Offshore Test of Hydro Sound Dampers at 'London Array’

Measurements of noise mitigation and ground vibrations

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Pile driving, using hydraulic hammers, during the installation of offshore wind energy foundations produces considerable underwater noise, which radially spreads into the surrounding water. These high acoustic levels pose a threat to marine animals such as harbor porpoises, seals or gray seals. Because of this, the German Federal Maritime and Hydrographic Agency (BSH) implemented a limiting value of 160 dB for the underwater sound level at a distance of 750 m to the pile driving location. This causes many problems at the offshore wind parks, which are currently being built. Due to an increasing economical pressure the size of the hydraulic hammers is increasing in order to drive the piles faster and also the pile diameter is being increased. Both lead to higher noise emissions during the pile driving process. Without any noise mitigation system acoustic levels of up to 180 dB SEL are quite common so that the challenge is to reduce these levels by up to 20 dB SEL. Therefore, to avoid the risk of suspensions of the construction of offshore wind parks, efficient noise mitigation systems are required. In the offshore sector this is the only solution to reach the goal to expand the renewable energies which was set by the German government.

The institute for soil mechanic and foundation engineering at the Technische Universität Braunschweig (IGB TUBS) is currently developing a new noise mitigation system within the research project (FKZ 0325365) „Untersuchung und Erprobung von Hydroschalldämpfern (HSD) zur Minderung von Unterwasserschall bei Rammarbeiten für Gründungen von Offshore-Windenergieanlagen” which is funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). This noise mitigation system uses air filled bladders and PE-foam elements of different sizes to absorb the hydro sound and reach the limiting value set by the BSH. For the developed noise mitigation system ‘Hydro-Sound-Damper’ (HSD) a patent has been granted to K.-H. Elmer in 2010. The HSD is a very promising and economical method to reduce the underwater noise and is based on the theories of dispersion, dissipation, and resonance effects. The principle of operation and the theoretical background of the HSD are explained in detail in previous publications [1], [2], and [3].

In summer of 2012 a first in situ test at the offshore windfarm ‘London Array’ in the North Sea was performed in cooperation with the Aarsleff Bilfinger Berger Joint Venture (ABJV). The main scopes of the test were to proof the applicability of the HSD under offshore conditions and to reach a noise reduction in the important frequency range between 100 Hz and 500 Hz.

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The developed HSD-system for the test meets the specific site conditions. It was designed for monopiles with a maximum diameter of 5.7 m and water depths of up to 25 m lowest astronomical tide (LAT). The HSD consists of three main parts; the buoyancy ring at the water surface, the HSD-net with the damping HSD-elements, and the ballast box, which expands the net down to the seabed. The design principles of the net are described in [2]. The focus was placed on reaching a significant damping effect in the range between 80 Hz and 1000 Hz. Fig. 1 shows a schematic drawing of the HSD on the left side and its application at the test pile on the right.

The construction site for the offshore wind farm ‘London Array’ is located within the Thames estuary and characterized by varying water depths and heterogeneous soils with partially distinct layers. For the tests three locations were available. These lie in very different geological settings with water depths of about 25 m, 19 m, and 15 m LAT. The testing procedure was as follows. First, the pile F05 was driven without any noise mitigation system until the self-stand-criteria (penetration depth of about 20 m) was reached. Now, the HSD was installed without any complications. The pile driving process was continued until the hammer was close above the water surface. At this point, the buoyancy ring was filled with water and lowered to the sea floor as the pile had to be driven until below the water surface and a contact between the hammer and the HSD had to be prevented. Also this additional requirement was fulfilled satisfactorily. It has to be noted that during the first driving phase without the HSD, at a penetration depth of about 7 m a ‘pile run’ of approximately 5 m occurred. During the driving of the reference piles this did not take place. The extra time resulting from the use of the HSD was about 2 hours.

To determine the efficiency of the HSD a measurement concept to meter the hydro sound propagation in the far field was planned and implemented in cooperation with the itap GmbH, Oldenburg. For this, two hydrophones in different water depths were installed at seven different measurement positions (MP). These were located in three directions (with the current, perpendicular to it and against the current) and at distances of 240 m, 750 m and 1500 m. For additional vibration measurements in the far field measurement systems of the Christian-Albrechts-University (CAU) Kiel were used. During the test, three monopiles were installed of which the second pile (F05) was driven while using the HSD. Because of the already mentioned strong geological variations between the test
locations, pile one (G10) and pile three (F04) were driven as reference piles without the use of the HSD. In addition to the hydro sound measurements in the far field by the itap GmbH further hydro sound and vibration measurements from aboard the installation vessel were conducted by the IGB TUBS. An overview of the measurements in the near and far field is shown in Fig. 2.

In the following, first the results of the itap GmbH measurements in the far field are presented. Fig. 3 and 4 show the difference spectra of the 1/3-octave analyses with respect to distance and direction for the piles F05 (with HSD) and F04 (without HSD). Both diagrams show very good damping of up to 19 dB in the relevant frequency range between 80 Hz and 2000 Hz which mainly influences the acoustic level. Moreover, an influence of the sea current on the acoustic damping efficiency cannot be seen. The curves of the results are almost identical for all three directions. The results lead to an overall noise reduction of 9 dBSEL and 10 dBpeak in terms of single values. Further, in the diagram showing the difference spectra with respect to distance in Fig. 4, it can be seen that at around 200 Hz (marked by the red circle) a difference in the levels of up to 8 dB exists. Evaluating the single sound exposure level this leads to an overall noise reduction of 13 dBSEL at this measuring position. This difference might be caused to the sedimentary layering at the location of pile F05. The bearing layer near the surface is followed by a weak layer (‘pile run’), which again lies on top of a bearing layer. Due to this weak layer, the pile driving has a higher effect on the upper bearing layer which besides others results in higher ground vibrations and an increased influence of the soil properties as compared to a homogenous soil.

The effect of the weak layer can also be seen in the vibration measurements on the sea floor (Fig. 5). The vibrations were measured independently in three directions and the maximum amplitude of the resulting vector of the vibration velocities with respect to distance to the pile at a driving energy of 400 kJ is shown in Fig. 5. The vibration velocity decreases from 20 mm/s at a distance of 15 m to 7 mm/s at 45 m. In comparison to other locations is this quite strong.

Summarizing, it can be said that the successful implementation of the HSD-system at the offshore wind farm ‘London Array’ located in the North Sea off of the British coast was shown. Besides demonstrating the applicability of the HSD under offshore conditions, acoustic reductions of the single event levels of 9 dBSEL on average and maximal 13 dBSEL as well as up to 15 dBpeak were determined. In
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the frequency range between 100 Hz and 2000 Hz, which mainly influences the sound exposur level, reductions of up to 19 dB were reached. Further, the evaluations did not indicate an influence of the direction of the sea current on the HSD’s acoustic damping efficiency. Moreover, vibration measurements were evaluated which still showed vibration velocities of 7 mm/s at a distance of 45 m to the pile. Since the offshore test the HSD-system was further optimized. Besides using additional damping elements to attain a better noise reduction in the frequency range below 100 Hz and above 1000 Hz, concepts were developed which allow a serial implementation of the HSD from the first until the last blow of the pile driving process.

References