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NDT OF CEMENTITIOUS MATERIALS

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ABSTRACT

The US method presented an automatically extract certain parameters of US waves, parameters that have been continuously recorded during the mortar hardening process. Until now, the standard methodes measured only one parameter, at certain stiffness stages. This method presents the material behaviour variation that depends on the hydration and on the elastic properties of mortar materials. In this way we have a visual of the hardening process, which was not available untill now. From now on this method can be used for applications in industrial laboratories.

Introduction

The area of concrete quality needs an advanced process technology which would be able to offer objective and reliable measurements [2]. This process technology uses the ultrasound technique. The stiffening process is caused by the hydratation of the cement-matrix and the proprieties of cementitious materials are changing from a suspension to a solid [4]. During the hardening process the age of the material can be determined by observing the amplitude and velocity variations. The physical properties of these materials are described by Biot's theory. Elastic waves in through-transmission were measured, using wave propagation theory and also Biot's theory, during ultrasound experiments and it was possible to characterize the material during the stiffening process.

The whole waveform represents the material properties. When using a measuring device which records the signals we can extract some parameters for quantitative analysis techniques.

These parameters (velocity and energy) are easy to determine. If the travel path of the wave is known the velocity is determined by measuring the onset time of the signals - shown in the graph for different admixtures. If we calculate the integral sum of the wave amplitudes we can determine the energy [1].

One single wave parameter is sufficient to characterize the material but for increased reliability of the method it is recommended to evaluate more than one. Other parameters can also be determined [5].

Theory

These methods are based on several widely used standards and are used for the quality control of concrete in civil engineering [4]. There are differences between the methods used for mortar or concrete, for the consistency or the workability and also for setting times or the control of air content. These methods are rough and have limited evidence for certain periods of the setting and hardening processes [3]. The quality or the effect of admixtures and additions are not reliable using this method.

The existing methods (figure 1) are easy to handle and in low-cost range but the range of applications and the reliability are limited. Because of this reasons the US technique became so important in the field of non-destructive testing.

Ultrasound measurements

There are several techniques to evaluate the setting process of concrete or mortar with ultrasound. One is the ultrasound wave evaluation in through-transmission.

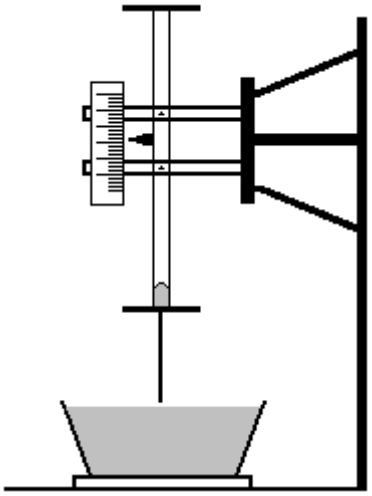

Fig. 1 Old testing method (vicat-needle) for cement paste

Another one is measurement of the energy of waves reflected at the surface of the material – the impedance of the waves is correlated to the material consistency [2]. These techniques are shown in figure 2. Other techniques use shear waves or other waves (electromagnetic waves). In the through-transmission method the waveforms of the emitted signal are recorded after their way through the material. The material properties influence the frequency, velocity, energy and the waveform.

Figure 6 presents a continuous measuring which illustrates the changes of the waveform during the setting of the material. The signals were normalized in amplitude in order to better see the changes. It can be seen that the original wave amplitudes grow rapidly.

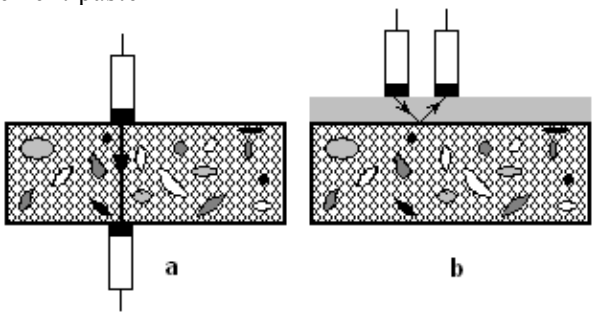

Fig 2 . a) Measurements with ultrasound in through-transmission using an US emitter and receiving sensor at the opposite side.b) Measuring the energy content of waves reflected at the surface between a well-known
dummy material (grey) and the concrete or mortar

Techniques

The ultrasound velocity is one of the main parameters used in the stiffness of the material evaluation. The velocity of a compression wave through a specimen can be extracted out of the onset time of the signal recorded at the receiving sensor. The onset time is determined manually by the operator. This is not feasible for a test which can last up to hours or even days. Because of this, an algorithm is needed to extract the onset times automatically. This algorithm would be able to determine automatically the velocity variation during the setting.

