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Modeling of Ice Conditions in the Gulf of Bothnia

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ABSTRACT

Ice conditions of the Arctic present the most significant hazard that offshore structures located there will encounter. In severe ice environments, ice loads influence size, stability, reliability and durability of engineering structures. In order to calculate ice load and effects from interacting ice features, it is necessary to determine statistical variability of the ice features, and develop probabilistic models of ice conditions.

The purpose of this study is to develop the probabilistic model of the ice cover on the Raahe lighthouse in the Gulf of Bothnia, taking into account correlation and statistical dependence of essential factors of ice environment. For the probabilistic analysis and modeling the full-scale observation data of ice regime of an Oulu and Raahe lighthouses zone in the Gulf of Bothnia have been processed for winter seasons of 2005÷2009 years. The result of investigations is the probabilistic model of ice conditions at concrete foundation of Raahe lighthouse for various ice scenarios with a view on correlation and stochastic relationship between observed values of ice parameters.

KEY WORDS: ice conditions, ice data, Gulf of Bothnia, Raahe lighthouse, ice scenario, correlation, probabilistic model.

INTRODUCTION

Ice investigations around lighthouses in the Gulf of Bothnia have been carried out for over 30 years by this time, and they have become more intensive in the last 5÷10 years with application of the up-to-date observation technologies and ice model tests. On this problem, dozens of the ice research programs have been realized and the significant amount of scientific studies and engineering reports from the key ice laboratories and centers has been published. The list of publications on this problem included by the authors into the references is far from being complete. On the basis of analysis of the available publications all the investigations can be divided conventionally as follows.

1.*Regular full scale observations* of hydrological, meteorological and ice regime of the sea area in the Gulf of Bothnia since 1979 till the present time with subsequent statistical data processing (http://en.ilmatieteenlaitos.fi).

Besides, during more than three years of measuring activities, data evaluation, interpretation, numerical modelling and documentation the STRICE project has achieved large amounts of versatile data and results (http://www.strice.org). In addition, the data were collected during the EU funded project LOLEIF on the lighthouse Norströmsgrund in 1999÷2000 (Schwarz et al, 2001).

2. *Full-scale (field) investigations* on definition of the physical and mechanical properties of ice (Fransson et al, 2004).

3. *Full-scale (field) investigations* of the ice failure process and full scale measurements of the ice loads on the lighthouses structures (Määttänen, 1977; Engelbrektson, 1989; Schwarz et al, 2001; Kärnä et al, 2003; Jochmann, et al, 2005; Kärnä et al, 2006; Kärnä, 2007).

Several field studies have been made on vertical structures to determine the response induced by crushing failure of ice. Ice force measurements have been conducted at the lighthouse Norströmsgrund in the northern part of the Baltic Sea. Detailed systematic observations of the ice structure interactions and ice failure modes were made concurrently with the force measurements in four winters 2000÷2003 (Kärnä et al, 2003). The main result of the analysis is expressed as a simplified formula for the largest peak values of the global ice pressure.

4. *Mathematical modeling of the process of ice abrasion* effect on concrete foundations of some lighthouses (Bekker et al, 2011).

In this paper ice abrasion depth for Raahe lighthouse is determined with special ICESTRIN program. The authors propose the original technique of statistical modelling of ice data that is used in the paper when developing assumptions of probabilistic model.

5.*Numerical and simulation modeling of interaction between ice and structures* of the lighthouses in the Gulf of Bothnia on the basis of the up-to-date software, such as LS-DYNA (Hilding et al, 2011).

During the last years, there has been an increasing amount of work published regarding simulation of ice action on structures using finite element models of the ice (Hilding et al, 2011). The ice in the area of the lighthouse Norströmsgrund is modelled using the Cohesive Element Method with Homogenization (CEMH).

The review analysis has shown that there are a great number of random factors affecting the ice environment. Parameters of the ice features are represented as random values; hence it is necessary to consider their distribution during ice season from the probabilistic point of view. The