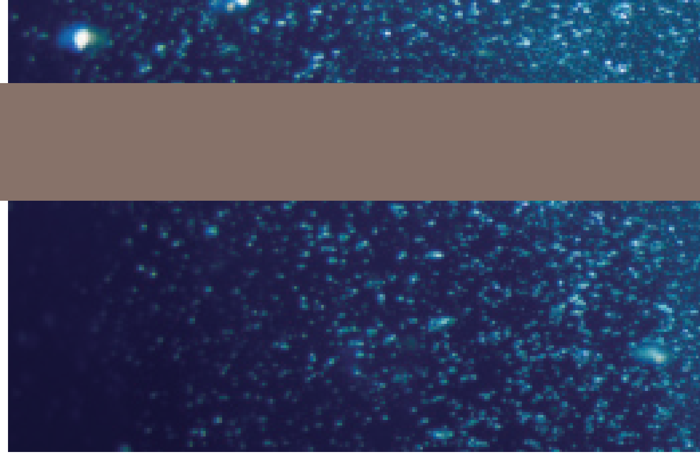

Pile Driving Noise Reduction Approaches

by Mark Wochner

There are various ways to reduce the underwater noise generated by pile driving, but they fall into three basic categories: reduce noise at the source, break the transmission path for it, or absorb it.

Reducing Noise at the Source

Usually the best way to address underwater noise generated from essentially any activity is to reduce it at the source, since noise mitigation technology is never perfect. Vibratory hammers can be used in specific applications where soil conditions allow the pile to be vibrated into the soil. It is a lower-noise solution because it does not require hammer impacts, but it is not an appropriate solution for many soil types where a pile simply needs to be driven into the ground. There are other methods to reduce the noise from impact hammers, though, including the high-frequency low-energy (HiLo) method introduced by IHC or using oversized hammers at lower energy levels, which not only strike the pile but also push it, introduced by Menck. A number of new impact pile driving hammers are also being developed to reduce the peak noise generated by the impact by softening it and extending the rise time of the pressure signal. This can be accomplished through the use of various fluids inside the hammer or by mechanical means using mass-spring systems. Testing shows that they are very promising technologies that should be entering the market very soon.

Break the Transmission Path

Not all noise can be reduced at the source, so other methods may also be required. One method to reduce noise emitted underwater is to contain the sound by breaking the transmission path. If done properly, this method stops the sound from travelling a certain pathway, and it can be done in a variety of ways. One method for infrastructure projects is to use a dewatered cofferdam, in which the water is removed from the area in which the pile is being driven, thus breaking the sound's transmission path through the water. There can still be transmission through the seafloor which can then get back into the water at further distances, so it is not a perfect solution. Other methods for containing sound include the use of barriers such as the IHC IQIP noise mitigation system, which is a double-walled steel pipe with an airgap between the two layers, or a big bubble curtain, which uses compressed air and diffuser hoses to create a wall of air in the water. Both the IHC system and air bubble curtains work primarily through the acoustic impedance mismatch between the water and either the steel of the IHC system or the wall of air bubbles produced by the big bubble curtain. In the field, both systems have proven to be effective, although the seafloor transmission path is still intact with both. It should also be noted that big bubble curtains, due to the fact that they are usually deployed


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much further from the pile than other systems, capture more of the ground-borne vibration than other methods, although they do not attenuate low frequencies as well.

Noise Absorption

The final approach to reducing underwater noise is to absorb the sound rather than just contain it. This is done through the use of acoustic resonator elements which utilize either bubble resonance or Helmholtz resonance phenomena. They are similar but distinct acoustical phenomena that both take advantage of the relatively high compressibility of air compared to water. The advantage of these methods is that they actually absorb the sound, and their acoustic behaviour can be customized to particular applications or regulations.

For bubble resonance, one can think of an air bubble as a mass-spring system in which the “spring” is the compressibility of the air bubble, which wants to spring back after being compressed by an acoustic wave, and the “mass” comes from the water the bubble needs to push in order to go through its volumetric oscillation. The resonance frequency of the bubble is directly related to its volume. To integrate this phenomenon into a noise mitigation system for the real world, the air bubble needs to be contained inside some kind of soft flexible membrane, which allows the bubble to behave as naturally as possible, while being durable enough that it will not break easily. This can be a challenging optimization problem.

The other option is to take advantage of Helmholtz resonance. The simplest example of a Helmholtz resonator is a soda bottle, where blowing over the top of it excites a volumetric oscillation of the air inside the bottle, producing a tone whose frequency is related to the bottle volume, neck length, and opening size. The AdBm noise mitigation system (see photo on page 8) uses this phenomenon and builds custom injection-moulded blocks containing many resonators which are placed open-side down into the water, thus trapping air bubbles in each cavity. They have many advantages: they are simpler to produce, integrate easily into deployment systems, and are durable, all while having higher performance, especially at large depths.

Conclusions

In reality, it is likely that at least a few strategies will be necessary in order to reach desired noise levels, and indeed most offshore wind projects in Europe use a near-pile system to absorb sound and a big bubble curtain to further remove ground-borne noise in order to meet regulations. The most appropriate technologies for a particular project will greatly depend on the relevant regulations and operational constraints specific to that project.

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