



ACBM Update

A Better Maturity Meter?

Research is currently underway at ACBM that investigates using high-frequency ultrasonic wave reflection measurements to study the hydration of concrete. ACBM's Industrial Partners and Northwestern University's Infrastructure Technology Institute collaboratively fund this research. Results to date demonstrate that this technique is able to track the very early age hydration of concrete and provide accurate measurements of maturity. This device holds promise to aid the concrete contractor in the earliest possible removal of formwork, to enable the precast supplier to cycle molds for greatest cost efficiency, and for paving contractors to open new pavement at the earliest and safest moment.

This technique, known as WRF for wave-reflection factor, is based on measuring high-frequency ultrasonic wave reflections to monitor the setting, hardening, and strength gain of concrete. The WRF technique measures the reflection of normally incident shear waves at the interface

between a steel plate embedded into the fresh concrete and the maturing concrete. A schematic representation of the experimental setup is shown in Fig 1.

The pulser/receiver unit sends and receives ultrasonic signals from the transducer attached to the steel plate. (In applications using steel formwork, the transducer may be attached directly to the formwork, eliminating the need for the embedded steel plate.)

The shear wave pulse undergoes multiple reflections at the steel/concrete interface. The computer automatically performs pulse generation, data collection, and signal processing. The wave-reflection coefficient is calculated from the first and second reflections transformed from time domain to frequency domain, and it represents the wave energy that is reflected from the steel/concrete interface.

Because liquids do not support shear waves, decreasing amounts of reflected energy is evidence of the progress of hydration. As the

concrete continues to harden, more and more of the wave energy is transmitted through the concrete.

A schematic representation of the concrete-setting process as monitored by the WRF technology is shown in Fig 2.

In the very early age of concrete, it is essentially a fluid, and very little decrease in reflected energy is detected. Point A represents the setting point, when the fluid concrete begins to stiffen. Beyond Point A, the concrete is undergoing hydration and becoming more and more solid. Point B corresponds to the time when the concrete is completely solid. Further decreases in the WRF beyond Point B are due to the continuing hydration of concrete, resulting in further strength gain.

Point A correlates with the set time of the concrete, the time beyond which the concrete is no longer workable. Incompatible concrete mixture proportions and ambient conditions that lead to flash setting can be identified using the WRF technique. Point B is being used to prescribe a threshold strength value, through the establishment of a quantitative relationship between compressive strength at the time corresponding to Point B and the design strength of the concrete. A linear relationship between the WRF and compressive strength at early ages (3 to 4 days) has been established.

The Center for Advanced Cement-Based Materials (ACBM) is a consortium of researchers from: Northwestern University, University of Illinois at Urbana-Champaign, Purdue University, The University of Michigan, and The National Institute of Standards and Technology.

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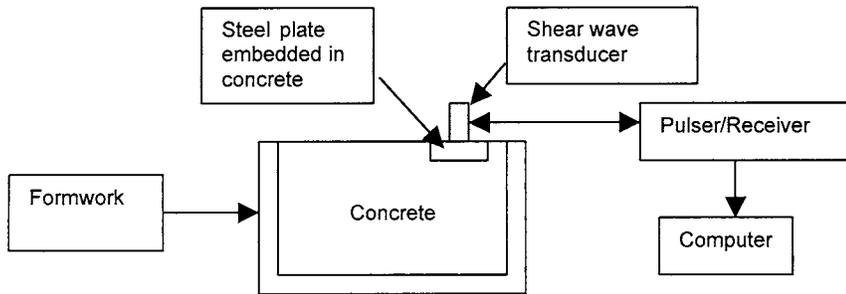


Fig 1: Schematic representation of the experimental setup

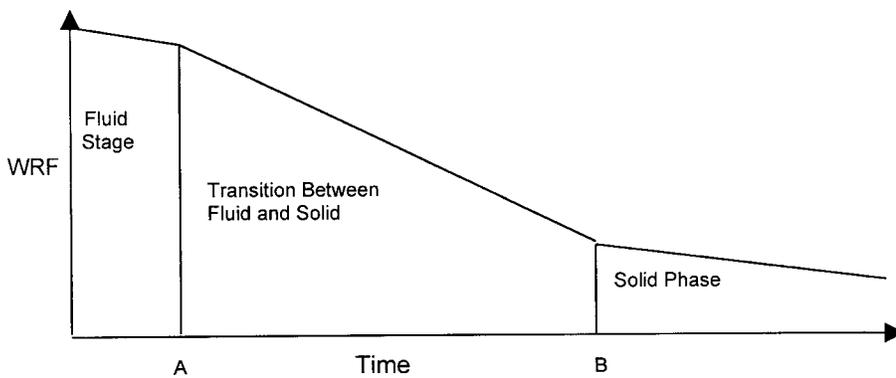


Fig 2: Schematic representation of the concrete-setting process as monitored by the WRF technology

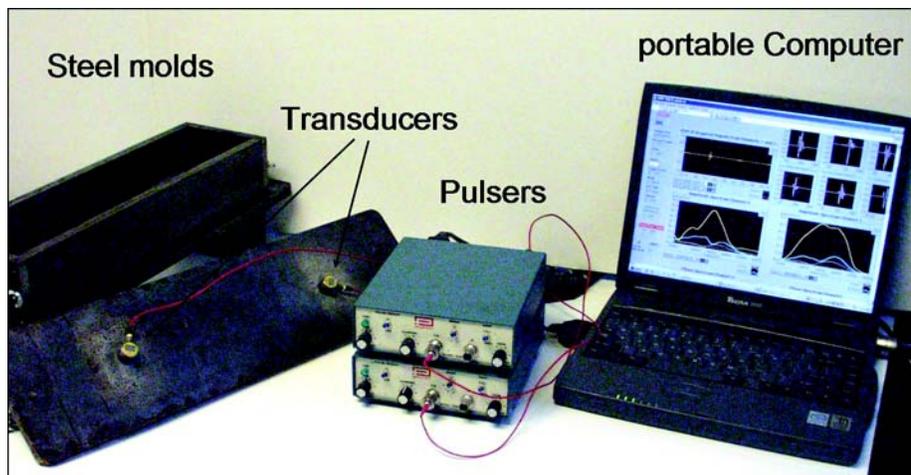


Fig. 3: Field instrumentation

Researchers have developed a test device for in place monitoring of concrete after placement. The equipment is robust enough for field applications, and a field trial at Rocky Mountain Prestress, located in the Denver, CO area, has just been completed. The results of that field trial were very positive. A picture of the field instrumentation in shown in Fig. 3.

In summary, the WRF technique provides a good tool for assessing concrete's:

1. Hydration progress;
2. Set time;
3. Early strength development; and
4. Elastic modulus development.

The main advantages of the WRF technique compared with current techniques are:

1. It is nondestructive;
2. Requires access to only one side of the structure;
3. Yields results based on physical properties of concrete;
4. Can be used in the laboratory or in the field; and
5. Provides continuous real-time monitoring.

Possible applications of the WRF technique include:

1. Optimization of hydration;
2. Prevention of cement/admixture incompatibility;
3. Identification of material compositions and environmental conditions that lead to early stiffening or flash set;
4. Optimization of delivery schedules, placing, and finishing operations;
5. Determination of earliest possible formwork removal; and
6. Determination of time for application or release of force for post- and pre-tensioned structures.

Please go to the ACBM website (www.acbm.info) for additional information on all the ACBM programs.