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Title of master project: Investigation of ice strength properties from in-situ experiments and numerical modeling

Résumé

Project works include the performing of mechanical experiments on sea ice in the field conditions and numerical simulations for the interpretation of the collected data. The experiments were performed by the loading of ice beams of specific shaped with measurements of the applied load and the displacement of the point of loading. Numerical simulations are used for the reconstruction of the failure envelope in stress space. Elastic and elastic-plastic rheology of ice in the simulations is used.

Knowledge of ice properties, especially ice strength are very important in different fields of human activities, such as shipping industry, oil exploration, designing of different structures located in the ice conditions, the stability of the ice as a platform for use by humans and other marine operations with ice. Sea ice has complex influence on economic, social and subsistence activities. Thus, experiments with ice are very important in order to investigate its properties and behavior.

In-situ full-scale tests are very important in the study of ice properties. They have great advantage: experiments are performed in real conditions and allow us to estimate original properties. Therefore, my master project is connected with these tests.

In-situ tests with cantilever beams have been performed on fresh and sea ice. Main goal of these tests is to find out flexural strength of ice. In addition, similar compression, tensile and shear tests were carried out (Figure 1). These tests allow learning some information about failure envelope.

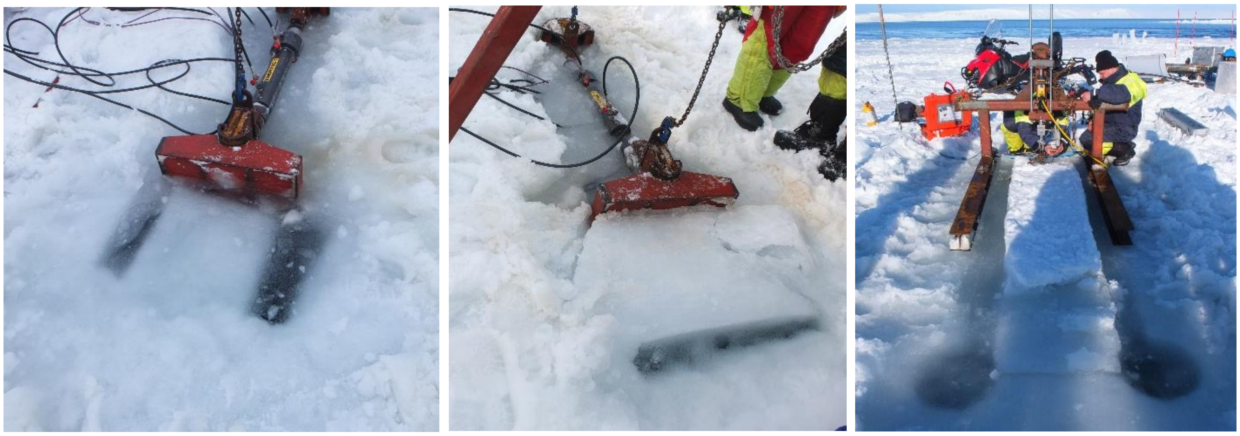

Figure 1: Setup of different tests (compression, shear, flexural)

In order to receive new information about ice properties, other shape of the beam was invented, which is modification of normal fixed end beam (cantilever beam). It has a shape of L-beam, where one lateral end is fixed and others are free, as can be seen in the Figure 2.

Main goal of the tests performed with L-beams is to observe torsion together with bending. In this particular case, failure may occur due to combination of tension and compression. Consequently, it may be possible to receive new information about failure envelope.

If one arm of the beam (BC) is sufficiently short then beam will failure due to tension on the top layer of ice, as cantilever beam (σ_{xx} are the highest and dominant stresses in whole volume). If the arm BC is sufficiently long, then other components of stress tensor (σ_{zz}, σ_{yz}, σ_{xy}) are becoming considerable. Increase of σ_{yz} stresses means that beam fails more likely due to torsion and crack can start its appearance in other place (not necessarily on the top surface). As a consequence, there is a relation between these two arms when two stresses σ_{xx} and σ_{yz} reach the same value. For this particular case, the problem of finding the ratio between length of arms (AB and BC) according to ice thickness also might be investigated.

