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Significance of Ice Sheet's Leading-Edge Roughness in Relation to Ice Load

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ABSTRACT

The effect on ice load of the initial shape of an ice sheet's leading edge is shown through field ice indentation tests using natural freshwater lake ice. The shape of the leading edge of natural sea ice near a bluff in the harbor is also measured to determine its surface roughness. Under the test condition here, the results show that subsequent ice load rather than first prominent peak ice load is likely to control the ice load on a structure in the real world. Furthermore, the shape of the leading edge of natural sea ice after an ice indentation test is measured to evaluate the actual ice/structure contact area during the subsequent ice load, and in turn to estimate the nature of the contact during subsequent (potential) local ice sheet failure.

INTRODUCTION

Ice loads on offshore structures were evaluated in the early stages of ice load research, based on the assumption of uniform contact between ice sheet and structural face. Under the idealized contact of a model structure with an ice sheet, the ice load depends on an effective ice strain rate ($d\varepsilon/dt$) calculated by $V/(2W)$ or $V/(4W)$ (where V is the relative velocity of the ice and the model structure and W is the width of the model structure). It was reported that ice load as well as ice strength are a maximum value in the order of 10^{-3} (s^{-1}) of effective ice strain rate ($V/(4W)$) (Saeki, 1978,1980). Under the conditions of both idealized contact and the order of 10^{-3} (s^{-1}) of effective ice strain rate ($V/(4W)$), ice load in a field ice indentation test shows a first prominent peak (maximum) due to uniform contact, and then ice load (called subsequent ice load) fluctuates, showing peaks due to nonuniform structure/ice sheet contact. The first prominent peak of ice load was targeted in considering design ice load on offshore structures, to take into account a lot of unknown effects. However, the importance of the scale effect, i.e., that ice load indentation pressure decreases as indentation area increases, was also reported (Kry, 1978; Ashby et al., 1986). The effect of nonsimultaneous ice sheet failure during ice indentation was used to explain the scale effect, and this in turn was related to irregular contact between structure and ice sheet in both the Kry and Ashby models.

However, the shape of a natural ice sheet's leading edge in the real world, and also the actual contact between structure and ice sheet in an indentation test have never been reported. This paper describes the results of measurements in Futamigaoka Harbor of Lake Notoro, where medium-scale field indentation tests of the JOIA (Japan Ocean Industries Association) project were performed:

• the shape of the leading edge of a natural sea ice sheet near a bluff in Futamigaoka Harbor; and

• the roughness of the leading edge of an ice sheet after the medium-scale field indentation tests of the JOIA project, and an estimation of actual contact between ice sheet and structure during an ice indentation test.

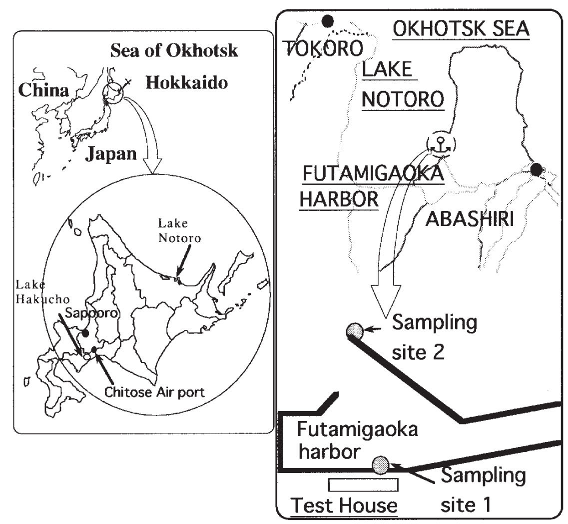

Fig. 1 Location of test sites

RELATIONSHIP BETWEEN INITIAL ICE SHEET'S LEADING-EDGE SHAPES AND ICE LOAD

Small-scale ice indentation tests were conducted using freshwater lake ice at Lake Hakuchyo, near Chitose Airport (Sapporo), Hokkaido (Fig. 1), to investigate the influences of the initial ice sheet's leading-edge shape on the total ice load (Takeuchi, Saeki et al., 1994). The model structure width was 1 m and the ice thickness ranged from 6.5 to 8 cm. The indentation velocity (V) was set such that the effective strain rate calculated by ($V/(4W)$) was in the order of 10^{-3} (s^{-1}). Three initial ice sheet/structure contact conditions in the indentation tests were considered: TYPE a, TYPE b and TYPE c, as shown in Fig. 2. The test conditions are summarized in Table 1. Ice temperature ranged from 0° to –2°C during the tests. Figs. 3~6 show the time series of total ice load. If

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KEY WORDS: Ice load, contact area, ice indentation test.