BURIEL AND SCOUR OF SHORT CYLINDERS DUE TO LONG-CRESTED AND SHORT-CRESTED NON-LINEAR RANDOM WAVES

Dag Myrhaug, Muk Chen Ong and Peder Hesten

Department of Marine Technology
Norwegian University of Science and Technology
Trondheim, Norway

Introduction

- Typical examples of short cylinders are sea mines on the seabed, which originally installed e.g. on a plane bed, may experience a range of seabed conditions.
  The bed may be flat or rippled, the cylinder may be surrounded by a scour hole, and they may be self-buried.
  This is caused by the complicated three-dimensional flow generated by the incoming flow, the cylinder and the seabed.
  Moreover, ocean surface waves are short-crested where the sharpening of the wave crests manifests wave nonlinearity making the problem more complex.

- Commonly used procedure for random waves is the deterministic method, i.e. to use the regular wave formulas by replacing all the wave-related quantities with their *rms* (root-mean-square) values and an appropriate characteristic wave period.

Some previous works

- Whitehouse (1998), Sumer and Fredsøe (2002); reviews of scour.
- Voropayev et al. (2003); burial of short cylinders under shoaling regular waves over a sloped sandy bottom.
- Catano-Lopera and Garcia (2006, 2007); scour around and self-burial of short cylinders exposed to steady currents and regular waves.
- Myrhaug and Ong (2009); burial and scour of short cylinders in long-crested random waves plus current, including effects of second order wave asymmetry.

Purpose

- To provide a practical stochastic method for calculating the burial and scour depths of short cylinders due to long-crested (2D) and short-crested (3D) nonlinear random waves.

This is achieved by using

- formulas for the burial and scour depths of short cylinders for regular waves plus currents presented by Catano-Lopera and Garcia (2006, 2007) in conjunction with a stochastic approach by assuming the waves to be a stationary narrow-band random process.

- the Forristall (2000) wave crest height distribution representing 2D and 3D nonlinear random waves.

Burial and Scour in Regular Waves

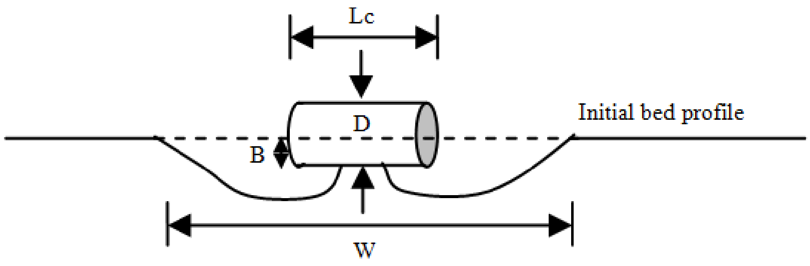


Fig. 1

$$\frac{Y}{D} = pKC^r\theta^s \qquad KC = \frac{UT}{D}$$

$$\theta = \frac{\tau_w}{\rho g(s-1)d_{50}} \quad ; \quad \frac{\tau_w}{\rho} = \frac{1}{2} f_w U^2$$

