PILE DRIVING: NEAR-FIELD CHARACTERISTICS/CONSIDERATIONS

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Outline

- Pile driving structure, components (pile, hammer)
- Near field sound structure
  - Mach wave
  - Effect of the seabed
- Numerical models of pile driving
- Measurements in the near field
  - Block Island Wind Farm
  - Raked piles (piles that are driven at an angle)
- Mitigation (bubble and resonator screens)

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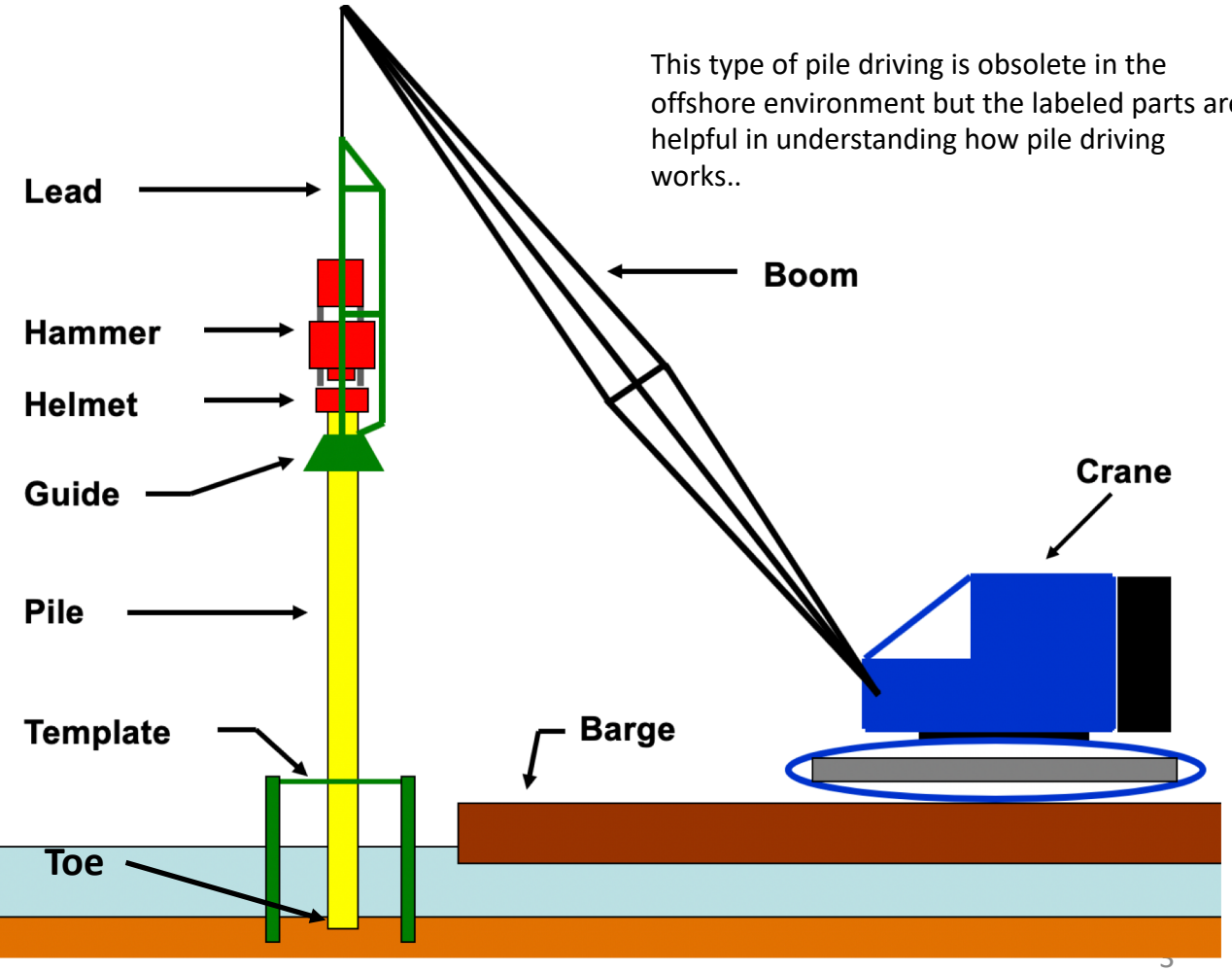
Pile Driving

Pile driving is the operation of forcing a pile into the soil or sediment. A number of methods exist to force the pile but we will concentrate on offshore impact pile driving.

