Backfilling of scour holes around piles

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INTRODUCTION

Observations show that, when the correct conditions exist, a previously generated scour hole around a pile may be backfilled; e.g., a scour hole generated by a steady current is backfilled when the flow conditions change from steady current to waves, see Figure 1. Great many works have been devoted to scour around piles. A detailed account has been given in the books of Whitehouse (1998), Melville and Coleman (2000) and Sumer and Fredsøe (2002). While much has been written on scour, only few studies have been reported on backfilling. The backfilling comes into focus when the time variation of scour depth in a continuously changing flow climate (current, waves and combined current and waves) is considered. Scour around offshore wind turbine (OWT) foundations is a typical example; the bed around an OWT foundation continuously experiences scour and backfilling in an alternating fashion under the ever changing wave and current climate. To the authors' knowledge, no study is yet available investigating, in a systematic manner, backfilling around piles.

The purpose of the study is twofold. One is to gain an understanding of the backfilling process around a pile when the pile is exposed to a changing flow environment (the flow environment changing from, e.g. a steady current to a wave; or from a steady current to combined waves and current; or from a wave to a smaller wave; etc.) The second purpose is to collect data for various characteristics of the backfilling process, including the time scale, for the purpose of establishing design diagrams.

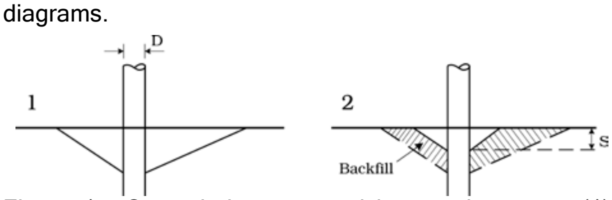

Figure 1 – Scour hole generated by steady current (1). Scour hole backfilled by waves (2).

EXPERIMENTAL SETUP

Experiments were, for the most part, conducted with piles with diameters of D =15 mm, 25 mm, 40 mm and 75 mm. However, some supplementary experiments were also conducted with a large pile with D = 310 mm. Irregular waves were used in the experiments to avoid bed undulations associated with very long testing times, up to 85 hours. The grain size of the sediment (fine sand) used in the experiments was d_{50} = 0.17 mm with a geometric standard deviation of $\sigma_g = d_{84}/d_{50}$ = 1.3. The model pile was embedded vertically in the sediment bed. It was rigidly fixed, extending down to the base bottom of the flume. The 40 mm and 75 mm diameter piles were transparent, enabling the scour and backfilling processes to be monitored by a mini video camera placed inside the pile with the help of a 45° mirror. The overall time development of the scour hole was monitored by a second camera placed outside the pile. With this setup, the scour and backfilling process was videotaped at the offshore side of the pile with a viewing area of approximately 100° in plan view. In the case of waves and combined waves and current, the orbital velocity of water particles at the bed was measured, using a Laser Doppler Anemometer (LDA). The development of backfilling also was monitored in a few experiments, using a 3D optical technique developed at the University of Catania.

RESULTS

The investigation has shed light onto the mechanism behind the backfilling process. The results show that the scour depth corresponding to the equilibrium state of backfilling is the same as that corresponding to the equilibrium state of scour around the pile for the same wave (or combined wave and current) climate.

The time scale of backfilling has been determined as a function of three parameters, namely (1) the Keulegan-Carpenter number, KC_i , of the initial wave (which generates the initial scour hole), KC_i being $KC_i = \infty$ if the initial flow climate is a current; (2) the Keulegan-Carpenter number of the subsequent wave which backfills the scour hole, KC_f ; and (3) the Shields parameter associated with the latter wave, for live-bed conditions. In the case of combined wave and current, the current-to-wave-velocity ratio is also involved. The results show that the time scale of the backfilling process is completely different from that of scour. The time scale of backfilling is much larger than that of scour when the backfilling Keulegan-Carpenter number is KC_f = O(10) or less (typical wind farm application), while the trend is opposite when KC_f >> O(10). A major paper summarizing the results is to appear in Sumer et al. (2012).

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