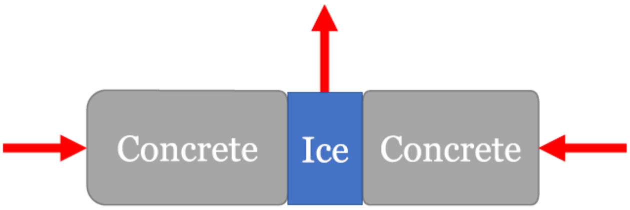
Offshore & Dredging Engineering

Technische Universiteit Delft

Ice-concrete bond analysis

In regions which experience arctic conditions, structures like offshore wind turbines, oil-platforms, light houses, piers and bridges suffer from abrasion by moving ice sheets. This results in challenging maintenance and repair works. At the ice-structure interface, several mechanisms exist which are responsible for the wear of concrete such as: freeze-thaw cycles, chemical effects of sea water, and mechanical loading of concrete. The main cause of concrete abrasion is however thought to be the flow of ice floes together with a layer of crushed ice, which is partly controlled by friction and adhesion between the two interfaces. Adhesion is thought to be the main component of the static friction and is, under certain circumstances, also directly responsible for concrete abrasion. It is yet not well known to what degree ice adhesion contributes to concrete abrasion, and how extrinsic parameters such as: pressure, hold time and submergence relate to the ice-concrete bond strength. This research aims to better understand the physical phenomena happening at the ice-concrete interface by shearing an adhesive ice-concrete bond to get a better understanding of the role of ice adhesion in concrete abrasion processes.



To achieve this goal, a double shear apparatus has been designed and ice-concrete shear tests have been performed in a thermal laboratory. The apparatus was designed to be relatively simple compared to conventional soil shearing machines. The design allowed for the ability of submergence, accurate and sustained application of normal load, improved implementation of standardisation procedures, and easy portability. The temperature during the test was remained relatively constant at around - 9° for dry the ice-concrete adhesion test, and around 0° C for submerged tests. The influence of hold time, varying from very short (6 seconds) to overnight, and pressure (51, 316 and 682 kPa) on the force required to break the ice-concrete bond has been investigated following a series of five test sequences. In sequence 1, the applied pressure was remained when shearing the ice. In test sequence 2, the shearing was initiated immediately after removing the applied pressure for a certain amount of time. In sequence 3, the time between removing the pressure and pulling out has been varied. In sequence 4, different materials have been used to clamp in the ice and sequence 5 investigated the influence of submergence.
The results show a positive influence of holding time on the force required to perform the shearing and although a higher normal load results in a higher shearing force, it is unclear what the result is of a higher normal load on the adhesive force. This result holds for both the remained and released pressure tests. The bond strength also appeared to increase when waiting after removing the applied load. Submergence showed to have a negative influence of the bond strength compared to the dry tests. When using a different surface as the concrete specimen, a pure paste surface showed to give the highest bond strength and a pure sandstone surface resulted in the lowest bond strength. The results of using a cut-concrete surface, as used in all other tests, were in between the pure paste and sandstone surfaces.

It is concluded from the experiments in this research, that mechanical theory seems to be the main mechanism of the ice-concrete bond. The failure type of the ice-concrete bond is dependent on holding time and pressure. Visual observations show an increase of ice stuck to the concrete surface for both higher normal loads and longer holding times.

Student
Bart Westerveld
October 11th, 2019

Sponsor
Memorial University of Newfoundland

Thesis committee
Prof.dr. A. Metrikine
Ir. J.S. Hoving
Dr. S.E. Bruneau, P.Eng