This type of pile driving is obsolete in the offshore environment but the labeled parts are helpful in understanding how pile driving works..



www.piledrivers.org/files/0524d1ba.../2011-pdca-pile-driving-equipment.ppt

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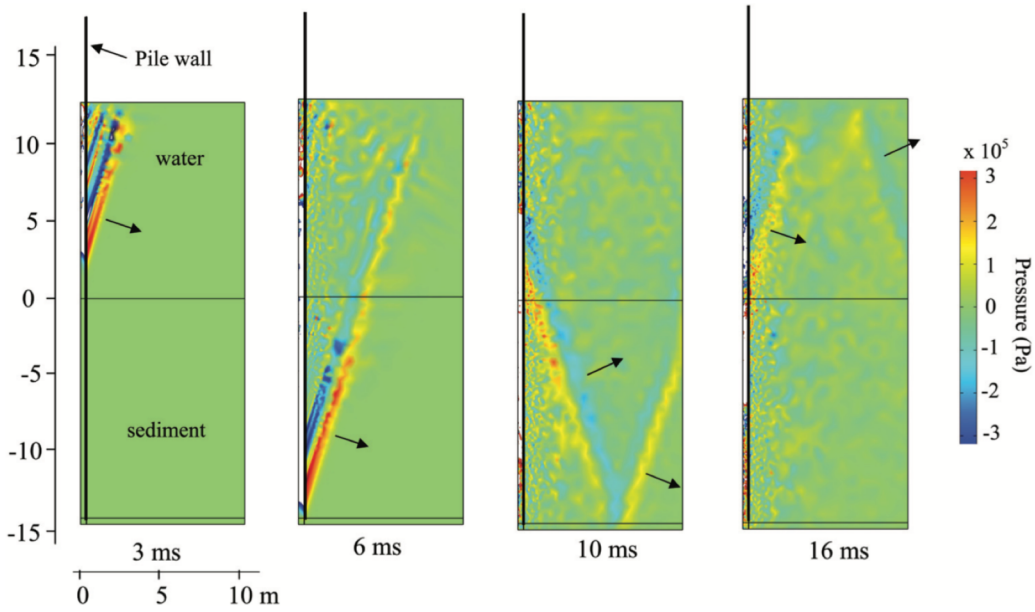
Mach Wave and Effect of Seabed

- The impact of the hammer causes a wave to travel down the pile.
- The wave speed in the steel is about 5900 m/s and greater than water sound speed of 1500 m/s.
- The pile driving creates a Mach wave in the water and sediment with angle of 15^{o} with vertical.
- The pile driving wave propagates down the pile and reflects off the pile toe. The wave also radiates into the sediment much like the water.
- Sediment wave speeds near the seafloor can vary depending on composition, e.g.
  - ~1500 m/s for mud,
  - ~1600 m/s for silt,
  - ~1700 m/s for fine sand, and
  - ~1800 m/s for coarse sand.



