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A COMPARATIVE EXPERIMENTAL STUDY OF WAVE FORCES ON A VERTICAL CYLINDER IN LONG-CRESTED AND SHORT-CRESTED SEAS

by

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Introduction

An experimental study is carried out to investigate the wave forces on a slender cylinder. Special attention is given to the wave forces in the surface zone and correlation of forces along the cylinder.

The experiments consider the effects of both long and short-crested irregular waves.

Model Facilities

Ongoing tests are performed in the 3-D ocean wave basin in the Hydraulics Laboratory at the Department of Civil Engineering, University of Aalborg (Fig. 1). The water depth during the experiments is 1.0 m and 1.20 m, respectively. The wave heights are ranging from 0.10 m to 0.30 m.

Experimental set up

A vertical pile with a diameter of 63.5 mm and a length of 1.5 m is equipped with 12 strain gauges shear force transducers, densily spaced mainly in the surface zone (Fig. 2). Each transducer consists of a 31 mm wide ring mounted on a central beam. Both in-line and transversal force measurements are carried out. In addition total forces at the bottom and the top of the pile can be recorded.

Test programme

Total and local in-line and transverse forces are measured over a Reynold's number range of $0.8 \cdot 10^4 \leq Re \leq 3.3 \cdot 10^4$ and a Keulegan-Carpenter number range of $5 \leq KC \leq 15$. Simultaneous measurements of the water surface profile are also recorded.

Both single harmonic monochromatic waves, irregular waves (random phase JONSWAP spectra), and short-crested seas having a $cos^2\theta$ distribution and zero correlation between the components are used.

Results

The scope of the tests is a comparative study of the wave forces, in the surface zone in 2-D seas and 3-D seas, respectively.

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The distribution of the in-line wave forces along the pile has been used to examine the validity of the Morrison-type force prediction models. Wave kinematics due to Stoke's 5. order wave theory together with Sarpkaya's force coefficients have been used in the predictions of the wave forces.

In accordance with many other authors the Morison force model is found to be a reasonable estimate in shallow water waves with small steepness while it is less reasonable for steep waves (Fig. 3).

It is known that the transversal forces generally have higher frequencies than the in-line forces and are smaller and more irregular than the in-line forces. The irregularity of the transversal forces are studied based on the correlation function or normalized covariance function

$$\rho_{F_yF_y}(z,\Delta z) = E\left[F_y(z)\cdot F_y(z+\Delta z)\right] \Big/ \sqrt{E\left[F_y^2(z)\right]\cdot E\left[F_y^2(z+\Delta z)\right]}$$

The length scale l_c of the correlation function corresponds to the part of the pile where the full correlated transversal force should act in order to give same resulting force as the transversal force if distributed in accordance with the correlation function.

$$l_c(z) = \int_{-\infty}^{\infty} \rho_{F_yF_y}(z,\delta z)\,d\Delta z$$

Fig. 4 shows an example of $l_c(z)$ corresponding to long crested regular waves (with mean water level as reference point). As seen $l_c(z)$ is not a simple function of just KC and Re.

Further results including comparisons of force correlation in 2-D and 3-D waves will be discussed in the paper.

