International Journal of Offshore and Polar Engineering
Vol. 8, No. 1, March 1998 (ISSN 1053-5381)

Assessment of the Wave-Iceberg Load Combination Factor

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ABSTRACT

The present paper describes an extension to a recent study (Foschi et al., 1996), which was undertaken to determine the appropriateness of the recommended value of the load combination factor relating to the combined effects of wave and iceberg loads, as described in the Canadian Standards Association (1992) code for the design and construction of fixed offshore structures. The study examines the sensitivity of the load combination factor to various iceberg and wave parameters typical of three sites off the East Coast of Newfoundland. The methodology is based on a numerical analysis in which loads due to waves alone, an iceberg alone, and an iceberg and waves in combination, have been calculated for a range of iceberg and wave parameters, with the results applied to a first-order reliability analysis to study force levels corresponding to specified annual exceedence probabilities. The results indicate that the load combination factor is most sensitive to the wave angle relative to the current direction, and to the wave climate during the iceberg season — therefore, the load combination factor is site dependent. A load combination factor has been calculated conservatively as 0.20, applicable throughout the range of situations considered. This compares with the Code values of 0.8 or 0.4, for icebergs and waves which are taken to be stochastically dependent or independent, respectively.

INTRODUCTION

The selection of suitable environmental loads and load events is of critical importance in the design of offshore structures intended for operation in extreme environments. Such loads may include those due to wind, waves, earthquakes, ice floes and iceberg collisions. The CSA Offshore Structures Code CAN/CSA-S471-92 (S471) (Canadian Standards Association, 1992) describes the use of such loads in offshore design, and indicates the use of probabilistic methods on which the selection of load events and design loads should be based. The Code has been subjected to a comprehensive verification process, and this has identified several issues which warrant further study. One of these is an assessment of the combined effects of wave and iceberg collision loading. At present, this combination is treated by the use of a load combination factor which is used to determine a design value for the load due to a companion frequent environmental process (waves) acting in combination with a rare environmental event (iceberg collision). For combined iceberg-wave loading, the load combination factor γ is defined in the Code as follows:

$$E = E_r + \gamma E_f \tag{1}$$

where E is the load due to an iceberg with waves with an annual exceedence probability of 10^{-4}, E_r is the iceberg-alone load with an annual exceedence probability of 10^{-4}, and E_r is the wave load with an annual exceedence probability of 10^{-2}. Suitable values of γ are specified in the Code. The definition of load in Eq. 1 depends on the limit state under consideration, and includes the maximum iceberg load (in the presence of waves), applicable to a local damage limit state; and the maximum combined wave-iceberg load, applicable to a global sliding limit state.

Wave-structure interactions (in the absence of icebergs) and iceberg-structure interactions (in the absence of waves) have been studied extensively in the past (e.g. Sarpkaya and Isaacson, 1981, and Cammaert and Muggeridge, 1988, respectively), whereas the case of waves and an iceberg acting simultaneously on a fixed offshore structure has not been studied to the same extent. Isaacson (1987) considered the effect of waves on an iceberg up to the instant of impact, and described wave effects on the iceberg velocity and effective mass at the time of impact. Related studies include Lever, Attwood and Sen (1988), Lever, Colbourne and Mak (1990), and Isaacson and McTaggart (1990). In a recent study, Foschi et al. (1996) and Foschi and Isaacson (1996) described a numerical analysis in which loads due to waves alone, an iceberg alone, and an iceberg and waves in combination have been calculated for a range of iceberg and wave parameters. The corresponding results were applied to a probabilistic study of the load event using the first-order reliability method (FORM), with the objective of determining suitable values of the load combination factor.

In the present study, the method of Foschi et al. (1996) is extended to examine the sensitivity of the load combination factor γ to wave and iceberg parameters typical of three sites off the East Coast of Newfoundland. Loads due to waves alone, an iceberg alone, and an iceberg and waves in combination have been calculated for a range of iceberg and wave parameters. These results have been used to develop expressions for wave and iceberg loads which are then used in a probabilistic study of the load event.

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Received March 10, 1997: revised manuscript received by the editors November 6, 1997. The original version (prior to the final revised manuscript) was presented at the Seventh International Offshore and Polar Engineering Conference (ISOPE-97), Honolulu, USA, May 25-30, 1997.

KEY WORDS: Hydrodynamics, icebergs, ocean engineering, offshore structures, wave forces, waves.