



Evaluating ice loads on windmill monopiles

As part of Aker Arctic's own research and development work, a series of ice model tests were conducted in November 2023 to investigate the ice loads affecting windmill monopiles.

Offshore windmills require robust foundations to withstand the harsh marine environment, including ice and waves. Similar to the planning of icebreakers or other ice-strengthened vessels, the testing of offshore structures with scaled models is a cost-efficient method to verify design adequacy before construction begins, ensuring suitability for the intended operational area.

Crushing strength is crucial

Aker Arctic's previous structural ice model tests have focused on researching cone-shaped structures where bending strength was determined to be the best ice scaling option. However, when testing vertical structures, such as monopiles, it is deemed crucial to scale the model ice in relation to its crushing strength.

"Model ice differs from natural ice in its homogeneity," explains Topi Leiviskä, Team Leader, Model Tests and Facility at Aker Arctic. "Addi-

tionally, model ice can be scaled for either crushing forces or bending forces, but not for both simultaneously."

Research engineer Toni Skogström adds, "We adhere to a systematic scaling and testing approach. While similar tests have been performed before, we aimed to delve deeper into vertical structures to identify the most appropriate model ice parameters."



Full-scale data has been gathered from the offshore lighthouse Kemi I, located in the Gulf of Bothnia, in 1984–1986

Four pillar sizes investigated

The research team examined four different pillar sizes across four distinct ice thicknesses with scale ratios ranging from 1:89 to 1:16. This approach allowed the team to

extrapolate data trends for a full-scale monopile with a 6.67-metre diameter in 80 cm thick ice.

"In real-life conditions, a windmill monopile will be wider than this size, but we opted for a diameter that yields the most data for our research," Leiviskä says. "It is the scaling ratio, rather than the absolute size, that is of greater interest in this case."

Straightforward testing procedure

Every model test requires a singular ice sheet which entails preparation and freezing time. As a result, each of the monopiles was tested in separate testing slots.

In November 2023, the various pillar shapes prepared for the tests were instrumented and mounted on a mobile platform. The aim was to capture comprehensive data on ice loads. This was achieved by moving the setup across the ice basin at different speeds in level ice conditions while measuring the global forces at the water line.

Skogström clarifies the unique failure patterns of natural ice compared to model ice, highlighting

why speed is important and how it affects the distribution of pressure.

“Natural ice breaks in multiple ways contrary to model ice. In nature, the highest pressure is focused on the centreline. The faster the speed, the more centred the pressure becomes. However, in low speed, the crushing pressure is spread wider.”

He predicts that while the tests were straightforward, analysing the data will be a complex and insightful process.

Conforming with calculations

The current monopile design calculations widely used adhere to ISO standards, yet lack full-scale empirical data for validation.

However, full-scale data has been gathered from the offshore lighthouse Kemi I, located in the Gulf of Bothnia, in 1984–1986. This area is ideal for tests in extreme conditions including fast ice, moving ice sheets, pack ice fields and ice ridges.

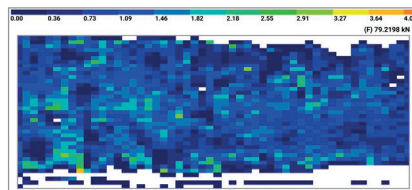
“Our goal with the monopile tests is to investigate how well the standards align with our findings,” says Leiviskä. “Through our research, we aim to enhance the reliability and safety of windmill structures in icy conditions, potentially leading to more durable and cost-effective designs. This could significantly contribute to the advancement of sustainable energy solutions in harsh marine environments.”

The research team anticipates publishing the results following a detailed analysis and review. ■

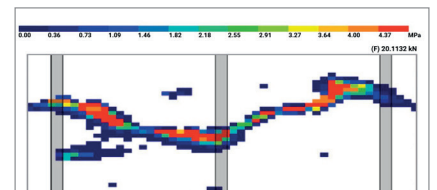


Our research aims to enhance the reliability and safety of windmill structures in icy conditions.

Natural ice breaks in multiple ways contrary to model ice:



Pressure distribution at a continuous creep speed when ice failure is ductile.



Pressure distribution at a continuous faster speed when ice failure is brittle.

Source: Määttä, M., Marjamaa, P., Saarinen, S. & Laakso, M. 2011. Ice crushing tests with variable structural flexibility. Cold Regions Science and Technology. Vol. 67. S. 120–128.