REFERENCES

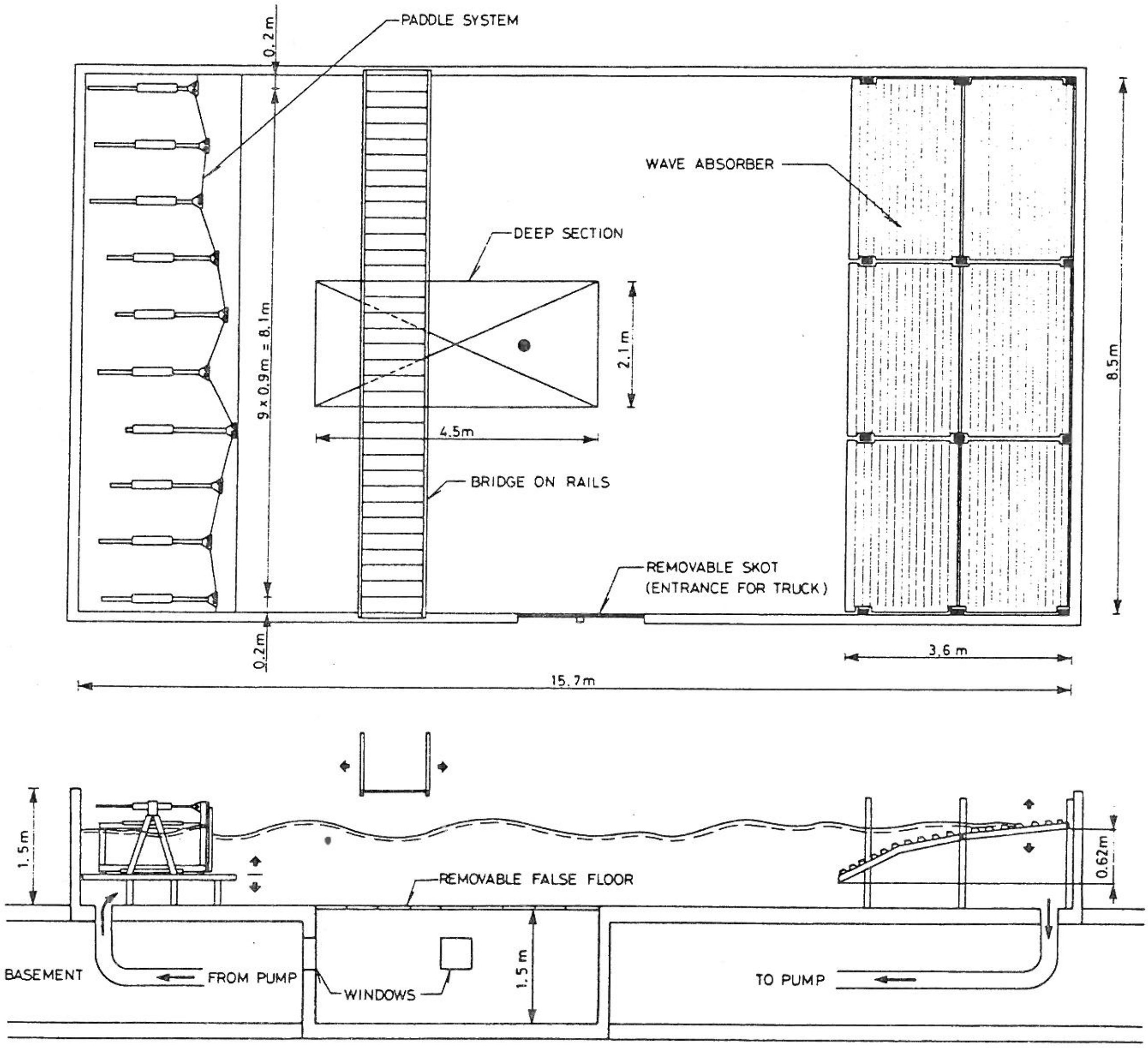
Burcharth, H.F., S.R.K. Nielsen and K. Schaarup-Jensen : *A three dimensional sea facility for deep and shallow water waves.* Proc. OMAE Symposium, Tokyo, 1986.

Sarpkaya, T. and Isaacson, M : *Mechanics of wave forces on offshore structures.* Van Nostrand, 1981.

Torum, A. : *Wave forces on a pile in the surface zone. Regular, non-breaking waves.* Marintek. Report No. 1.9, Dec. 1985.

Kjeldsen, S.P. and Aahre, A. : *Wave forces on vertical piles near the free surface caused by 2-D and 3-D breaking waves.* Marintek. Report No. 1.10, Nov. 1985.

LIC Engineering A/S : *Bølgebelastning på cylinder i 2-D og 3-D bølger. Forsøgsbehandling.* Energiministeriet EFP 85. July 1987 (in Danish).



● cylinder

Figure 1. The 3-D ocean wave basin in the Hydraulics Laboratory, University of Aalborg.