P. G. Reinhall and P. H. Dahl: Underwater Mach wave radiation

J. Acoust. Soc. Am., Vol. 130, No. 3, September 2011

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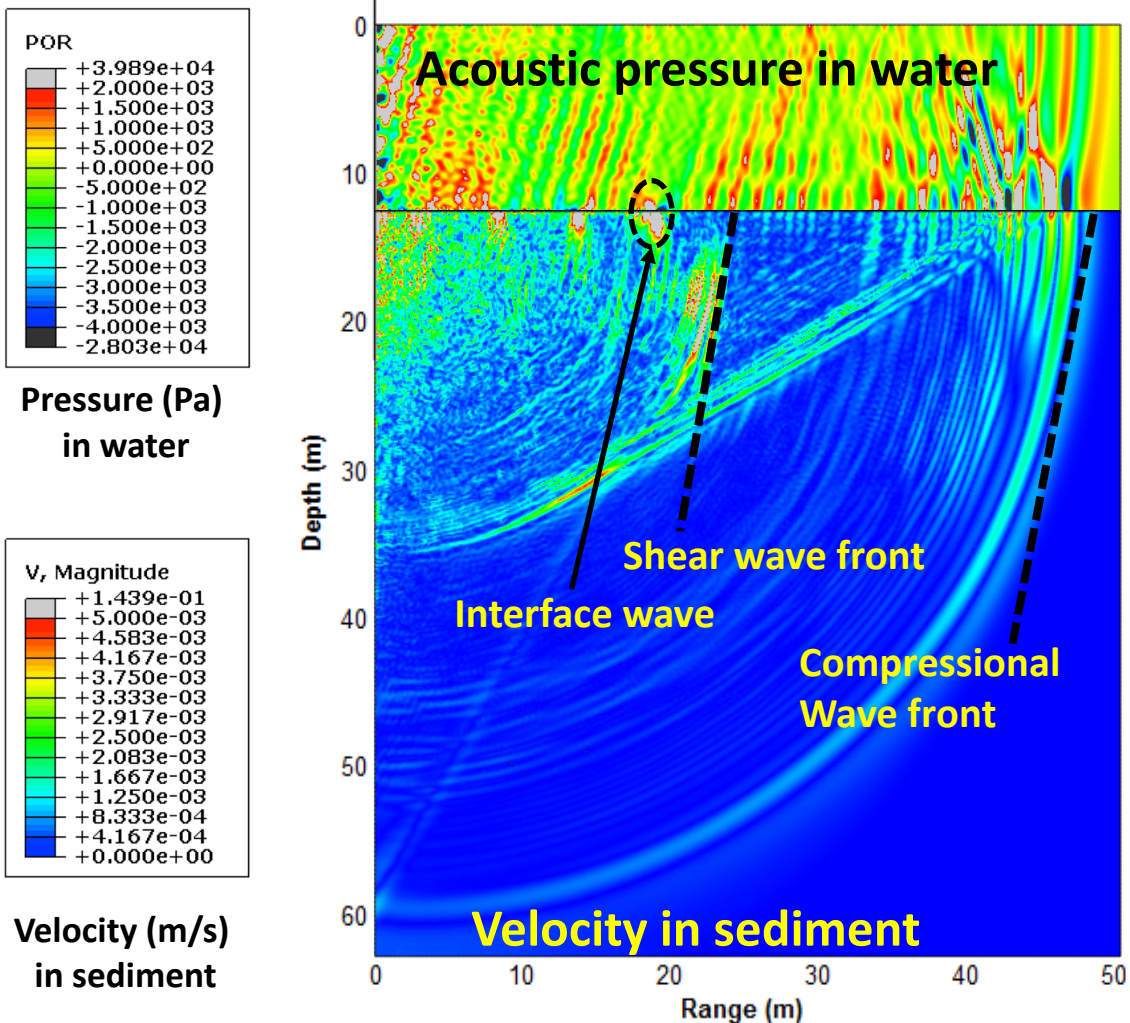
Finite Element Modeling

Compressional wave speed in steel pile is 5920 m/s vs. 1500 m/s creates "Mach wave"



Angle of Mach Wave = 15° in water wrt to the vertical.

- The higher the angle of the Mach wave, the more energy is absorbed by the seafloor.
- But the Block Island Wind Farm piles are not vertical but are raked at an angle of 13.27°.
- Acoustic energy will be very dependent on direction.
- Modeling problem is now 3D!!!

Kim, Miller and Potty, JASA, 2013.
Kim, URI PhD Dissertation, 2014.