Table. 1

Y	p	r	s
B	0.24	0.4	0.4
L_{sd}	0.75	0.56	0
L_{st}	$0.75a_r^{0.3}$	0.6	0

$$Y = B: \quad 2 \le KC \le 48$$

$$Y = L: \quad 2 \le KC \le 71$$

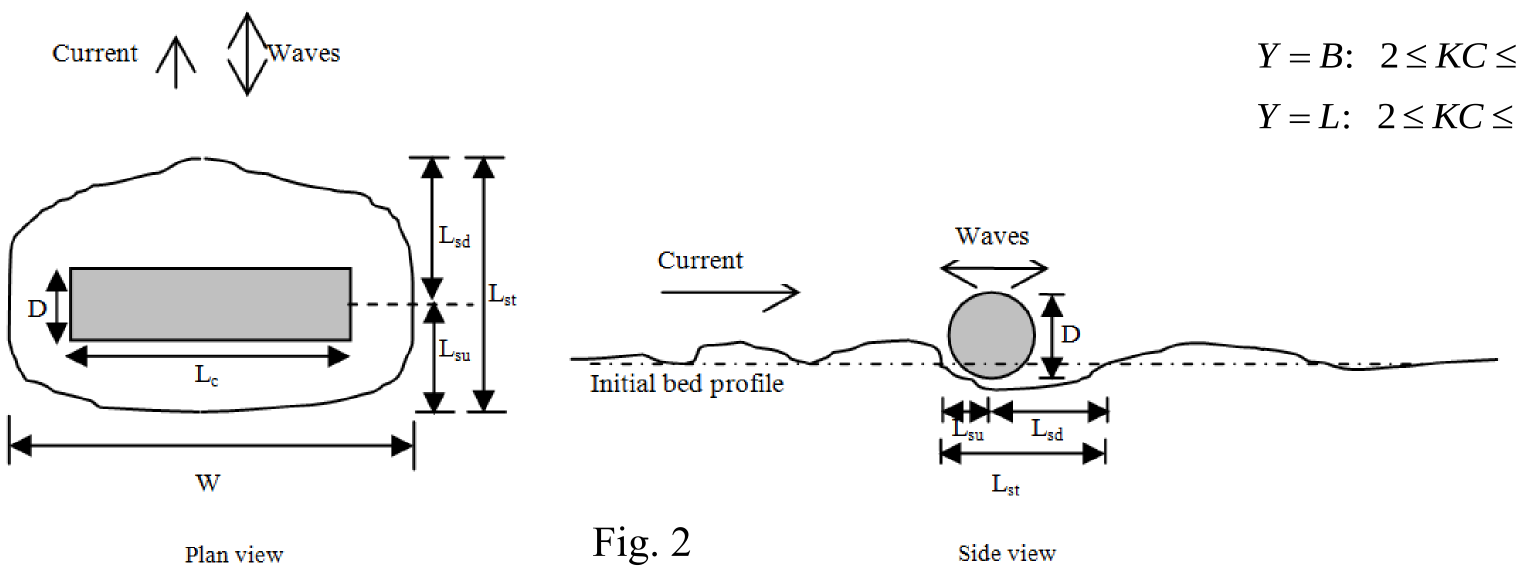


Fig. 2

Burial and Scour in Random Waves

The mean value of the maximum equilibrium burial and scour characteristics caused by the (1/n)th highest wave crests

$$E\left[Y(\hat{U})\,|\,\hat{U} > \hat{U}_{1/n}\right] = n\int_{\hat{U}_{1/n}}^{\infty} Y(\hat{U})\,p(\hat{U})\,d\hat{U} \quad ; \quad \hat{U}_{1/n} = \sqrt{8}\alpha(\ln n)^{1/\beta}$$

$p(\hat{U})$ is the probability density function (pdf) of the non-dimensional near-bed wave induced velocity under the wave crest (i.e. Forristall, 2000)

$$p(\hat{U}) = \frac{dP(\hat{U})}{d\hat{U}}, \qquad P(\hat{U}) = 1 - \exp\left[-\left(\frac{\hat{U}}{\sqrt{8}\alpha}\right)^{\beta}\right] \quad ; \quad \hat{U} = U_c / U_{rms} \geq 0$$

α, β estimated from the fit to the simulated wave data based on Sharma and Dean (1981) depending on the wave steepness $S_1 = 2\pi H_s / gT_1^2$ and Ursell number $U_R = H_s / k_1^2 h^3$

This is based on the assumptions

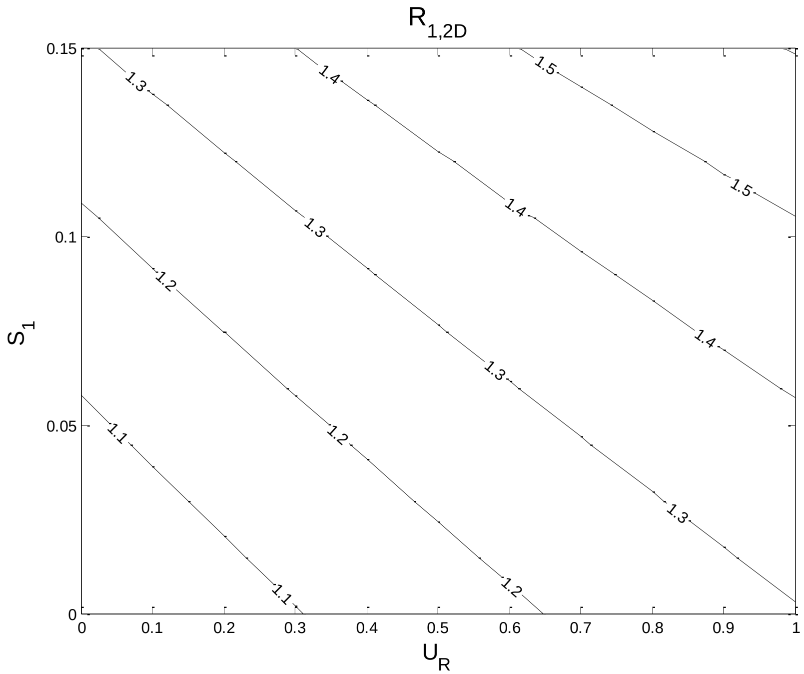
- the wave motion is a stationary narrow-band random process