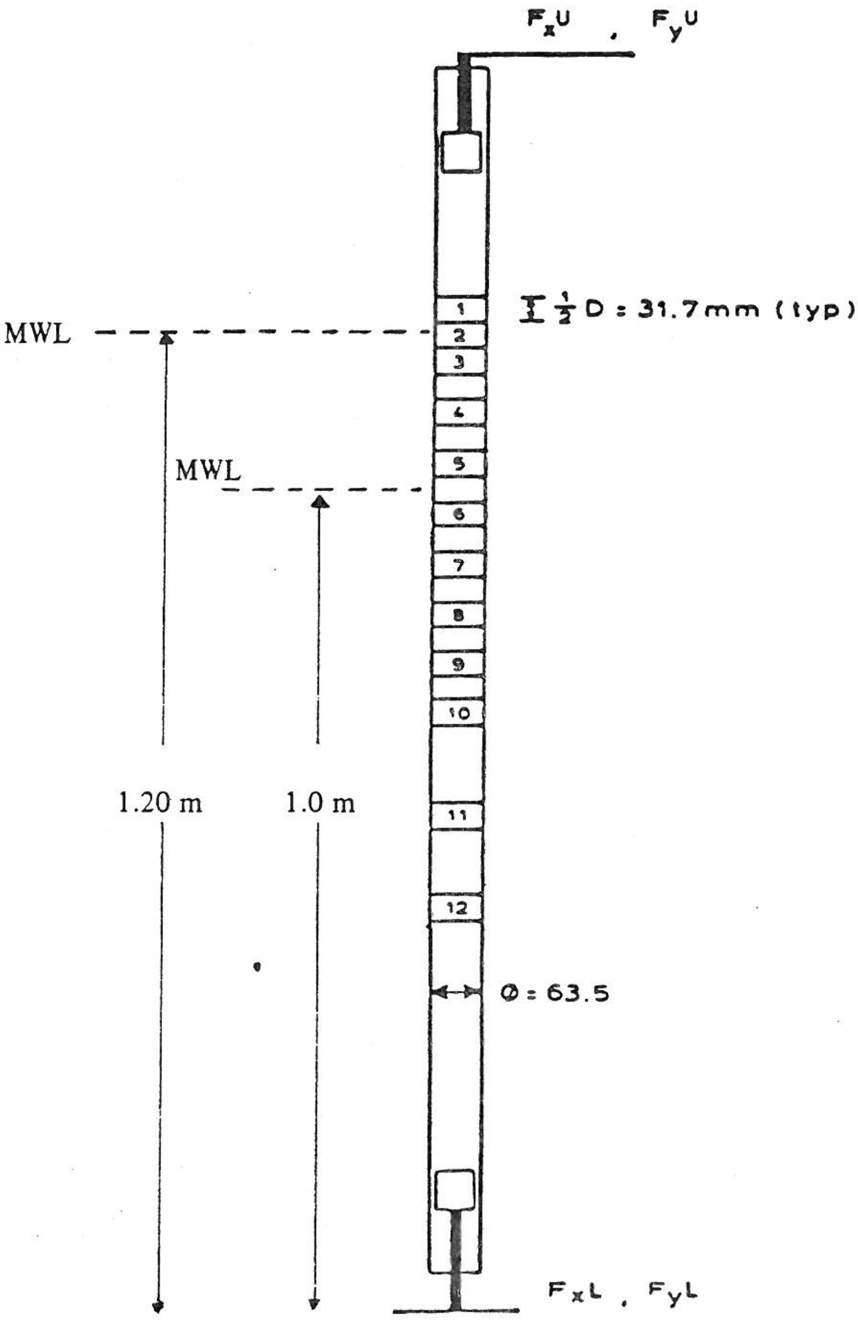


Figure 2. Sketch of the cylinder.

