

## Chapter 27

# Safety of Industrial Development and Transportation Routes in the Arctic (SITRA) – Collaboration Project for Research and Education of Future High North Experts

Nataliya Marchenko, Rocky Taylor, and Aleksey Marchenko

**Abstract** Industrial development in the Arctic enhances the potential risk of accidents occurring under severe conditions. Detailed knowledge of the physical environment and understanding of risk reduction methods are necessary for technical experts and young specialists planning to work in companies dealing with the Arctic. The Arctic is a place of close contact between many countries, where harsh and fragile environment demands the most advanced technology for sustainable development and international collaboration to ensure safety of industrial activity. The SITRA (Safety of Industrial Development and Transportation Routes in the Arctic, 2015–2018) project focuses on organizing an international research and educational network of High North experts for joint investigation and teaching of Arctic engineering courses. SITRA is funded by the Norwegian Centre for International cooperation in Education (SIU). The project is a part of the High North Program. It continues the more than 20-year-long Norwegian-Russian collaboration in the field of Ice Engineering and expands it overseas by means of students and staff/professors exchange and joint field work. Canadian and US universities have also joined the team. The SITRA project multiplies the understanding and awareness of the Arctic problems through education and outreach.

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N. Marchenko (✉) • A. Marchenko  
The University Centre in Svalbard, Longyearbyen, Norway  
e-mail: [natalym@unis.no](mailto:natalym@unis.no); [alekseym@unis.no](mailto:alekseym@unis.no)

R. Taylor  
Memorial University of Newfoundland, St. John's, NL, Canada  
e-mail: [rocky.taylor@card-arctic.ca](mailto:rocky.taylor@card-arctic.ca)



**Fig. 27.1** SITRA map. Project participants (from west to east): University of Alaska Fairbanks (Fairbanks, US), Dartmouth College (Hannover, US), Memorial University of Newfoundland (St. Johns, Canada), Norwegian University of Science and Technology (Trondheim, Norway), The University Centre in Svalbard (Longyearbyen, Norway), State Marine Technical University of Saint-Petersburg (Russia), Moscow Institute of Physics and Technology (Russia), Lomonosov Moscow State University (Russia)

## 27.1 SITRA Partners and Objectives

The SITRA project builds up an international team of experts from eight universities of Norway, Canada, US and Russia specialized in Ice Engineering (Fig. 27.1) and providing unique education in the Arctic.

Project activities include teaching and study on courses at the University Centre in Svalbard (UNIS), performance of joint PhD and MSc projects, joint field and laboratory work, numerical modelling, workshops, and international conferences. The teaching methodology follows the research field-based education strategy of the host institution – UNIS.

The main objective of the project is to increase basic knowledge in the following safety aspects: (1) estimation of ice actions on offshore and coastal structures, (2) description of dangerous ice phenomena for navigation in the High North regions, (3) probabilistic methods of risk estimates and practical methods of accident risks reduction. The project aims at organizing joint lecture courses about the physical environment in relation to running industrial activity in the Arctic. Important elements of collaboration are student exchange and joint field work in Svalbard and the Barents Sea.

Project partner's PhD/MSc students visit partner universities for studies and joint research. International cooperation in education increases the flux of knowledge of students significantly. Students get more information about the ongoing industrial projects and research activities focused on safety issues that arise through both industrial activity and navigation within ice-infested waters.

Joint field work helps students to master modern equipment and gain skills necessary for safe work in the Arctic. Collaboration with the large research projects allows to use the expensive devices and attracts experienced researchers.

The project focuses in organizing lectures on:

1. fundamentals of ice mechanics and engineering applications;
2. hydrodynamics of ice-covered waters and its applications;
3. safety problems of offshore and coastal structures in the Arctic;
4. safe navigation in Arctic straits.

All main project activities are reflected on the project website (UNIS and SITRA 2017).

Lectures are organized at UNIS as part of four existing courses, available on the UArctic Study Catalogue (UArctic 2017a): Physical Environmental Loads on Arctic Coastal and Offshore Structures, Ice Mechanics, Loads on Structures and Instrumentation, Arctic Offshore Engineering, and Arctic Offshore Engineering-Fieldwork. Detailed course descriptions are available in UNIS online course catalogue (UNIS 2017). Professors from partner universities visit UNIS as guest lecturers for a period of 1–2 weeks for teaching and field activities.

## 27.2 Project Implementation and Development in 2015–2016

The project activities in 2015–2016 followed the project goals and plans:

- Three field work series (March, April, November) with full scale ice mechanical tests yearly performing by international research team with participation of UNIS course students;
- MSc student projects;
- Lecturing of professors from partner universities;
- Publication and presentation of the results on the conferences.

