated when the water density is known. ■

Text by Toni Skogström, Research Engineer at Aker Arctic