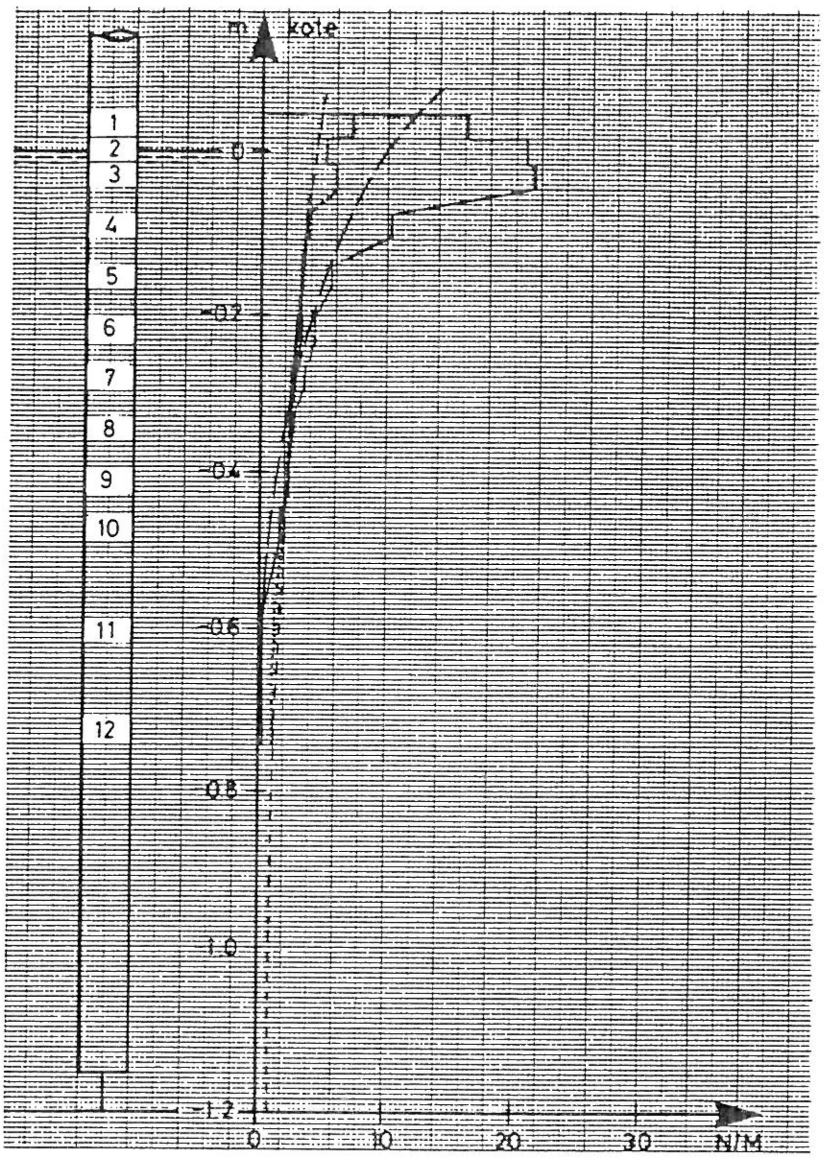


Figure 3. Comparison of measured and computed in-line force distribution (example).

H = 0.15 m T = 1.0 sec. t = 0.25 sec.

——————— measured

— —— — computed using Morison's equation.
Kinematics from Stoke's 5. order wave theory.
$C_d = 1.8$ $C_m = 1.0$

H = 0.15 m T = 2.0 sec. t = 0.50 sec.

. . . . measured

– – – – – – – computed using Morison's equation.
kinematics from Stoke's 5. order wave theory.
$C_d = 1.8$ $C_m = 1.0$

$10^{-4} \cdot Re$	KC	l_c/D
1.5	4.9	0.9
3.0	9.9	0.5
1.8	7.5	3.7
2.7	12.0	0.7
1.2	9.0	1.8
0.8	6.0	2.4
1.2	5.0	2.3
0.9	5.6	1.1
1.1	5.1	0.9

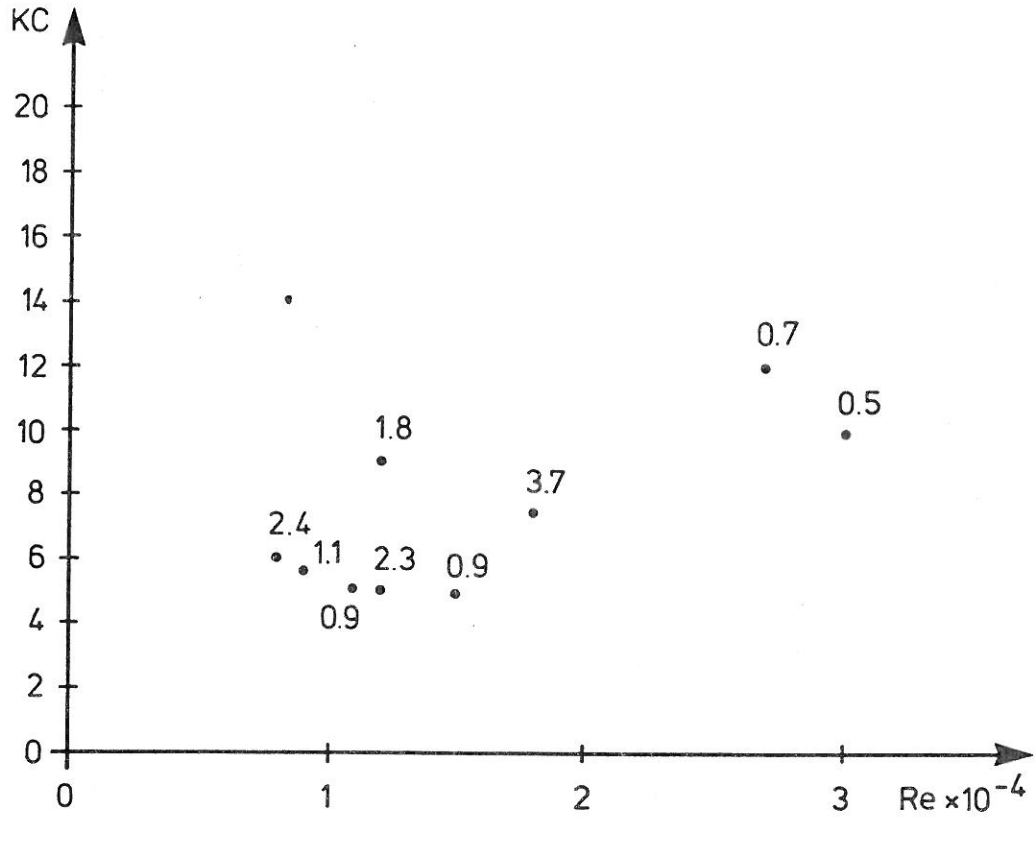


Figure 4. Examples of the ratio l_c/D from experiments in regular waves.