Figure 3 shows the resulting velocity curves for concrete admixed with different quantities of a retarder.

The retardation effect is expressed trough different slopes of the velocity up to a consolidation value of around 4000m/s. If the additive exceeds the permitted value (25ml/kg) the material do not reach this plateau.

There are similar graphics for all types of concrete, mortar materials, for different kind of admixtures and additives. Figure 4 shows the influence of accelerators and retarders in comparison to a material without any additive, for different types of admixtures.

For the velocity only the very first beginning of the signal is evaluated. If analyzing the change of the signal amplitudes during the setting of the material we can obtain additional information. Figure 5 shows the automatic real-time extraction of the velocity of the signal.

A full-automatic determination of the initial and final setting time was implemented for a rapid first interpretation for material properties. We can find differences in quality and workability for different material compositions if we compare the graphs.

The ultrasound waves traveling through cementitious materials are highly attenuated in the beginning, right after mixing.

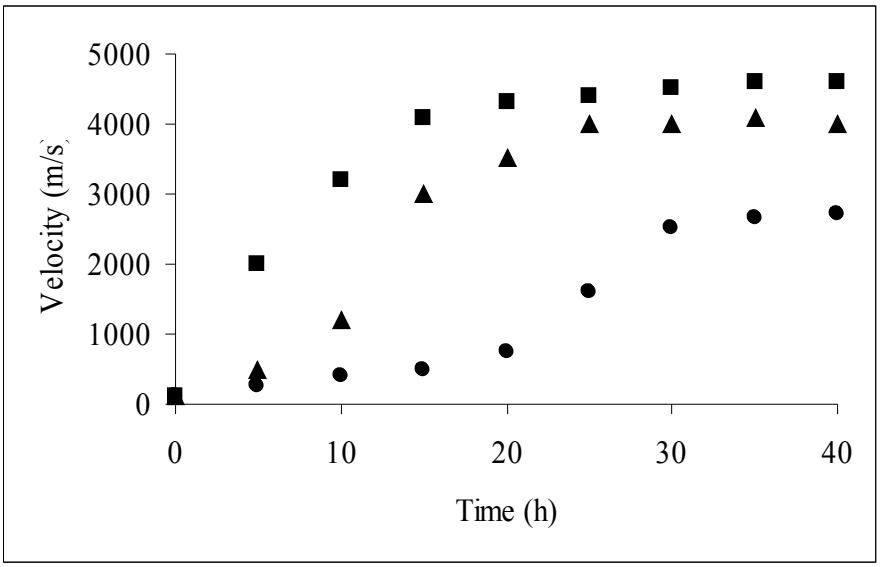

Fig. 3
The US velocity for different quantities of retarder

■ - reference

▲ - 8ml/kg

● - 25ml/kg

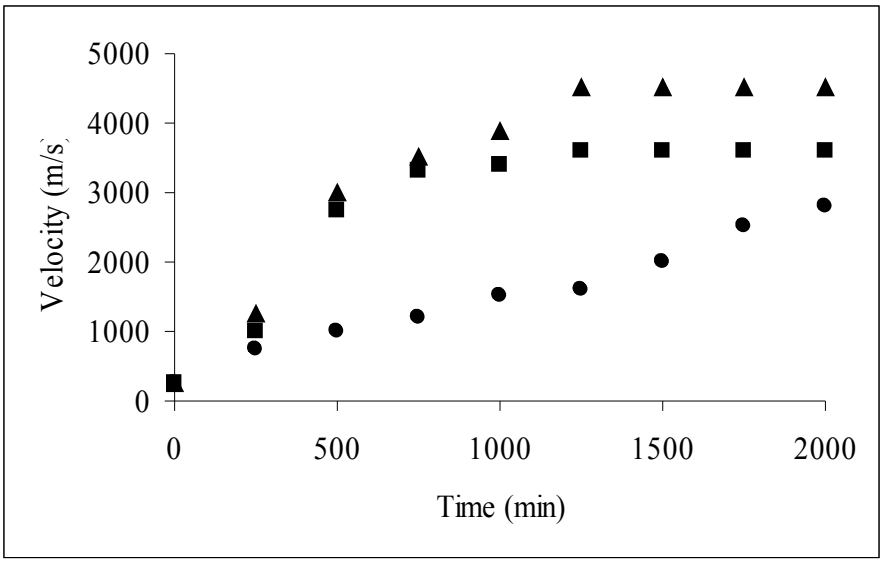

Fig. 4
The US velocity for different kind of admixtures

■ - without additive

▲ - accelerator

● - retarder

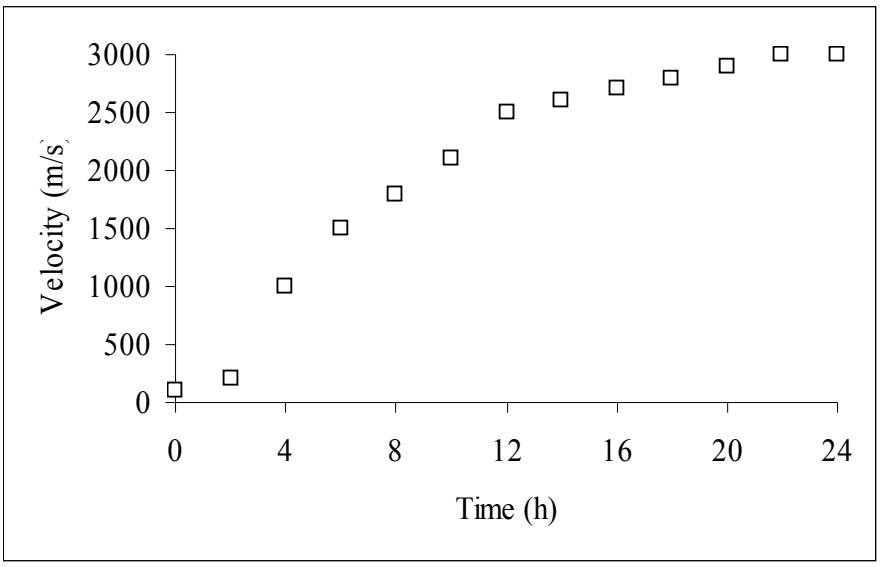