- the burial and scour formulas for regular waves are valid for irregular waves (i.e. are re-arranged to be valid for individual irregular waves)

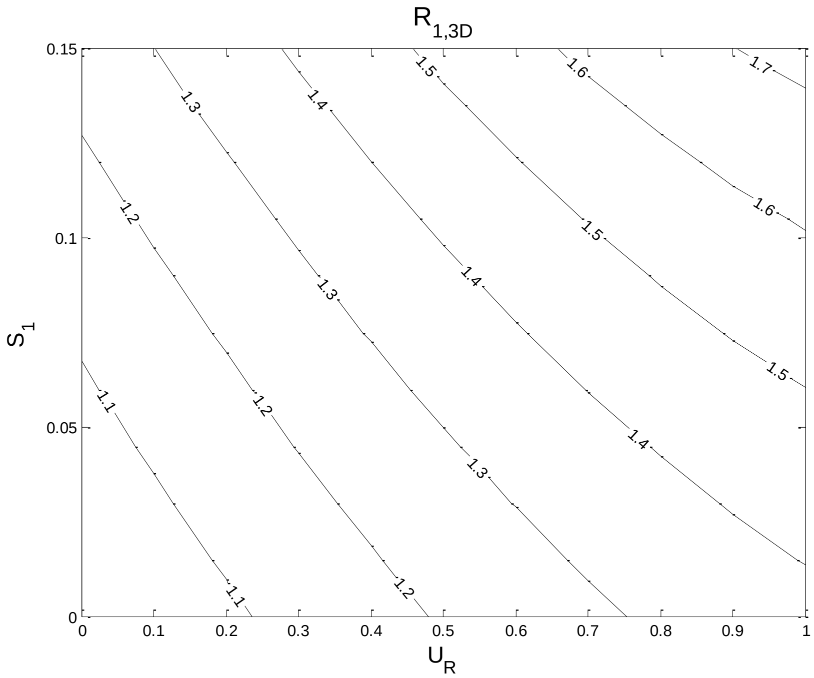
Results and Discussion (1)

