International Journal of Offshore and Polar Engineering
Vol. 6, No. 1, March 1996 (ISSN 1053-5381)

Wave Forces on a Horizontal Plate

Michael Isaacson* and Shankar Bhat
Department of Civil Engineering, University of British Columbia, Vancouver, Canada

ABSTRACT

An experimental study of the vertical force due to regular nonbreaking waves acting on a rigid horizontal plate located near the water surface is described. Time histories of the force and corresponding water surface elevations are measured for various wave heights, wave periods and plate elevations. These are analyzed to provide results relating to the maximum upward and downward forces, their times of occurrence, and their points of application. The results are used to relate the force characteristics to suitable parameters governing the problem. A numerical model of the force time history is considered and compared with the experimental results.

INTRODUCTION

Impact forces due to wave slamming are of considerable importance in the design of coastal structures. In particular, wave slamming on the underside of the deck of a wharf is a critical factor in the selection of deck elevation relative to the still water level and in the structural design of the wharf. Although the Morison equation is widely used for the calculation of wave forces on fully submerged slender structural elements, it is unable to predict such impact forces acting on a deck which encounters intermittent submergence.

Several experimental studies have addressed the problem of waves interacting with a horizontal plate close to the still water level. Measured uplift forces and pressures have been compared with theoretical predictions based on momentum and energy considerations (Wang, 1970; El Ghamry, 1971; French, 1979; Tanimoto and Takahashi, 1979). Toumazis, Shih and Anastasiou (1989) studied the impact by analyzing measured pressures in conjunction with observations based on video records. More recently, Kaplan (1992) extended the theory of ship bottom slamming to the case of a flat plate, and expressed the vertical force as the sum of momentum and drag components. In spite of these and other studies, the various results that have been obtained exhibit considerable scatter, giving rise to some uncertainty in the application of such results to design situations. Such scatter arises, in part, because wave slamming experiments generally involve the measurement of forces which are highly dynamic, so that the dynamic response of the measurement system may influence the characteristics of the measured force. Furthermore, the observed force is also dependent on various factors such as air entrainment, air compressibility, the roughness of the structure surface, and structure inclination.

The present paper describes an experimental investigation of the vertical force acting on a fixed, rigid, horizontal plate located above the still water level. The corresponding study has been described in detail by Bhat (1994) and a brief summary has been given by Isaacson and Bhat (1994). The case of unidirectional periodic nonbreaking waves propagating in a direction parallel to the longitudinal axis of the plate is considered. The vertical force and corresponding wave records are measured for various wave heights, wave periods, and plate elevations. These force records are analyzed to provide an assessment of the influence of relevant dimensionless parameters on the measured force. Video records have also been used to assess the impact process. The results are used to relate the characteristics of the force to suitable parameters describing the problem. A numerical model of the force time history is considered and compared with the experimental results.

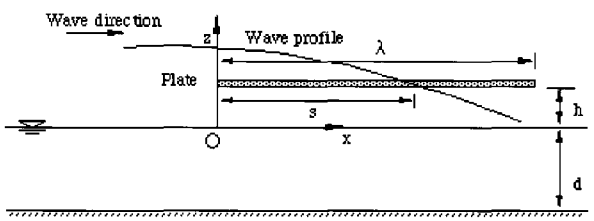

Fig. 1 Definition sketch

THEORETICAL CONSIDERATIONS

A rigid horizontal plate of length λ, width b, and negligible thickness is located at an elevation h above the still water level, and is subjected to a unidirectional, regular, nonbreaking wave train propagating in the direction of the plate's longitudinal axis (Fig. 1). On the basis of a dimensional analysis, the vertical force F on the plate may be expressed in the form:

$$\frac{F}{\rho g H b \lambda} = f\left(\frac{H}{L}, \frac{d}{L}, \frac{h}{H}, \frac{\lambda}{L}, \frac{b}{\lambda}, \frac{t}{T}\right) \tag{1}$$

where ρ is the water density, g is the gravitational constant, H is the wave height, L is the wave length, T is the wave period, and t is time. This equation ignores the influence of fluid viscosity, air compressibility and surface tension. H/L is the wave steepness, d/L is a depth parameter, λ/L is a relative plate length, b/λ is the relative plate width, and h/H is the relative clearance of the plate such that for sinusoidal waves there is no wave contact for $h/H > 0.5$.

It is of interest to examine the possibility of developing an expression for the time-varying vertical force F acting on the plate, particularly during the initial stages of submergence. Such

*ISOPE Member.

Received February 15, 1995: revised manuscript received by the editors October 13, 1995. The original version was submitted directly to the Journal.
KEY WORDS: Coastal engineering, coastal structures, hydrodynamics, wave forces, waves.