Fig. 5
The US velocity evaluation during the hardening of concrete

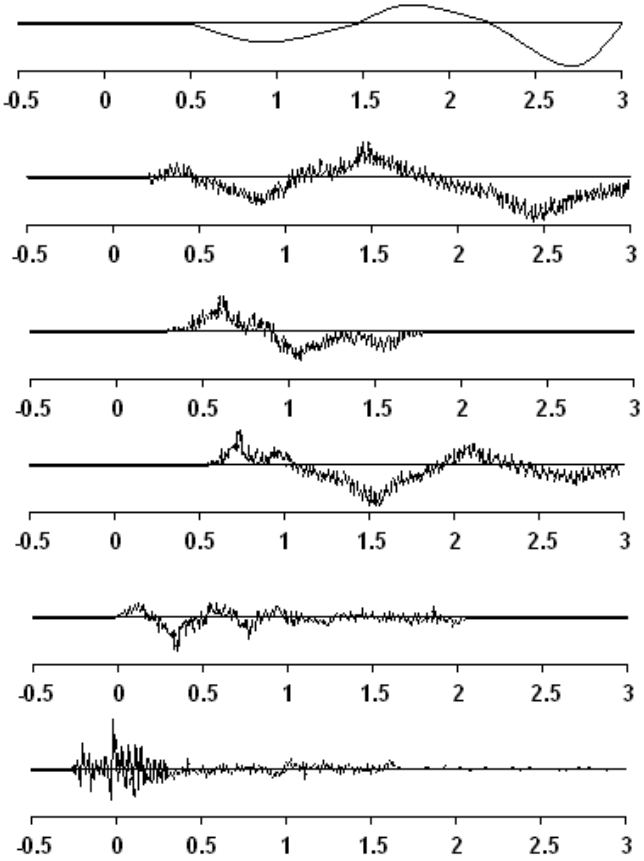

Fig. 6 Ultrasonic waves recorded in through-transmission at certain intervals during the hardening of concrete.

In the hardened state the signal is several decades higher in amplitude – this is why it is sometimes more important to focus on the parameter energy than on the velocity for the interpretation of the hardening process. The main frequencies are at the end of this measurement, after 24 h and have values between 20-200 kHz.

Applications

There are numerous applications which can use this method for material characterization. There is a great demand for different types of concrete. The contractor needs self-leveling concrete, highly workable concrete, slip formed concrete and retarded mixes. Also there is also less available workmanship on the construction site and the quality required for durable concrete increases. The material producers are interested in the effect of admixtures and additions on the fresh or the hardened state of concrete or mortar.

Conclusions

The presented technique, using US measurement, can automatically extract some ultrasound wave parameters which are continuously recorded during setting and hardening of cementitious materials like concrete or mortar. This method evaluates different waveform parameters which are directly linked to the hydration process of the mortar. It offers a more detailed insight into the, in comparison to standard procedures.

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