Scour around Offshore Wind Turbine Foundations

Over the last decades several offshore wind farms have been installed and commissioned in the European waters. Typically the foundations of the wind turbines are protected against scour at the base by installing scour protection with rock dump. The Egmond aan Zee offshore wind farm located about 10 – 18 km off the coast of the Netherlands constructed in 2006, utilized such a scour protection system to prevent removal of the sediment base. Following the installation of the scour protection system and subsequently on a yearly basis an extensive survey campaign has been carried out, to evaluate the performance (stability) of the scour protection and to quantify the edge scour development at the circumference of the scour protection. The survey campaign showed considerable edge scour of up to 2.7 m, which was expected from design considerations. However, no clear information exists on the mechanisms causing the edge scour development around scour protections at offshore wind turbine foundations. The purpose of the present thesis is to investigate and explain the development of the edge scour in such applications, and describe the flow mechanism causing the scour. Furthermore, the dissertation also focuses on the case where the foundation is placed without scour protection.

Here the continuously changing flow climate, comprising currents, waves and combined waves and current forces the scour depth around the foundation to change over time experiencing scour and backfill in an alternating fashion. The scour mechanism and the time development of a scour process in waves, current and steady current has received a vast amount of research over the last decades revealing various features of scour processes. While the scour process seems well documented, relatively few studies have been reported on backfilling and to the authors knowledge no study is yet available, investigating in a systematic manner the backfilling process around monopiles. The thesis therefore also aims at explaining the mechanism and time development of backfill. In Chapter 2, flow and edge scour adjacent to stone covers in steady current propagating in-line with a stone cover layer is studied. The results indicate that the exposure to steady current scours the bed at the side edge of the cover structure, the edge scour. The model tests show that the edge scour is caused by the combined action of the following two effects: (1) Primary flow; and (2) Secondary flow. The primary flow stirs up the sediment and entrains the sediment into the main body of the flow by, and the secondary flow carries the sediment away from the junction between the sediment bed and the cover stones, resulting in the edge scour. With this, stones at the edge of the cover structure are “undermined”, and as a result, slump down into the scour hole. The maximum scour is about 0.8 times the equivalent stone diameter. Abstract XIII

In Chapter 3, flow and edge scour around scour protections at offshore wind turbine foundations are studied by means of particle image velocimetry, hot-film measurements and actual scour tests. The experimental results are supported by a field investigation of edge scour at the offshore wind park Egmond aan Zee and Scroby Sands offshore wind farm. It is found that the edge scour is caused by the local increase in the hydrodynamic field leading to increased sediment transport and scour. The governing flow processes are the horseshoe vortex generated in front of the scour protection berm, the contraction and acceleration flow at the side edge of the scour protection, and a pair of counter-rotating vortices emerging in the near bed wake region of the pile and scour protection. The latter mentioned flow features show a significant potential to scour the adjacent sea bed, and in turn cause loss of stability of the scour protection. Design guidelines are provided to determine the equilibrium stage scour in current, tidal current and combined waves and current. In Chapter 4, a description of the backfilling process around both slender and large piles exposed to waves and combined waves and current, is given, based on results of physical model tests. Using the results it is possible to numerically model and estimate the changing scour depth over time. It is shown that the scour depth corresponding to the equilibrium stage of the backfilling process is the same as that corresponding to the equilibrium stage of the scour process for the same wave or combined waves and current climate. The time scale of the backfilling process has been determined as a function of three parameters namely: (1) the Keulegan-Carpenter number of the initial wave or the current (which generate the initial scour hole); (2) that of the subsequent wave which backfills the scour hole; and (3) the Shields parameter associated with the latter wave for live-bed conditions. In the case of combined waves and current, the current-to-wave-velocity ratio is also involved. 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 Keulegan-Carpenter number associated with the backfilling is ṽ잉 vững锣< ṽ(10) (typical wind farm application), while the trend is opposite when ṽ(10). In Chapter 5, the time scale of scour around a slender vertical pile in combined waves and current is studied. The time scale of scour in combined waves and current is found to depend on three parameters: (1) the Keulegan-Carpenter number; (2) the Shields parameters of the wave component of the flow; and (3) the current-to-wave-velocity ratio. The study indicates that the time scale of scour increase significantly when superimposing even a slight current on a wave. The results further show that the time scale of scour approaches the wave-alone time scale in the wave-dominated regime, and it approaches the current values in the current-dominated regime, as anticipated.

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