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Block Island Wind Farm

- Construction took place in late 2015 on the 30-megawatt Block Island Wind Farm (BIWF) consisting of five turbines in water depths of approximately 30 m.
- The substructure for these turbines consists of jacket type construction with piles driven to pin the structure to the seabed.

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Monitoring Pile Driving

- Pile driving operations carried out in 2015 generated intense sound, impulsive in nature at close range, which radiated into the surrounding air, water and sediment.
- Our team deployed a number of instruments to monitor this noise at several locations from 500 m to 15 km from the pile driving.
- Note the piles are driven at a angle of 13.27^{o} with the vertical.

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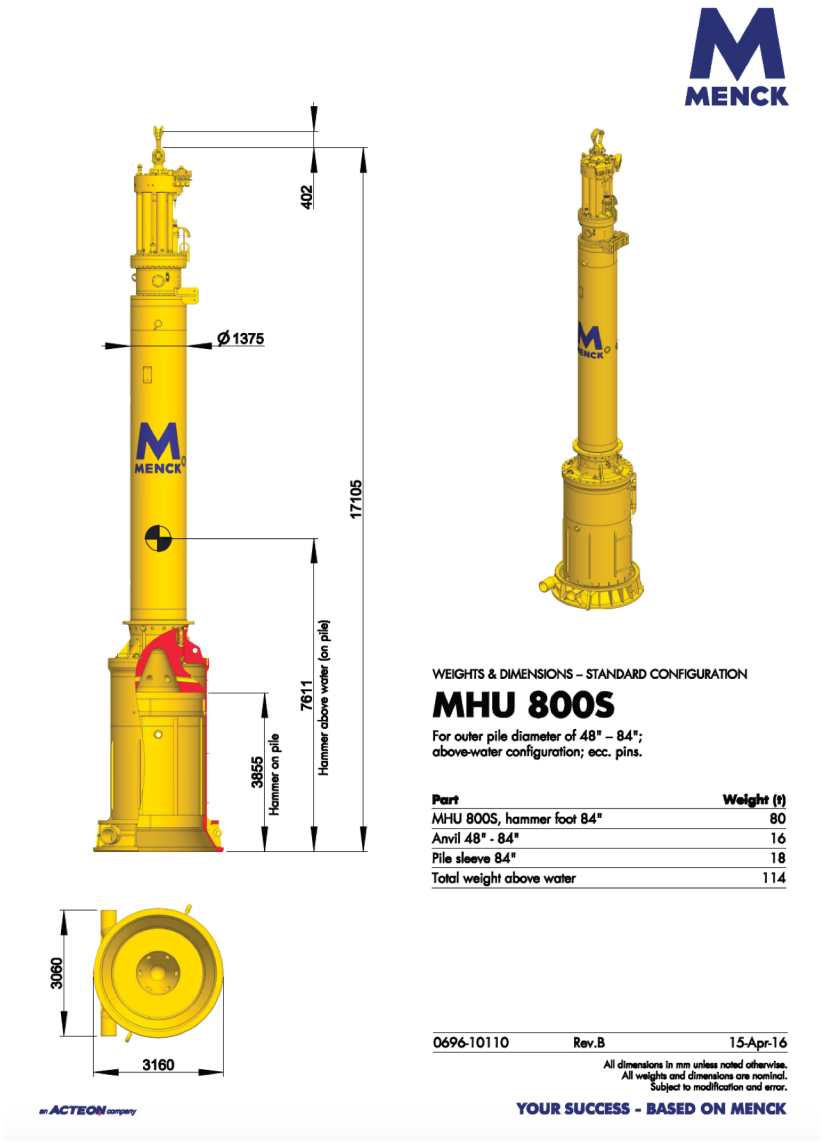
Lattice Jacket Structures

- The Block Island Wind Farm (BIWF) used lattice jacket structures in which piles (“pin piles”) were driven into jackets (templates) supported by a lattice structure.
- This type of construction is appropriate for the moderate water depths of the BIWF. (~27 meters)

