International Journal of Offshore and Polar Engineering
Vol. 10, No. 2, June 2000 (ISSN 1053-5381)
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On the Selection of Design Wave Conditions

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ABSTRACT

In the design of coastal and offshore facilities, it is customary to estimate parameters of a design sea state corresponding to a specified return period or annual risk, and then develop an estimate of the expected largest individual wave height within that sea state. It turns out that the expected largest individual wave height in a sea state with a specified return period may be significantly different than the maximum individual wave height with the same return period. The present paper serves to highlight this difference. It describes for different situations the calculation of the long-term distribution of individual wave heights and of the maximum individual wave height with a specified return period. Results are presented (i) for a specified wave scatter diagram; (ii) for hindcast wave parameters for a sequence of storms or hurricanes; and (iii) for a range of parameters relating to analytical descriptions of long-term sea states. In addition, a comparison of alternative methods of computation is made. It is found that the maximum individual wave height with a given return period is generally appreciably larger than the expected maximum individual wave height in a sea state with the same return period.

INTRODUCTION

In the design of coastal and offshore facilities, it is customary to estimate parameters of a design sea state corresponding to a specified return period or annual risk, and then develop an estimate of the largest individual wave height within that sea state. In fact, the expected or most probable height of the largest individual wave height H_m within a design sea state with significant height H_s is often taken as $H_m \approx 1.8 \sim 2.0\, H_s$. It turns out that the maximum individual wave height with a specified return period, estimated from the long-term distribution of individual wave height, may be significantly different than the expected maximum individual wave height in a sea state with the same return period. Thus, if an individual wave event corresponding to a specified return period is indeed required, the more common procedure may be unconservative. In addition, the return period of an individual wave with the same height as the expected largest individual wave height in a design sea state is significantly different than the return period of the sea state itself.

Most design codes and guidelines (e.g. U.K. Department of Energy, 1977; Shore Protection Manual, 1984; Canadian Standards Association, 1992) refer only incidentally to this issue, although Det Norske Veritas (1991) describes the selection of significant and individual wave heights with specified return periods in some detail, based on an analysis developed by Gran (1991). Also, most coastal engineering texts provide relatively brief descriptions, if any, of the selection of return period or risk associated with specific design situations, and of the estimation of wave conditions corresponding to specified return periods or annual exceedence levels.

The purpose of the present paper, then, is to examine the difference between the maximum individual wave height with a specified return period and the expected largest wave height in a design sea state with the same return period. Procedures are described and results are obtained for (i) a specified wave scatter diagram; (ii) hindcast wave parameters for a sequence of storms or hurricanes; and (iii) a range of parameters relating to analytical descriptions of long-term sea states. It is not recommended that design procedures be altered as such, but rather that coastal engineers be aware that the return period of an individual maximum individual wave height may be notably lower than that of the sea state on which design is based, so that this wave height may occur somewhat more often than may have been recognized.

THEORETICAL DEVELOPMENT

Descriptions of the estimation of extreme waves include those given by Sarpkaya and Isaacson (1981), Isaacson and MacKenzie (1981), Muir and El-Shaarawi (1986), and Gran (1991). There are several approaches to developing design wave conditions, depending in part on the nature and extent of available data. Most commonly, hindcast or recorded data of one or more sea state parameters, such as the significant wave height, are fitted by a suitable probability distribution, and this is extrapolated so as to estimate a suitable design sea state described in terms of the same parameter(s). Once this design sea state is known, an estimate is then made of the maximum individual wave height within this sea state.

In the present context, consideration is now given to the estimation of the maximum individual wave height from the long-term distribution of individual wave heights. In the following development, attention is given in turn to the basis for the use of return period or annual risk; descriptions of the long-term probability distribution of the significant wave heights characterizing sea states; and then to the long-term distribution of individual wave heights. The approaches are developed for cases in which the data are specified (i) in the form of a wave scatter diagram obtained by sampling sea states at a constant recording interval; (ii) in terms of relevant hindcast parameters for a sequence of storms or hurricanes; and (iii) in terms of analytical probability distributions of significant wave height so that the parametric dependence of the results can be

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Received March 13, 1998; revised manuscript received by the editors October 30, 1999. The original version (prior to the final revised manuscript) was presented at the Eighth International Offshore and Polar Engineering Conference (ISOPE-98), Montréal, Canada, May 24-29, 1998.

KEY WORDS: Coastal engineering, design waves, maximum wave height, return period.