International group of scientists extended the experiments that were started in 2013–2014: investigation of mechanical properties of ice (testing of the new rig for ice beam tests, *in-situ* indentation tests, tests for compression and tensile strength of ice) and ice actions on coastal structures (coal quay in Kapp Amsterdam), investigation of drag forces on ice and under ice turbulence (ADV measurements, CTD, and ADCP profiling), and investigation of tides in Svalbard fjords. Students of the UNIS course had unique possibility to participate in these scientific experiments, work with state-of-the Art equipment and get experience of Arctic research with well-qualified instructors. See (Murdza et al. 2016; Chistyakov et al. 2016) as an example of the work and results.

Spring investigations and teaching in the field have been continued during the UNIS study cruise and survey on the vessels Bjørkhaug (2015) and Lance (2016), including icebergs observation and towing attempt, tests on fast ice.

MIPT MSc student made comparison of ice strength properties collected from experiments with indentation and uniaxial compression and worked with demo version DE software ITASCA PFC 2D (ITASCA 2017) for the modeling of the towing of a floating structure in broken ice, in the frame of collaboration with the company “Kvaerner Concrete Solutions” project in 2015–2016. In the group of researchers/supervisors he performed the test with L-shaped cantilever beam for complex shear and bending strength (Murdza et al. 2016).

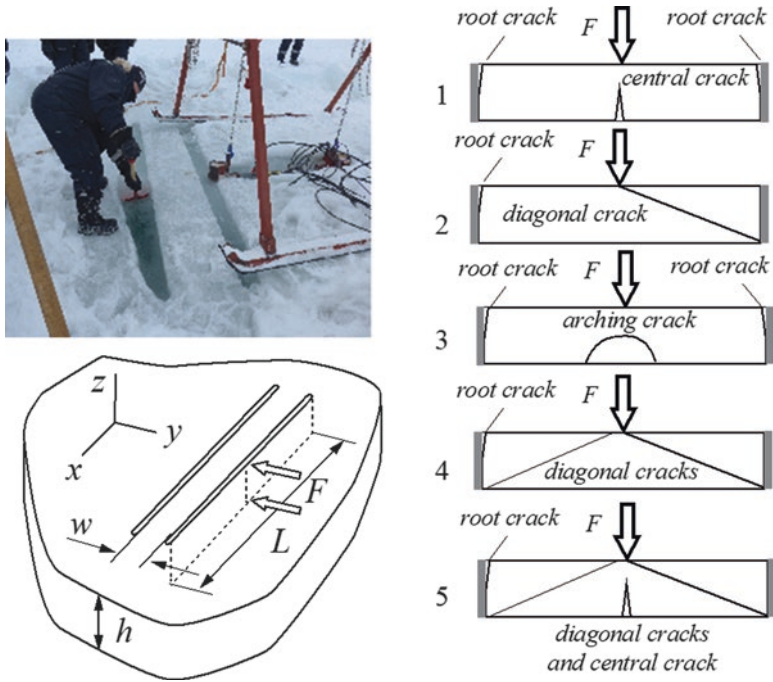
In November 2015, a joint research group, including 2 professors from MSU and 1 from SMTU, led by Arctic Technology department of UNIS made full scale tests of fresh ice on the lake near Longyearbyen. UNIS students took part in the work as a part of the study, they worked in four groups, performing indentation test in the lab and *in-situ*; beam test *in-situ*, fracture toughness test *in-situ*, uniaxial compression test in the lab, analysis of thin sections of ice in the lab; computer modelling of beam test in Comsol Multiphysics (COMSOL 2017). In 2016 due to warm autumn and unfrozen lake, the same experiments were carried out in laboratory conditions. That gave the new experience.

Investigation of wave propagation below the ice registered during the join expedition with C-CARD/MUN Group in 2014 was performed in 2015 (Marchenko et al. 2015a).

Altogether 12 scientific papers (Murdza et al. 2016; Chistyakov et al. 2016; Marchenko et al. 2013, 2015a, b; Mohammadafzali et al. 2016; Marchenko 2015, 2016; Konstantinova et al. 2016; Karulina et al. 2016; Sakharov et al. 2015; Marchenko and Marchenko 2015; Marchenko and Onishchenko 2015; Kowalik et al. 2015) have been published as a result of collaboration, which will be continued in the frame of SITRA project in 2017–2018.

