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Comparison of Setting Time Measured Using Ultrasonic Wave Propagation with Saw-Cutting Times on Pavements

Peter Taylor

Iowa State University, ptaylor@iastate.edu

Kejin Wang

Iowa State University, kejinw@iastate.edu

Xuhao Wang

Iowa State University, wangxh@iastate.edu

Xin Wang

Iowa State University, xin@iastate.edu

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Abstract

At present, there is little fundamental guidance available to assist contractors in choosing when to schedule saw cuts on joints. To conduct pavement finishing and sawing activities effectively, however, contractors need to know when a concrete mixture is going to reach initial set, or when the sawing window will open. Previous research investigated the use of the ultrasonic pulse velocity (UPV) method to predict the saw-cutting window for early entry sawing. The results indicated that the method has the potential to provide effective guidance to contractors as to when to conduct early entry sawing. The aim of this project was to conduct similar work to observe the correlation between initial setting and conventional sawing time. Sixteen construction sites were visited in Minnesota and Missouri over a two-year period. At each site, initial set was determined using a p-wave propagation technique with a commercial device. Calorimetric data were collected using a commercial semi-adiabatic device at a majority of the sites. Concrete samples were collected in front of the paver and tested using both methods with equipment that was set up next to the pavement during paving. The data collected revealed that the UPV method looks promising for early entry and conventional sawing in the field, both early entry and conventional sawing times can be predicted for the range of mixtures tested.

Keywords

Admixtures, Guidelines, Pavement performance, Portland cement concrete, Sawing, Setting (Concrete), Stripping (Pavements), Ultrasonic tests, concrete mixtures, initial set, pavement saw-cutting, ultrasonic pulse velocity

Disciplines

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Comparison of Setting Time Measured
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PRINCIPAL INVESTIGATOR

Peter Taylor, Director
National Concrete Pavement Technology
Center
Iowa State University
515-294-9333
ptaylor@iastate.edu

CO-PRINCIPAL INVESTIGATOR

Kejin Wang, Professor
Civil, Construction, and Environmental
Engineering
Iowa State University

MORE INFORMATION

www.cptechcenter.org

**National CP Tech Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-3230**

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tech transfer summary

The ultrasonic pulse velocity (UPV) method has the potential to predict the saw-cutting window.

Background

To conduct pavement finishing effectively and schedule saw-cutting at joints accurately, contractors need to know when the sawing window will open. If the cuts are made too early, there is a risk of raveling, but if the cuts are made too late, there is a risk of random cracking.

Commonly used methods to determine sawing time include scratching the surface with a penknife or standing on the slab and observing the footprint depth. However, these methods are subjective, and the results are open to dispute. In addition, different aggregate types, sawing machines, ambient temperatures, and wind speeds make it difficult for contractors to determine saw-cutting times using these methods.

One approach to more reliably predicting saw-cutting time is to monitor temperature rise using a semi-adiabatic calorimeter. However, concerns have been raised that temperature is not uniquely tied to setting, and that tests conducted using a semi-adiabatic calorimeter may not represent the environment to which a given slab is exposed.

A pilot project conducted by the research team indicated that the ultrasonic pulse velocity (UPV) method has the potential to predict the saw-cutting window for early entry sawing. This method is based on the principle that the velocity of an impulse through a concrete sample begins to increase when hydration products start to interact, i.e., when initial set occurs.



Non-typical conventional gang-saw machine used at one site



Typical conventional saw-cutting process

In the pilot project, however, all field work was conducted with early entry saws and all sites used similar mixtures, most of which contained limestone aggregate. Therefore, there was a need to widen the range of the data to include different mixtures, aggregate types, and sawing methods. There was also a need to assess the viability of using thermal-based approaches, including i-buttons placed in the slab or calorimeters.

Objective

The objective of this research was to evaluate the effectiveness of the UPV method along with thermal-based systems to predict sawing time by measuring the initial set of a mixture in situ.

Research Methodology

Sixteen construction sites using a variety of mixtures, aggregate types (granite, limestone, quartzite, gravel), and sawing methods were visited in Minnesota and Missouri over a two-year period. At each site, a concrete sample was collected at the front of the paver and cast into three 4 by 8 in. cylinder molds: one for a UPV measurement and two for the semi-adiabatic calorimetry test.

Initial set was determined using a commercial UPV device, which was set up next to the pavement during paving to expose the sample to the same conditions as the slab. Calorimetric data were collected using a commercial semi-adiabatic device at a majority of the sites. No additional instructions were provided to saw-cutting crews regarding when sawing should take place, and site staff were asked to report the time at which that portion of the slab was sawn.

Data collected included paving start time, initial set determined by the calorimetry and UPV methods, sawing time, and average ambient temperature on the day of testing.

Key Findings

- Early entry sawing times measured via the UPV method at the sites in Minnesota fit well within the previously established relationship observed in the pilot study.
- The UPV data for the observed mixtures indicated that once initial set is achieved, conventional sawing should begin in accordance with the relationship established in the following equation: $\text{Saw time} = 1.24 \times \text{initial set time (UPV)} + 273$. Conventional sawing should thus begin about 310 to 390 minutes later for an initial set between 150 and 500 minutes.
- The UPV approach appears to be promising for timing early entry sawing (sawing beginning about 220 minutes after initial set) and conventional sawing (sawing beginning about 310 to 390 minutes after initial set).
- Both early entry and conventional sawing can be predicted effectively using the UPV method for the range of mixtures tested in this research.

Implementation Readiness and Benefits

An approach that can be used to apply the UPV method in the field is for the contractor to conduct sawing using traditional approaches for the first day or two while developing a relationship between sawing time and initial set time based on UPV measurements for the materials at hand. The relationship can then be extended based on the equation under Key Findings and used to guide saw timing for the remainder of the contract.



Typical early entry saw-cutting process