International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 15, No. 3, September 2005, pp. 215–222

Numerical Calculation Model of Sea Freezing in Fishing Port During Winter

S. Kioka, D. Honma and Y. Yamamoto
Civil Engineering Research Institute of Hokkaido, Sapporo, Japan

T. Terashima
Kumashiro System Frontier Co., Ltd., Sapporo, Japan

We developed a multipurpose freezing simulation model that can be used as a tool to provide an evaluation of proposed countermeasures to port freezing during winter and examined its application to a field site. This freezing simulation consists of 3 submodels: Seawater flow field calculation; phase changes in ice or snow; and movement of ice floes. The phase changes in ice and snow are able to take into consideration a variety of meteorological conditions and stages of melting. We confirmed from comparisons between observed and calculated results that this simulation method could roughly reproduce freezing tendencies and characteristics.

INTRODUCTION

Harbor freezing, a phenomenon in which water in harbors freezes during winter, causes considerable economic damage to ports, harbors and fishing ports in Hokkaido, in northern Japan, due to the inability to fish and anchor, the damage to ships, and other problems. We are engaged in developing a multipurpose numerical simulation model of port sea freezing as a tool to provide a relative evaluation of proposed countermeasures against freezing for Otsu Fishing Port, which suffers serious damage from freezing nearly every year. The port is an excavated-type fishing port facing the Pacific Ocean in eastern Hokkaido, at the southwest corner of the Tokachi River estuary (Figs. 1 and 2). Fig. 2 shows the sea freezing that occurred at Otsu Fishing Port in 2000. One of the main factors behind the freezing of this fishing port is the relatively low air and seawater temperature in winter. It has also been pointed out that it is difficult to remove frazil crystals and pancake ice because the port is excavated and tidal exchange (or heat exchange) with the open sea is unlikely to occur (Kodama et al., 2003). The freezing period in Otsu Fishing Port occurs from late December through early March. While overall ice thickness varies greatly by year, it consistently reaches up to 50 cm in the inner part of the port. The open sea does not freeze. It is necessary to study the meteorological conditions of Otsu Fishing Port from the viewpoint of heat budget to obtain ideas for freezing countermeasures, and to input heat fluxes such as solar radiation and long-wave radiation for the freezing simulation noted above. We then conducted meteorological observation, including direct onsite measurement of solar and long-wave radiation, and studied frazil production in the winters of 2002–03 and 2003–04 (Kioka et al., 2004a and b). We also introduced a model for phase changes in ice and snow, which enables the consideration of a variety of meteorological conditions. Although this is a moving boundary and nonlinear problem, we developed a numerical calculation method (Kioka et al., 2004b).

In this study, we developed a numerical simulation model of sea freezing in port, with ice movement and flow field models that included a model of phase changes in ice or snow. We also verified the application of the numerical model to a field site through comparisons with onsite observation results.

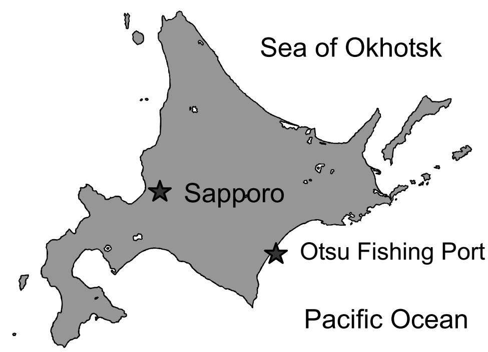

Fig. 1 Map of observation site

Fig. 2 Sea freezing in Otsu Fishing Port (in winter, 2000)

NUMERICAL SIMULATION METHOD OF FREEZING

Overall Configuration of Numerical Simulation Model

This freezing simulation model consists of 3 submodels: Seawater flow field calculation; phase changes in ice or snow; and movement of ice floes. It also enables outputting time series variations, such as that of seawater temperatures and ice thickness distribution (planar distribution). Fig. 3 shows the calculation process.

Received February 25, 2005; revised manuscript received by the editors July 22, 2005. The original version (prior to the final revised manuscript) was presented at the 15th International Offshore and Polar Engineering Conference (ISOPE-2005), Seoul, June 19–24, 2005.
KEY WORDS: Port freezing, numerical simulation, meteorological condition, ice growth, ice melting.