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Onset of Scour Below a Pipeline Exposed to Waves

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ABSTRACT

Experiments were carried out in a wave flume to investigate whether or not tunnel erosion will take place. The main parameters studied are the initial burial depth and the Keulegan-Carpenter number (KC). The results indicate that the critical burial depth beyond which no scour occurs is a function of the KC number. The larger the KC number, the larger the critical burial depth. Also presented in the paper are the results of bed shear-stress measurements in the vicinity of a pipeline exposed to an oscillatory flow as well as the pressure distributions around a pipeline mounted on the bed. The latter information sheds light onto the mechanism responsible for the onset of scour in waves.

NOMENCLATURE

C_p : pressure coefficient (Eq. 6)
d : sand size
D : pipe diameter
e : burial depth of pipeline
e_{cr} : critical burial depth beyond which no scour occurs underneath pipeline (Eq. 8).
f : friction coefficient ($U_{fm} = \sqrt{f/2}\ U_m$)
f_w : wave frequency
g : acceleration due to gravity
k^* : relative roughness ($k^* = k/D$)
KC : Keulegan-Carpenter number
n : porosity
p : pressure
Re : Reynolds number (Eq. 3)
s : specific gravity of sand
t : time
T : wave period
U : outer flow velocity
U_m : maximum outer flow velocity (Eq. 2)
U_f : friction velocity
U_{fm} : maximum value of friction velocity
x : distance from pipe in streamwise direction
γ : specific weight of water
θ : Shields parameter, corresponding to undisturbed flow
θ_{cr} : critical value of Shields parameter for threshold of sediment motion
ν : kinematic viscosity
ρ : water density
τ_o : bed shear stress, corresponding to undisturbed flow
ω : angular frequency of waves
Δp : pressure difference between upstream and downstream ends of part of pipe circumference in contact with bed
Δx : part of pipe circumference in contact with bed

INTRODUCTION

Scour below a partially buried pipeline may occur if the burial depth of the pipe is not very large, and if the flow around the pipe is sufficiently strong.

The conditions under which the onset of scour occurs have been studied by Mao (1986) and more recently by Chiew (1990) in steady currents.

Mao described the role of separation vortices that form in front and at the rear of the pipe in the process of the onset of scour. Also, he discussed the groundwater flow underneath the pipe in relation to the onset of scour. The latter has been further elaborated by Chiew. He measured the pressure distribu-tions around a pipe buried in the bed with two embedment ratios, namely 0.06 D and 0.5 D where D = the pipe diameter. It was found that the pressure gradient across the pipe was greatly reduced in the latter case. Chiew further linked the onset of scour to the phenomenon of piping.

The purpose of the study presented in this paper is to investigate the onset of scour underneath a pipeline partially buried in the seabed and exposed to waves.

EXPERIMENTAL FACILITY

Two kinds of experiments were conducted:

1) Bed shear-stress measurements in the vicinity of a pipe mounted on the bed in oscillatory flows, and 2) actual scour experiments in waves.

Bed Shear-Stress Measurements

The bed shear-stress measurements were carried out in a U-shaped oscillatory-flow water tunnel, which has a working section 10 m in length, 0.39 m in width and 0.29 m in height. This tunnel is the same as that described by Jensen et al. (1989). The pipe was a circular cylinder, 5 cm in diameter and 39 cm in length. The surface of the cylinder was smooth. Two kinds of tests were conducted in the study: One with the cylinder placed on the bed, and the other with it placed just above the bed with a gap of 0.05 times the pipe diameter. In the former case, the contact line between the cylinder and the pipe was sealed to ensure no flow of water under the cylinder.

The ratio of the tunnel height to the pipe diameter was 6. According to the potential flow theory, the blockage effect for this value of the height-to-diameter ratio is less than 1%.

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