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Partial safety factors for berthing velocity and loads on marine structures

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ABSTRACT

Design methods for marine structures have evolved into load and resistance factor design, however existing partial safety factors related to berthing velocity and loads have not been verified and validated by measurement campaigns. In this study, field observations of modern seagoing vessels berthing in Bremerhaven, Rotterdam and Wilhelmshaven were used to evaluate partial safety factors for berthing energy and berthing impact loads. Various types of vessels and navigation conditions were statistically examined. The results show that characteristic values of berthing velocity with a return period of 50 years are in line with design recommendations in literature. Design values of berthing velocity are sensitive to the number of berthing operations during the lifetime of a marine structure. Typical partial safety factors for sheltered and exposed navigation conditions were derived by extrapolating distribution fits and applying extreme value theory. Differences in structural response due to soil stiffness and the type of berthing system installed influence partial safety factors for berthing impact loads. The probability of an uncontrolled berthing event was higher for exposed navigation conditions (strong tidal currents). In these circumstances, higher partial safety factors for berthing velocity should be considered in the design of marine structures. When berthing aid systems are used, the probability of extreme berthing velocities is lower, resulting in lower partial safety factors. The key findings of this study could be beneficial for the structural design of new and lifetime extension of existing marine structures.

1. Introduction

Numerous marine structures, such as quay walls, jetties and flexible dolphins, have been realised all over the world to accommodate ships' berthing, mooring and loading operations. During the service life of a marine structure, functional requirements may change. These changes often result in uncertainty regarding actual berthing energy and structural integrity, especially if size of design increases at existing berthing facilities. Existing design guidance for assessing berthing energy, such as PIANC [17], British Standards [4], EAU [6] and Spanish ROM [13], suggest applying an overall safety margin. These guidelines do not include partial factor analyses of individual parameters and their individual contributions to the uncertainty in berthing energy. It is often not clear how resultant fender forces derived from such analyses should be applied in accordance with the safety philosophy of Eurocode standards

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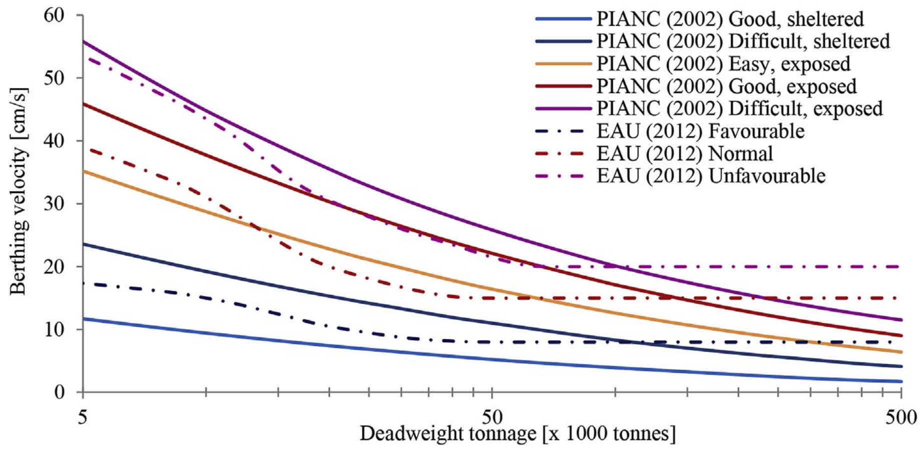

Fig. 1. Berthing velocity curves of PIANC 2002 (Brolsma curves [2]) and EAU 2012 as a function of navigation conditions and vessel size [14].

[10], which predominantly recommend applying a partial safety factor to characteristic values of loads and resistance.

Metzger et al. [9] stated that load demands on berthing structures are not well understood due to a lack of information about berthing parameters. Therefore, there is a strong need to determine design values of berthing parameters and partial safety factors by using field observations. Although design guidelines recommend collecting sophisticated berthing records, data are mostly not available. Ueda et al. [19] showed that berthing velocity is the most important design parameter in defining berthing energy. The port authorities of Bremerhaven [7] and Rotterdam [14] therefore decided to start a measurement campaign on berthing velocity in order to evaluate and validate the performance of existing berthing facilities and the design guidance of EAU and PIANC. They wanted to know whether the berthing velocity curves of EAU and PIANC, presented in Fig. 1, are still representative of and safe for modern vessels.

The statistical meaning of berthing velocity curves is often unknown to or misinterpreted by designers and code writers of marine structures [1]. Where berthing records are available, existing design guidelines do not provide explicit recommendations with regard to the statistical examination of berthing velocities. It is therefore mostly not clear how to use field observations.

This study aims to provide guidance to code developers and engineers on the use of field observations and derivation of partial safety factors for berthing velocity and loads on marine structures. The main focus is on deriving characteristic values and associated partial safety factors for berthing velocity, because this is the dominant parameter in assessing berthing impact [19]. It should be noted that ship collision impact is not taken into consideration in this study [18]. During the study, recently recorded field observations of berthing velocity in the ports of Bremerhaven, Rotterdam and Wilhelmshaven were used to determine theoretical design berthing velocities and corresponding partial safety factors in accordance with the Eurocode standard [10]. The main focus was on comparing characteristic and design berthing velocities based on field measurements with previous design practice. Following modern design principles, partial safety factors were derived by using large datasets for sheltered and exposed navigation conditions.

It was expected that collecting and analysing field observations would contribute to the assessment of berthing facilities and the evaluation of design recommendations. The results of this study show that research could introduce new (business) opportunities by, for example, allowing larger vessels to berth at existing marine structures and/or extending the service life of marine structures.

2. Literature survey

2.1. General principles of berthing energy and impact

The objective of this section is to elucidate the general principles of and methods to account for berthing energy and the resulting berthing impact loads in structural design. Berthing energy is generally calculated on the basis of a large number of parameters in line with the following equation:

$$E_{kin} = {}^{1}\!/_{2} M v^2 \, C_m C_s C_c C_E \quad (1)$$

in which:

E_{kin} Kinetic energy [kNm]
M Mass of vessel/water displacement [tonnes]
v Total translation velocity of centre of mass at time of first contact (includes component parallel and perpendicular to berthing line) [m/s]
C_m Virtual mass factor [−]
C_s Ship flexibility factor [−]
C_c Waterfront structure attenuation factor [−]