RESEARCH ADMINISTRATION
Bureau of Field Services
Michigan Department of Transportation

Research Spotlight

Project Information

REPORT NAME: Effect of Pile-Driving Induced Vibrations on Nearby Structures

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Minimizing the effects of pile driving vibrations

Engineers must take care that the vibrations from pile driving operations during bridge construction do not damage underground utilities or cause settlement in the foundations of nearby structures. In this project, researchers developed a simpler and more accurate method for estimating vibration dissipation as the distance from pile driving increases and predicting where ground settlement will occur. They developed a software tool MDOT can use to identify potentially troublesome sites and avoid costly damage to nearby structures.

Problem

New bridges and other structures are typically supported by piles—steel or concrete shafts that are driven into the ground during construction using large mechanical hammers. Pile supports are often used in response to the heavier truck loads adopted by AASHTO, the use of concrete (as opposed to steel) superstructures, and the use of longer spans between foundation units. The process of pile driving creates vibrations that can sometimes damage nearby structures with shallow foundations, or cause cracking or deformation in underground utilities, such as water and sewer pipes, power lines, and communications cables.

Researchers used sensors (shown in foreground, connected via cables) to measure vibrations at various distances from pile driving operations, both on the surface and at various depths.

Knowing the rate at which vibrations dissipate (called "attenuation") helps determine when it is necessary to use mitigation techniques such as pre-boring pile holes, using less impact energy during driving, or using a different kind of pile and foundation design.

The first models used for estimating vibration attenuation were based on surface data from mining operations and earthquakes rather than pile driving operations,

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> *"This is the first time such extensive, high-quality data on full-scale pile driving vibrations has been collected. The ground response measured at various depths and distances significantly improves MDOT's modeling of pile driving operations."*
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> **Dick Endres, P.E.**
> Project Manager

which involve less intense vibrations but many more vibration cycles. Developed in the 1990s, the adapted pile driving models currently used do not account for the changing response of the soil to vibrations at various soil depths and distances from pile driving operations.

Research

Researchers began by conducting a literature review of relevant research that could be used to help calibrate existing analytical models for estimating vibration-induced settlement and vibration attenuation. They then conducted testing at five different MDOT project sites where pile driving operations were taking place. Using a drill rig, they embedded two types of motion sensors (geophones and accelerometers) in the ground at various depths and at different horizontal distances from the driven pile. Researchers analyzed the resulting data to help determine how pile vibrations are transferred to the ground, and to help develop an improved vibration attenuation model.

Researchers installed sensors by pushing them into the ground with a common drill rig.

Results

The literature review and field measurements helped researchers develop improved models of both the transfer of vibrations from piles to the ground and the attenuation of vibrations as they propagate away from piles. Researchers chose an existing equation for predicting this attenuation, but refined its coefficient of attenuation—a value that captures the rate of dissipation—based on the conditions at the five sites where they took measurements.

Researchers used these results to develop a software tool with screening criteria for identifying troublesome sites where pile driving might cause ground settlement under nearby structures. Potentially vulnerable sites typically include those with loose- to medium-dense sands, coupled with existing in-service bridges supported on shallow-spread footing foundations. Adjacent utilities also may be critical. Of special concern is the increasing use of accelerated bridge construction techniques that involve constructing a new bridge alongside an old one while it is still in use. This requires pile driving very close to an existing structure that may have shallow foundations. If this structure is too sensitive, it may be necessary to build the new bridge farther away or use more traditional construction methods.

By inputting information about soil layers and the energy generated by pile drivers, engineers can use the software tool to estimate the distance in each stratum to which vibrations capable of causing settlements will be propagated. As an input to this tool, researchers developed a database of the vibration characteristics of hammer and pile combinations commonly used by MDOT contractors.

Value

The software tool developed in this project can be used with certain kinds of soils to estimate recommended standoff distances from sensitive structures or facilities, preventing settlement due to pile driving and helping prevent costly damage to nearby structures.

MDOT is currently using the tool on a pilot basis on projects with appropriate soil conditions, with good results. Expanded implementation is planned in the coming months.

Research Administration

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