Nonlinear to linear ratio

Example of results for the burial depth for *n* = 10



2D



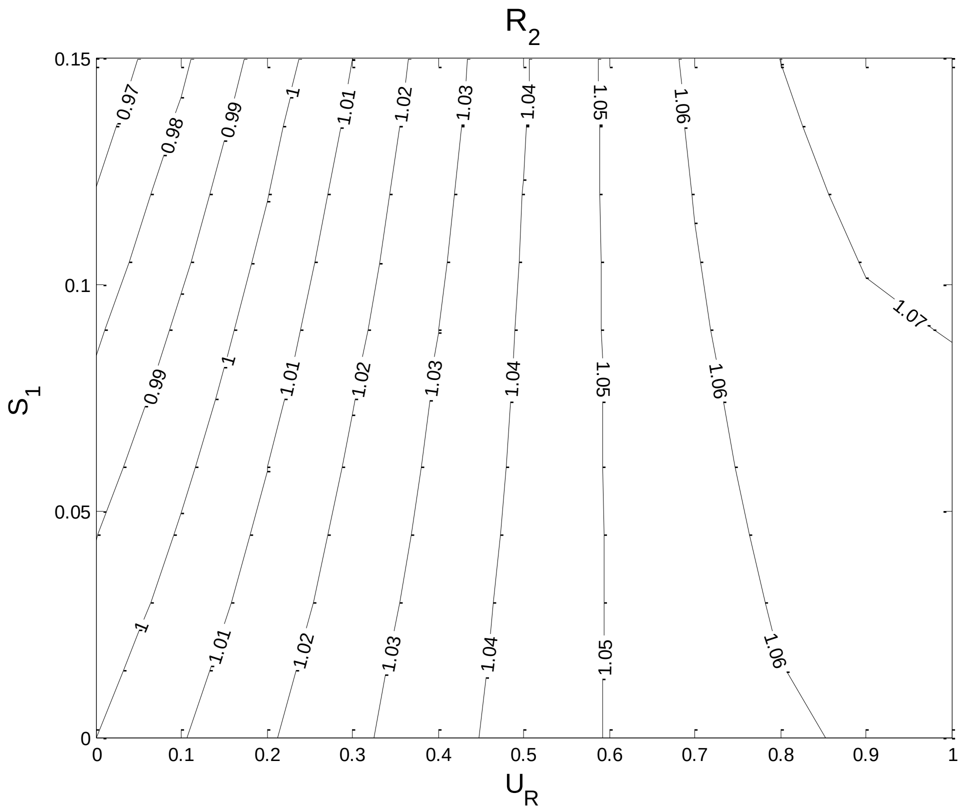
3D

NTNU

Institutt for marin teknikk

Results and Discussion (2)

Ratio between maximum equilibrium burial depth for 3D waves and max equilibrium burial depth for 2D waves for n = 10



NTNU

Institutt for marin teknikk

Summary

A practical approach for estimating the burial depth and the length of the scour hole for short cylinders exposed to 2D and 3D nonlinear random waves is provided.

Examples of results for the burial depth, *B*, show that:

•For both 2D and 3D waves

$$B_{2Dnonlin} > B_{lin} \quad ; \quad B_{3Dnonlin} > B_{lin}$$

The difference increases as the water depth decreases and as the steepness of the sea state increases.

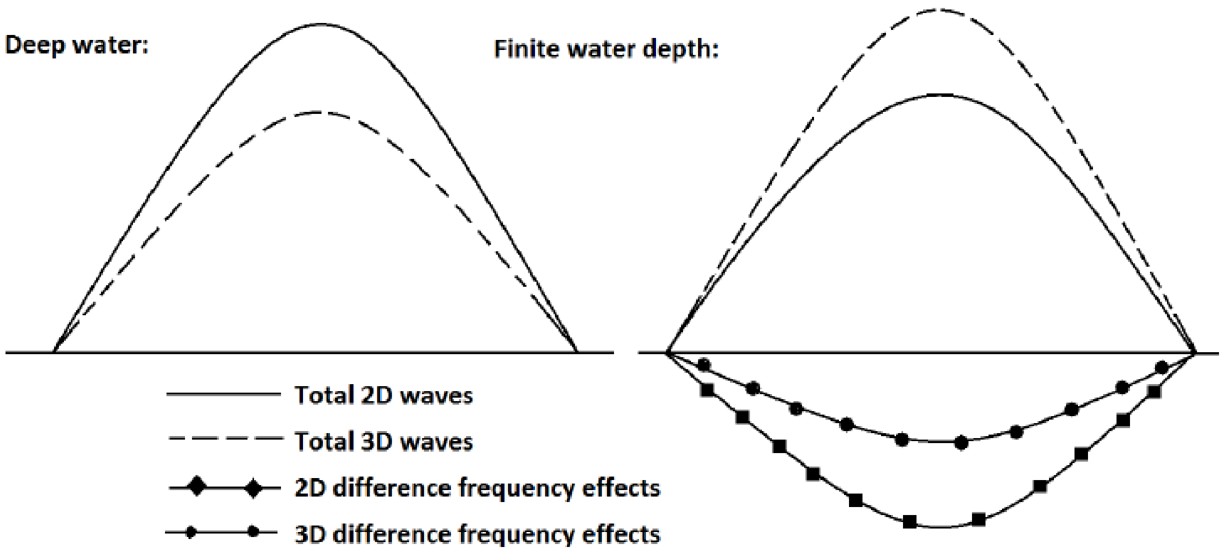
•When the water is shallow enough it appears that $B_{3Dnonlin} > B_{2Dnonlin}$, and that this difference increases as the water depth decreases. This behaviour is attributed to the smaller wave setdown effects for 3D waves than for 2D waves; the difference, however, appears to be small.

•The present results should be taken as tentative, and data for comparison are required before any conclusion can be made regarding the validity of the approach.

Features of 2D and 3D Random Waves included in the Forristall (2000) distribution

The wave setdown effects are smaller for 3D than for 2D waves, which is due to the fact that the 2nd order negative difference frequency terms are smaller for 3D waves than for 2D waves.

Consequently: $\eta_{c3D} > \eta_{c2D}$



NTNU
Institutt for marin teknikk