Chapter 1

INTRODUCTION

1.1 Scope of problem

First-year pressure ridges usually form at the boundary of two ice sheets or spontaneously within an ice sheet due to compressive stresses. The crushing and fracturing of the ice sheet produce blocks and brash ice that are ultimately forced beneath the surface forming the *keel* and to a lesser extent are forced upwards to form the *sail* of a ridge (Figure 1.1). In time, the keel becomes interlocked with a refrozen core that forms at the waterline and may exceed parent ice sheet thickness. First-year pressure ridges and ice rubble features will control the design ice loads for offshore structures in those regions where icebergs and multi-year ice are absent.

During a ridge interaction with a structure the clearing of the blocks which form the keel may contribute substantially to the total applied force, yet there are significant uncertainties in the modelling of the process. The problem involves both model and parametric uncertainty and stems from a scarcity of field observations and data, the complex characteristics of submerged ice rubble and the complicated task of reproducing the natural environment in scaled laboratory tests. Though previously identified, this problem came to the fore as a research issue during design work on the Northumberland Strait Crossing Project (NSCP). The bridge project, between Prince Edward Island and New Brunswick involved placing concrete gravity-based piers in a dynamic first-year ice environment. During the project, consensus was not achieved amongst international ice experts on the first-year ridge keel failure loads. This underscored the need for fundamental research and provided the impetus for this thesis.

The NSCP design experience indicated that efficiencies in new offshore developments can be expected if first-year ridge load models were improved. The commercial significance of this research area continues as interests expand in oil and gas exploration in Canada, including the West Coast of Newfoundland, and abroad, in the Sea of Okhotsk and the Pechora Sea.

1.2 Purpose and methodology

The purpose of this thesis is to improve the modelling of first-year ice ridge loads on structures. This is a complex multi-faceted problem, which has not been fully understood, in spite of many investigations. This thesis provides additional insight based on a systematic organisation and analysis of prior work and new experimental investigations.

The body of this thesis is partitioned into background research, exploratory experimentation and model development phases. The background chapter provides a state-of-the-art basis for new work by interpreting, grouping and examining a broad range of new and old literature sources. The subjects of the background chapter include physical characteristics of ridges, parent ice properties, ice rubble shear strength, field and laboratory investigations of ridge loads, and, first-year ridge load models.

Following the background chapter several unique exploratory experiments are introduced. They include rubble property investigations, small- and large-scale ridge interaction tests and ice rubble shear experiments. Collectively these programs represent the most significant body of first-year ridge force data known. When this new data are grouped with the literature sources a new opportunity for the development an analytical force model arises.

Chapters 4 through to 7 describe the process in which this opportunity for model development is exploited. The first phase, Chapter 4, is a multi-variable regression study which isolates the fundamental parametric form of equations describing rubble shear strength and ridge interaction forces. Chapter 5 describes a series of experiments which pioneer the use of sand as an analogue for ice rubble. The sand indentation tests afford a high level of control which enables a calibration and adaptation of earth pressure formulas for ridge keel boundary conditions. Reconciling the sand-based models from Chapter 5 with laboratory ice ridge experiments is the subject of Chapter 6. The performance of force prediction models for both vertical and conical structures is judged through sensitivity studies and regression techniques. Chapter 7 considers fluid dynamics, inertia effects and the application of the newly calibrated ice load model to full-scale.

It is the goal of this thesis to provide an approach to force modelling that is mainstream; that is, a model which is heavily supported by the broadest possible range of experimental and field data, and practical for contemporary probabilistic modelling methods. The structure of this thesis permits the attainment of this objective while providing a series of studies which independently document useful reference material and provide impetus for new research thrusts.

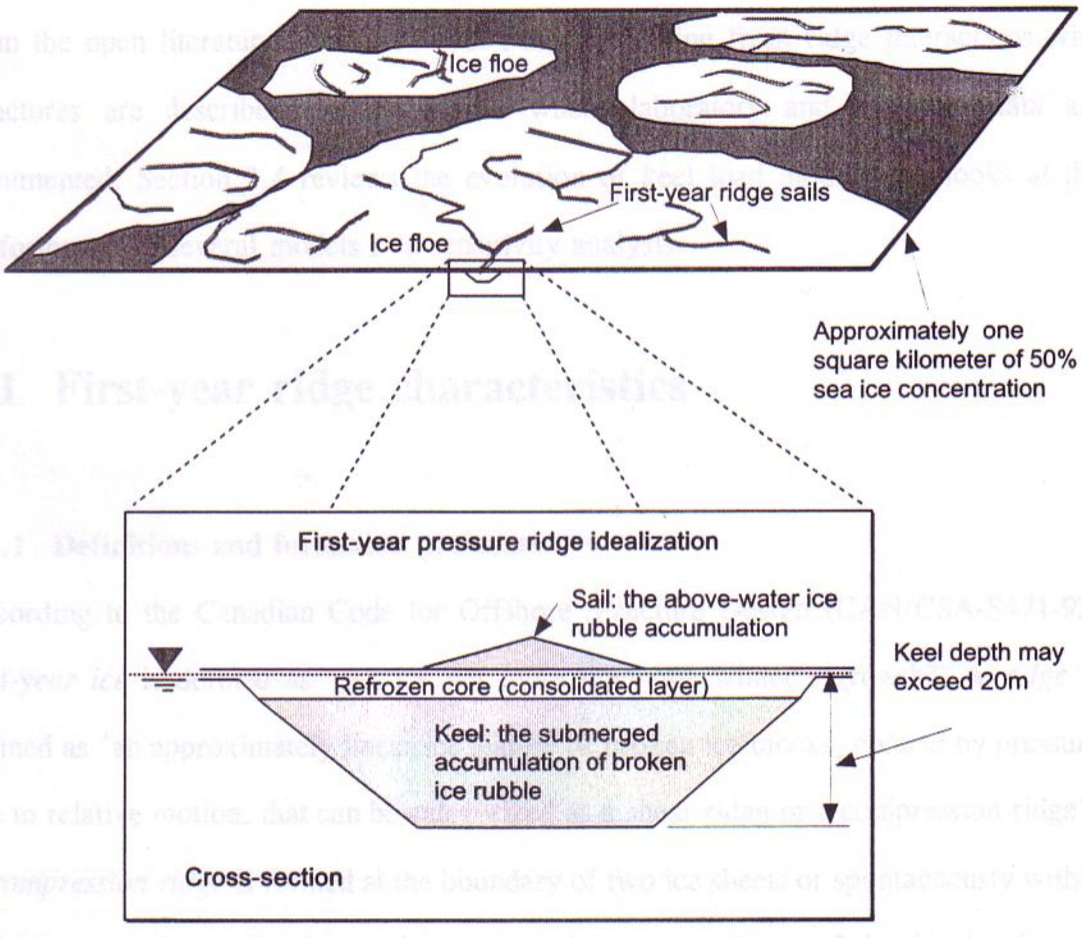

Figure 1.1 First-year pressure ridge schematic.