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Impact of Offshore Wind Energy Plants on the Soil Mechanical Behaviour of Sandy Seafloors

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Over the last decade, wind energy has become an important renewable energy source. Especially, the installation of offshore windfarms offers additional space and higher average wind speeds than the well-established windfarms onshore.
Certainly, the construction of offshore wind turbines has an impact on the environment. In the framework of the Research at Alpha VEntus (RAVE) project in the German offshore wind energy farm Alpha Ventus (north of the island Borkum in water depths of about 30 m) a research plan to investigate the environmental impact had been put into place. An ongoing study focuses on the changes in soil mechanics of the seafloor close to the foundations and the development of scour. Here, we present results of the first geotechnical investigations after construction of the plants (ca. 1 – 6 months) compared to geotechnical measurements prior to construction.
To study the soil mechanical behaviour of the sand, sediment samples from about thirty different positions were measured in the laboratory to deliver, e.g., grain size (0.063 – 0.3 mm), friction angles ($\sim$ 32°), unit weight ($\sim$ 19.9 kN/m^3) and void ratios ($\sim$ 0.81). For acoustic visualisation, side-scan-sonar (towed and stationary) and multibeam-echosounders (hull mounted) were used. Data show a flat, homogenous seafloor prior to windmill erection, and scouring effects at and in the vicinity of the foundations afterwards. Geotechnical in-situ measurements were carried out using a standard dynamic Cone Penetration Testing lance covering the whole windfarm area excluding areas in a radius < 50 m from the installed windmills (due the accessibility with the required research vessel). In addition, the small free-fall penetrometer Nimrod was deployed at the same spots, and furthermore, in the areas close to the tripod foundations (down to a distance of $\sim$ 5 m from the central pile). Before construction, CPT as well as Nimrod deployments confirm a flat, homogenous sandy area with tip resistance values ranging from 1200 – 1600 kPa (CPT with a mass of $\sim$ 100 kg and an impact velocity of $\sim$ 1 m/s) and quasi-static bearing capacities (qsbc.) mainly ranging from 39 – 69 kPa (Nimrod: mass of $\sim$ 13 kg, impact velocity of $\sim$ 8 m/s). There was no evidence for layering in results of both in-situ instruments. After construction, most of the positions show changes in sediment strength ranging from 10 % up to 100 % compared to the results prior to windmill construction. Extreme changes (> 50 %) occur above all close to the foundations. Furthermore, patterns of relatively soft zones (qsbc.: 50 – 80 kPa) and hard zones (qsbc. > 100 kPa) were mapped during the high-resolution surveys close to the foundation. Beside that, a very soft sediment layer (0.03 – 0.05 m) drapes most of the soft zones. This may be recently eroded and re-deposited sediment, whereas the hard zones may indicate areas of sediment erosion where looser material has been carried away. Reasons for sediment remobilization and changes in geotechnical properties may be scouring as a consequence of the changed hydrodynamics in the vicinity of the windmills. Besides first developments of scour, the side scan sonar results show relicts of the wind turbine erection (e.g., footprints of jack-up-platforms). First multibeam-echosounder measurements confirm sediment re-deposition due to scour in the lee of the main current direction and show traces of wind turbine erection equipment in the same areas where also the penetrometer measurements took place. In summary, a local impact of the wind turbines on the soil mechanical properties of the seafloor is attested from this initial post-erection survey. Future cruises (every 6 months) will complement those data, which will eventually allow us a comparison to, or even refinement of long-term scouring models.