### 27.3 Beam Test Modelling – Example of a Joint Student Work

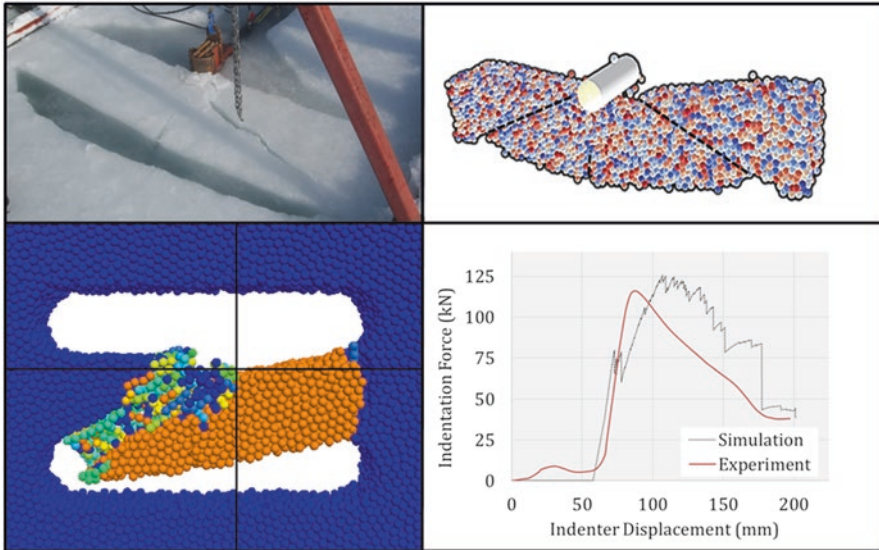
Flexural failure of sea ice is of interest in many different shipping and industrial development applications in Arctic regions, ranging from understanding rubble formation processes to modeling bending failure of ice sheets against sloped structures and ship hulls. As part of the study program, students worked together with researchers on investigating mechanical properties of sea ice. Figure 27.2 demonstrates the test with fixed ends beam. In this test, ice beam is prepared by sawing of two ice-through cuts along the beam axis. In the test the beam is broken by the load (indicated by letter F), applied to the beam in the horizontal direction as it is shown on the scheme (left down of Fig. 27.2). The load F is applied to the beam by a hydraulic indenter. The indenter consists of two vertical cylinders (indenter and root cylinder) connected with each other by two horizontal hydraulic cylinders connected to oil pump station. The indenter is mounted on a steel frame with sledges.



**Fig. 27.2** Organizing of the *in-situ* test with fixed ends beam (top left) schematic of the test (right), and observed ice failure modes (below left) (Photograph by Aleksey Marchenko)

Failures and strengths of ice were studied. Five different scenarios of the beam failure shown in Fig. 27.2 from the right were observed depending on the length to thickness ratio of the beam. Bending strength and compressive strength of ice both are calculated from the record of the load in the test if the beam follows the first failure mode. This scenario is well reproduced by finite element modeling. Four other scenarios with formation of diagonal and arching cracks were observed (Mohammadafzali et al. 2016), but not explained and reproduced by the modeling. Results of *in-situ* tests performed in joint expedition by RV Lance in Store Fjord in 2014 were used to parameterize a discrete element model of ice fracture under flexural loading. Simulations of these experiments in 3D were carried out using a new material model within the open-source Discrete Element Method (DEM) code WoodDEM (WoodDEM 2017) which features cohesive bonds in tension, shear, flexure and torsion based on a contact model with normal, shear, torsional and flexural springs. A comparison of simulated and field test results, such as those in Fig. 27.3 below, along with recommendations for future work were provided (see Mohammadafzali et al. 2016).

Figure 27.3 (Top right) demonstrates ice failure mode 5 reproduced by WoodDEM. Two MSU students used a commercial code ITASCA PFC 3D (ITASCA 2017) during their study at UNIS in the autumn 2016. Figure 27.3 (Bottom left)



**Fig. 27.3** *In-situ* beam test result (Top left); Results of discrete element modeling by MUN PhD Student (Top right); Simulated DEM results produced by UNIS/MSU MSc students (Bottom left); Force-displacement curve comparing simulation and field experiment results (Bottom Right)

demonstrates ice failure mode 2 reproduced with PFC3D. Numerical simulations of the test currently continue in close cooperation between UNIS-MSU-MUN.

## 27.4 Future Development and Perspective

The SITRA project is helping to increase the knowledge needed to ensure Arctic safety throughout the High North. In spring 2017, Canadian students will come to UNIS to participate in Arctic Technology courses and project work, under joint supervision. Canadian and US professors will also teach at UNIS in 2017. The main challenges the project has faced until now have been logistic, connected to remoteness and harsh weather conditions on Svalbard, as well as challenges associated with arranging funding, coordinating the time schedules of students and professors, and resolving visa issues, particularly for the international students. The Arctic Engineering Thematic network in the framework of the University of Arctic (UArctic 2017b) also provides a valuable connection point for this initiative. Even more intensive collaboration with this Thematic Network could prove fruitful for the future project development.



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