Measurements of Ice Sheet Strain Area During Ice/Vertical Sided Structure Interactions Using Strain Gages in Field Indentation Tests

Masafumi Sakai and Masakazu Aoshina
Taisei Corporation
Yokohama, Japan

Hiroshi Saeki
Hokkaido University
Sapporo, Japan

ABSTRACT

A study on ice loads during ice-structure interactions was started in 1993 by the Japan Ocean Industries Association (JOIA). Medium Scale Field Indentation Tests (MSFIT) were conducted during the winters of 1996 and 1997. The purpose of the tests was to investigate ice loads and ice failure characteristics, and to establish a new method of estimating ice loads during ice-structure interactions. The tests consisted of ice indentation tests, tests on physical properties of ice sheets, and measurements of ice sheet deformation. The test site was located at Futamigaoka Harbor on Lake Notoro, Hokkaido, whose entrance faces the Sea of Okhotsk. This paper describes the results of ice sheet strain measurements using strain gages and the estimation of strain area during ice/vertical-sided-structure interactions obtained during a winter test in 1997.

KEY WORDS: ice sheet deformation, strain area, strain rate, strain energy

INTRODUCTION

It is important to determine the design load on a structure to study how an ice sheet is destroyed, based on the parameters of structure width, ice thickness, and ice sheet indentation rate, during interaction between the structure and the ice sheet. A more rational design load can be determined if the ice sheets failure mode and the ice load can be estimated, based on the above three conditions. Ice load is known to be substantially influenced by the strain rate \( \dot{\varepsilon} \) defined by the indentation rate and the ice sheet strain area. Therefore, it is necessary to evaluate the strain rate (strain area) to estimate the ice load and to evaluate the structure design load. Strain area has been measured in many laboratory experiments; however, this is difficult because of the limited experimental scale in the laboratory. Furthermore, many theories have been proposed for evaluating the strain propagation area, but no rational theory has yet been established.

The present study takes advantage of the large scale of the field indentation test. The strain gages used to measure how strain is produced from a concrete structure and a steel structure were embedded in the ice sheet, and the strain data during ice sheet loading was measured. Thus, the area of strain propagation on ice sheet and the strain distribution were determined. This paper summarizes the basic data which establishes the ice sheet strain area evaluation technique.

EXISTING THEORIES

There are three possible failure modes, depending on strain rate: the lower strain rate range (ductile failure range \( \dot{\varepsilon} \leq 10^{-4} \)), the higher strain rate range (brittle failure range \( \dot{\varepsilon} \geq 10^{-2} \)) and the intermediate strain rate range (transition failure range \( \dot{\varepsilon} \approx 10^{-3} \)). According to studies made to date, the maximum ice load is recognized to occur in the transition failure range.

However, for the area of strain propagation in an ice sheet the following theories have been proposed, and the definitions are based on the width of the structure or the ice thickness.

The following describes the major proposals on the existing strain rate:

(1) Korzavin (1962), Ralston (1979)

\[ \dot{\varepsilon} = \frac{v}{2b} \]  

where \( v \) = indentation rate, and \( b \) = structure width.

(2) Michel & Toussaint (1977)

\[ \dot{\varepsilon} = \frac{v}{4b} \]  

where \( v \) = indentation rate, and \( b \) = structure width.

These equations are generally used to evaluate the strain rate. The area of ice sheet strain during interaction between the structure and the ice sheet is set to about 2b to 4b with reference to the structure width (b).