Menck Hammer

- Most of the Block Island Wind Farm construction used a hydraulic hammer from Menck.
  - 17 meters tall
  - 3.1 meters dia. base
  - 114 tons



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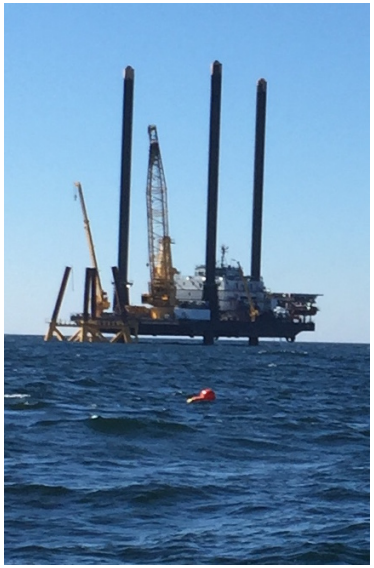
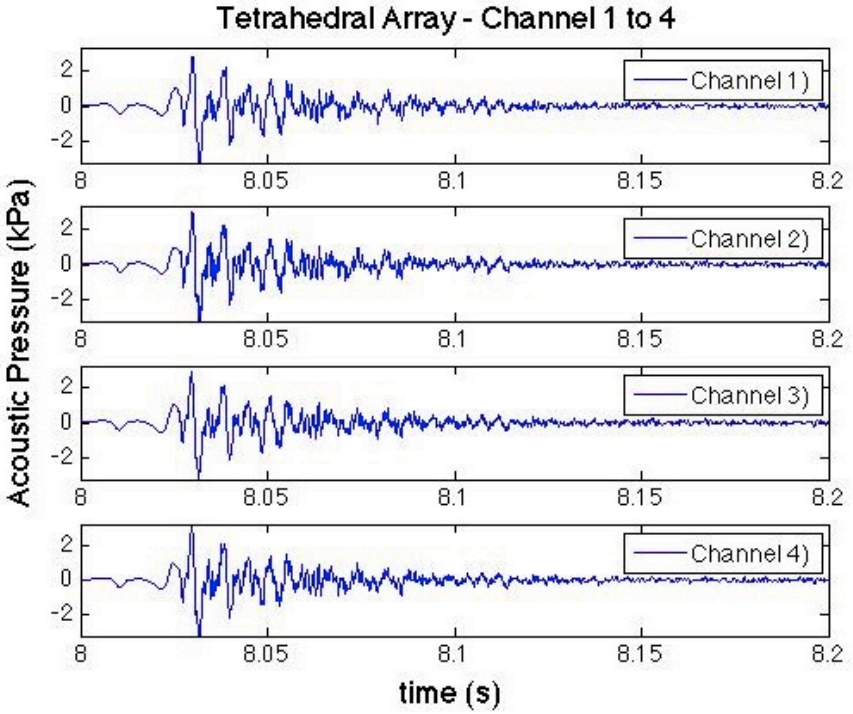
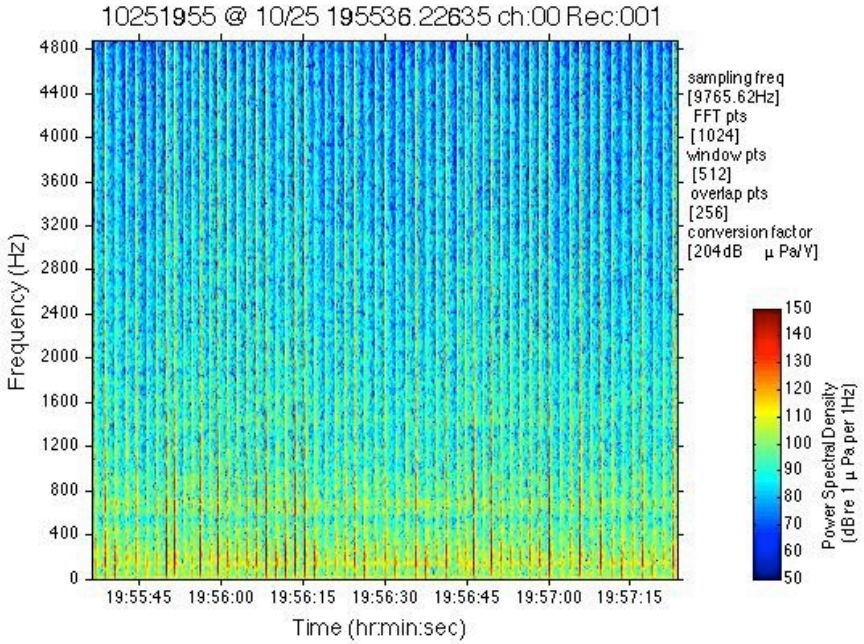


