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Ice Loading on a Multifaceted Conical Structure

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ABSTRACT

An upward breaking cone is a common shape proposed for Arctic offshore structures. The conical shape will induce ice bending failure, and hence reduce the horizontal ice forces on the structure. In order to save on fabrication costs, it may be desirable to approximate the smooth conical surface by a series of flat faces or facets. The present paper documents an experimental test program which studies the ice loading on a multifaceted conical structure. A 1 : 50 model scale of a six-sided or six-faceted cone is tested. The model is instrumented to measure separately the ice loads on different parts of the structure. The faceted cone is subjected to a range of ice conditions representing level ice sheets and ridges. The present paper describes the model construction, associated instrumentation, the experimental techniques and test conditions for the model test program. The test results are presented in tabular form. Comparison is made of the experimental results with the predictions of two theoretical models developed for computing the ice forces on smooth cones. The forces measured on the multifaceted cone show reasonable agreement with the Ralston (1980) theoretical model.

INTRODUCTION

A common shape proposed for Arctic offshore exploration and production structures is that of an upward breaking cone (e.g., Wasilewski and Bruce, 1981; Della Greca, 1984). This type of structure is expected to be made of steel. The curved shape of the cone would make fabrication with steel very difficult and costly. Thus, for ease of fabrication and saving in construction costs, it would be desirable to approximate the smooth conical surface by a series of flat faces or facets. However, to-date, only smooth-surfaced conical structures have been tested for ice loading. Hence it is necessary to investigate the effects of a multifaceted surface on the ice failure process and subsequently on the ice loading on the structure itself.

A joint university-industry research program was initiated to study the different aspects of ice loading on a multifaceted conical structure. This program was conducted jointly by Esso Resources Canada Ltd. (ERC), Memorial University of Newfoundland (MUN) and the National Research Council of Canada (NRC). The program involved two series of tests at relatively large model scales of 1:10 and 1:20 conducted at ERC's outdoor ice basin in Calgary (Metge and Weiss, 1989; Metge and Tucker, 1990), one test series at a smaller scale of 1:50 conducted at NRC's Institute for Mechanical Engineering in Ottawa (Irani et al., 1992), and another test series at intermediate scales of 1:25 and 1:50 at NRC's Institute for Marine Dynamics (IMD) in St. John's, Newfoundland.

The principal objective of the test program was to understand the interaction and forces of floating ice, multi-year ice floes and ridges with a multifaceted conical structure. In addition, the test program was devised to address the issue of model-scale effects. In physical model testing, it is important to have confidence in the extrapolation of the model test results to full-scale conditions. The present test program, conducted over a wide range of model-scale factors, will allow the comparison of results from tests conducted at different scale factors.

Fig. 1 shows a schematic of the generic full-scale structure that was modelled. It is a six-sided or six-faceted cone with an inscribed diameter of 30 m at the waterline and 10 m at the neck. A similar structure with a neck twice as large was also modelled. The dimensions of this structure are similar to several concepts which have been proposed for Arctic use. The number of sides, six, was chosen to emphasize the effect of a multifaceted structure as distinct from a smooth cone. The slope of each side is 5:6 or about 40° with the horizontal. At the top of the six-sided truncated cone is the "collar," which is a transition section to the vertical "neck" above it. Each side of the collar has a steep 2:1 slope designed to prevent thick ice pieces from jamming against the neck. The neck itself is a vertical six-sided surface placed on top of the collar.

The present paper documents the tests conducted at NRC-Ottawa, where an 1:50 scale model was tested. The model was instrumented to measure the six components of forces and moments on the entire structure. In addition, the model was segmented to measure the forces on different parts of the cone. Namely, the three components of forces acting on the neck, collar and three of the facets were measured separately. Also, the test setup was such that the orientation of the structure with respect to the direction of ice motion could be changed. The roughness of

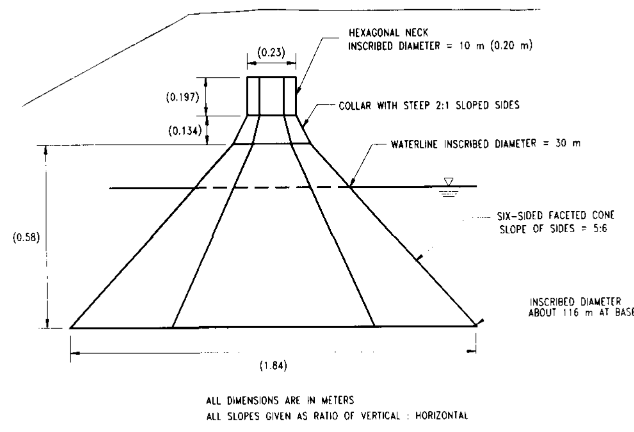

Fig. 1 Schematic of faceted cone. Typical full-scale dimensions are shown and actual 1:50 model-scale dimensions indicated in parentheses.

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KEY WORDS: Model testing, ice, conical, offshore structure.