



PUTTING RESEARCH TO WORK

BRIEF

Limiting the Effect of Pile-Driving Vibration on Curing Concrete

For many years, engineers have measured and regulated the impacts of pile driving on existing structures. Vibrations from pile driving can impact buildings, affect safety and also be a major annoyance to people and businesses. However, while pile driving typically occurs early on highway projects, on complex projects the pile driving may occur concurrently with other work. In these cases, the vibrations from pile driving might not just impact surrounding properties – they may also affect recently placed concrete on the highway project itself.

What's the Problem?

To allow for concrete to properly cure, WisDOT's Standard Specifications regulate the distance of pile driving from early-age concrete and limit how soon pile driving can occur after the concrete has been placed. While the impacts of pile-driving vibration on existing structures has been well established, fewer studies have evaluated the impacts on fresh concrete and results published to date for research in this area vary.

With the scarcity of conclusive research recommendations, state specifications tend to take a conservative approach. WisDOT currently requires pile driving to be kept at a distance of 15 feet or more from a concrete-filled pile shell until it has cured for at least seven days. This specification does not mention freshly placed concrete structures such as footings.

Research Objectives

This research evaluated the potential of pile-driving vibrations to damage concrete-filled pipe piles and recently placed structures in which concrete is still curing. The study measured how the vibrations diminished with distance and depth from their source, and established a relationship to concrete performance through evaluation of the effects of distance and elapsed curing time on the compressive strength of recently placed concrete.

Methodology

After carrying out a literature review of related research, the investigators took the following steps to study the impacts of construction vibration on early-age concrete:

- Finite element modeling to evaluate the effects of varying pile sizes, pile types and hammers.
- A laboratory study of the compressive strength of concrete samples exposed to varying levels of vibration at different times during curing.
- A field evaluation of the compressive strength of concrete block samples placed at varying times and subjected to pile driving vibrations.

Results

These analyses yielded the following results:

- **Finite element modeling (FEM).** Compared to empirically based equations and predictive models based on field tests, finite element modeling proved effective. FEM accommodates a number of variables not included in these other approaches, and simulates complicated soil-pile-hammer interactions well in two-layer and single-layer soil systems.
- **Laboratory.** Researchers subjected 90 12-inch concrete cylinders and 36 concrete beams to 15 minutes of vibration each. Both the level of vibration and concrete curing time were varied. Generally, vibration levels and elapsed curing time had little impact on the stiffness and strength of specimens tested at three, seven and 28 days. However, beams that were vibrated very early—within four to six hours of pouring—had substantially less strength than the three-day average of control beams.

Investigator



"This research will allow the department to reduce the amount of time between driving a cast in place pipe pile at point A and driving a pile at point B."

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“Our current design procedure might be on the conservative side. There wasn’t as much damage to the concrete as expected.”

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Vibrations from pile-driving hammers (left) may inhibit the development of strength in fresh concrete nearby. In this study, subjecting concrete cylinders and beams (right) to various vibration levels as they cured had minimal impacts on their stiffness and compressive strength.

- **Field.** Investigators placed 72 cast-in-place pullout cylinders and 24 pullout beams at varying distances from the vibration source (pile driving) in the field, then drove two test piles at different times within their curing periods. Placing materials at different distances allowed for the concrete to experience varying vibration levels. Geophones on the surface and at depths of 10 feet measured vibrations in relation to distance. The field data showed more variability than the laboratory data, but vibration level and curing time again seemed to have little impact on the compressive strength of specimens tested at three, seven and 28 days.

As a result of this study, investigators recommended that WisDOT consider modifying the Standard Specifications to reduce the required distance of pile driving from early-age concrete in pile shells to 10 feet rather than 15 feet and to shorten the required curing time to five days rather than seven days. Study results indicate that these adjustments will still allow concrete to meet its design strength, but will also allow more rapid construction, which will save money and reduce inconvenience to the public.

Further Research

Investigators recommended follow-up research to explore a variety of conditions that may affect the hammer-soil-pile interaction and the strength of early-age concrete. Potential areas to be studied could include soil settlement due to pile driving, freeze-thaw effects on early-age concrete, microscopic inspection of concrete specimens, and evaluation of samples for additional properties such as durability and workability.

This brief summarizes Project 0092-06-04, “Construction Vibration Attenuation with Distance and Its Effect on the Quality of Early-Age Concrete,” produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

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