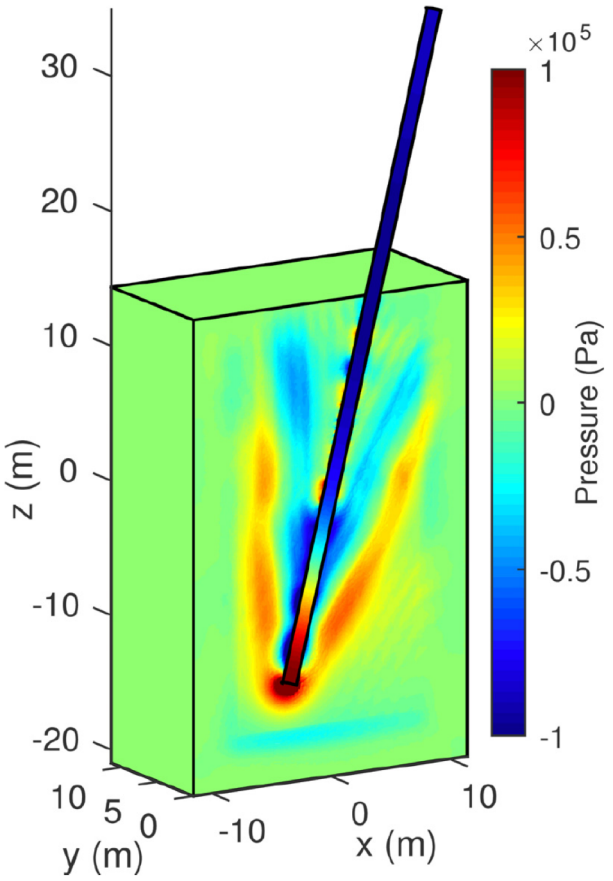




- Pile driving signals at Block Island consisted of intense short duration signals every 1 to 2 seconds for an hour per pile section.
- Peak pressure measured near the seafloor at 500 meters was about 2.5 kPa and SPL peak about 188 dB re 1 µPa.
- Assuming spherical spreading, peak source level is about 242 dB re 1 µPa at 1 m.

Raked Piles

- The piles used in the Block Island Wind Farm were raked (tilted) about 15 degrees with the vertical.
- This caused significant azimuthal dependence of the peak pressure.



Daniel R. Wilkes and Alexander N. Gavrilov, "Sound radiation from impact-driven raked piles," J. Acoust. Soc. Am. 142 (1), July 2017.

