Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Wave Loads on Piles — Spectral Versus Monochromatic Approach

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ABSTRACT

In this paper, wave loads on a surface piercing vertical cylindrical pile are presented using the spectral and monochromatic approaches. While the basis of wave load computation for both the approaches is the Morison equation, the spectral method is dependent on the force spectrum - a product of RAO and random sea state described in this paper by JONSWAP spectrum. Horizontal load comparisons are made for a total of 4 cases of low Ursell numbers in the applicability range of linear wave theory. For the cases considered, the results indicate that in deep waters > 15 m, the computation intensive spectral method yields the best load estimate.

KEY WORDS: Wave; force; spectrum; RAO; drag; inertia; cylinder.

NOMENCLATURE

A = cross-sectional area of the cylinder
C_d = drag coefficient
C_m = inertial coefficient
d = still water depth
D = diameter of the cylinder
d_h = linear theory depth reduction factor
k = wave number = $2\pi/L$
L = local wave length
f = wave frequency = 1/T
f_p = peak wave frequency = $1/T_p$
H_s = significant wave height
t = time
T = wave period
T_p = peak spectral period
u = wave orbital velocity
u_{av} = depth-averaged orbital velocity
$\dot{u}$ = wave orbital acceleration
x = distance along the direction of wave propagation
z = vertical coordinate, positive upward from still water level
γ = JONSWAP peak shape factor
ρ = density of water
σ_u = standard deviation of the velocity spectrum
ν = kinematic viscosity
ω = wave angular frequency = $2\pi/T$

INTRODUCTION

Shore-attached pile-supported port structures are increasingly moving to open deep-waters as demands for accommodating deep-draft vessels continue to grow (see e.g. Gaythwaite, 2004; Allsop et al, 2006). Despite often being located in the hydrodynamic shallow water regions in considerations of peak spectral period, such structures are subjected to wave loads from unmodulated random sea states. This requires that the usual practice of applying the simplistic method using monochromatic wave is compared against the more sophisticated spectral method.

This paper examines this issue, and presents the computational results for some low Ursell number (around 5) cases. Waves around this Ursell number can be described by linear wave theory. For diffraction parameter ($\pi D/L_p$) < 0.5, the basic tool for estimating wave load on a vertical cylindrical pile is the Morison equation (Morison et al, 1950). Figure 1 shows a schematic vertical cylinder in a linear wave field.

The random sea state is described in this paper by one-dimensional JONSWAP spectrum (Hasselmann et al, 1973; Goda, 1979). JONSWAP spectrum, developed using North Sea wave measurements is often used to describe offshore waves (Wilson, 2003). The corresponding monochromatic wave is characterized by significant wave height and peak spectral period. Random wave load computations are based on spectral wave kinematics with the in-line inertial and linearized drag force RAOs (Response Amplitude Operators) and depth-varying drag and inertial coefficients. The corresponding monochromatic wave load computation is based on similar depth-varying coefficients.

With a brief description of study cases and methods, the paper presents the investigated cases and results.

STUDY CASE

Four study cases of different wave heights, periods, depths and cylinder diameters are included in this study. Table 1 describes the case parameters together with the computed Ursell numbers (UR = H_s^2L/d^3) and Kuelegan-Carpenter numbers (KC = $u_{av}T_p/D$). The choice of the wave parameters is arbitrary, but reflects the necessity of maintaining a