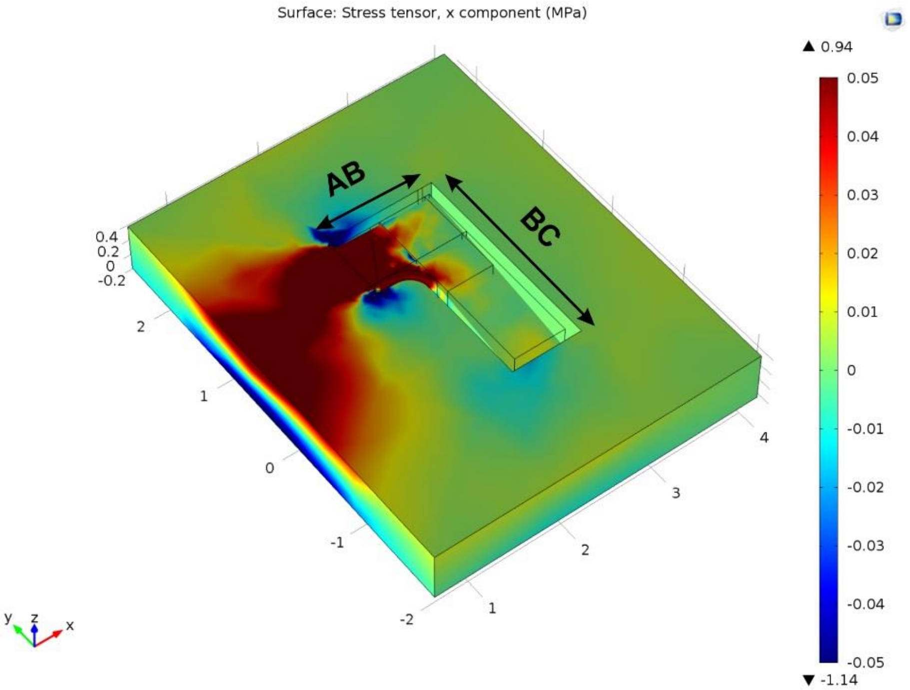

Figure 2: Simulation of the beam in Comsol Multiphysics

Figure 3: Test setup of the L-beam

Tests were performed in Svea and in the east north of Svalbard in Palanderbukta fjord during the AT-211 course fieldwork ("Ice Mechanics, Loads on Structures and Instrumentation") with UNIS students under supervision of group of highly qualified professors with Aleksey Marchenko. Three L-beam test were performed during the fieldwork: two beams were loaded downwards and the last one was pulled upwards (Figure 3). One of the arms was around 1.1 m, another was 2 m.

Preparation procedure was the same as for cantilever beam tests. Firstly, a drill of 10-centimeter diameter was used for preparation corners near beam root. These semi cylindrical openings help to decrease stress concentration at the root. Secondly, the beams were cut in the ice. The main top cuts were made with a chain saw, remains bottom parts were cut with hand saw. All beams were fixed at their one ends. The following rig for loading beams was used: steel frame was placed over the beam at the free end, as can be seen in Figure 3. Hydraulic cylinder located beneath top part of the frame. The rig was attached to the ice from both sides with two chains. A displacement sensor was fixed to the frame and a steel thin wire was stretched between this sensor and top part of the beam. Thus, beam deflection (deflection of the end of the beam) could be measured. The hydraulic cylinder was driven by a hydroelectric power station.

Procedure for loading upwards was slightly different. The rig was placed atop two long metal battens. The hydraulic cylinder was planted opposite direction and was fixed to the big framework together with new small framework in order to change direction of the load. In addition, in the middle of the beam end round hole through the ice was made. It was used to anchor small framework to the end of the beam with a chain.

Force and displacement data were recorded within the time.

Afterwards, received data were used for numerical simulations in finite-element-analysis software Comsol Multyphysics, as shown in Figure 2.

During the time, which I spent on Svalbard, I learned a lot of interesting and important information and got extremely useful skills working with different instruments.

I wish to thank Aleksey Marchenko and Nataly Marchenko for providing me great opportunity to participate in SMIDA project and study at UNIS. I am very grateful to my supervisor professor Aleksey Marchenko, professors from Moscow State University and Arctic Engineering Centre and all UNIS staffs who provided me with any aid.