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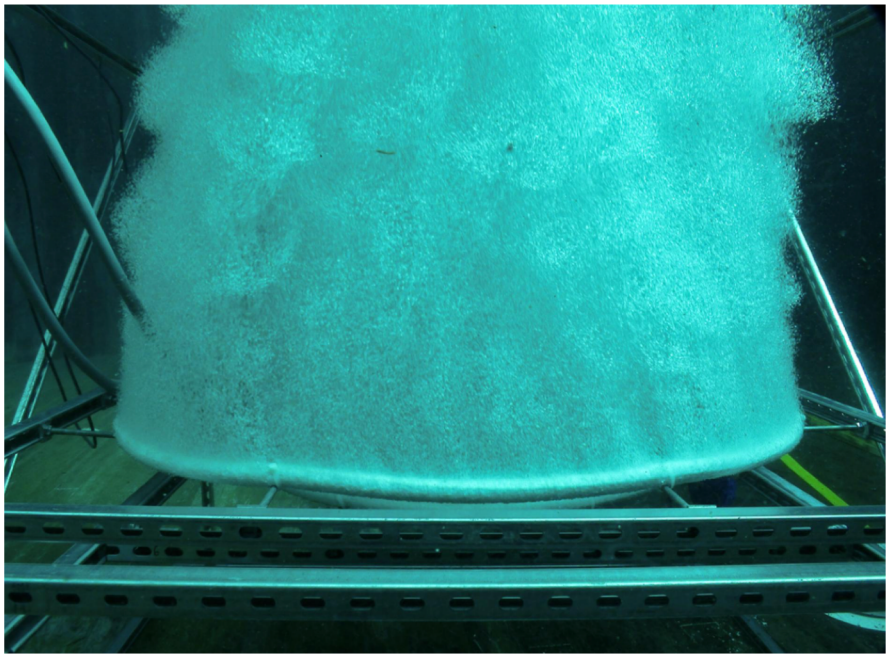
Mitigation: Bubble Curtains

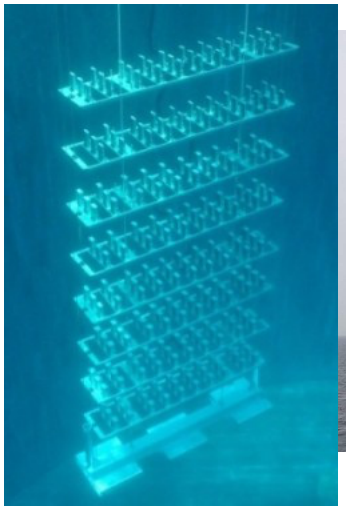
- Bubble curtains and related technology can be used to dampen the intense pressure signals radiating from the pile.
- Freely-rising bubble curtains can be effective in shallow water and calm conditions.
- But this type of freely-rising bubble curtain can be difficult to use and not as effective in high current and deep regimes.

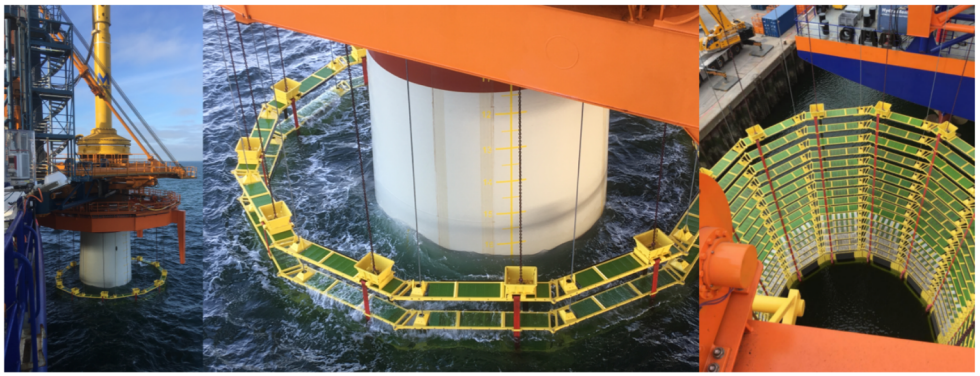


PHOTOGRAPH COURTESY JAMES N. PIPER, ARL, UNIVERSITY OF TEXAS AT AUSTIN

Mitigation: Helmholtz Resonators

- An interesting type of damping system uses Helmholtz resonators around the pile to absorb noise from pile driving. The more resonators around the pile the better the performance, and the resonators can be customized to target any frequency band of interest.
- Attenuation of up to 36.8 dB was realized across all hammer strikes in one test.





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