FRESHCON 2.0 – SOFTWARE FOR DATA ACQUISITION AND DATA ANALYSIS

FRESHCON 2.0 – SOFTWARE ZUR DATENERFASSUNG UND DATENANALYSE

FRESHCON 2.0 – PROGRAMME D'ENREGISTREMENT ET D'ANALYSE DE DONNEES

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SUMMARY

The setting and hardening process of several concrete and mortar mixtures as well as the influence of concrete additives are monitored by an ultrasonic transmission technique. For the automatic data acquisition and processing of data, the program *FreshCon 2.0* was developed under LabVIEW. It can automatically detect signals and calculate the velocity, energy and frequency spectrum, parameters indirectly correlated to the stiffness of the material.

ZUSAMMENFASSUNG

Zur Untersuchung des Erstarrungs- und Erhärtungsprozesses diverser Beton- und Mörtelmischungen, sowie zur Kontrolle der Wirksamkeit von Betonzusatzmittel, wird ein Ultraschallmessverfahren verwendet, das auf dem Durchschallungsprinzip basiert. Zur automatischen Datenaufnahme und Datenauswertung wurde das Programm *FreshCon 2.0* unter der Programmiersprache LabVIEW entwickelt. Es ist in der Lage Daten automatisch zu erfassen und während der Messung diejenigen Parameter auszuwerten, die indirekt mit der Steifigkeit des Materials korrelieren. Dies sind Geschwindigkeit, Energie und Frequenzspektrum des Signals.

RESUME

Les processus de prise et de durcissement de différents mélanges de mortier et de béton, ainsi que l'influence d'adjuvants, ont été observés par transmission d'ultrasons. Pour automatiser la saisie et le traitement de données, le programme FreshCon 2.0 a été développé sous LabVIEW. Il est en mesure de détecter automatiquement les signaux et calcule la vitesse, l'énergie et le spectre des fréquences, paramètres indirectement corrélés avec la rigidité du matériau.

KEYWORDS: *Freshcon*, ultrasonic testing, LabVIEW, data acquisition and data analysis

1. INTRODUCTION

An advanced technology in the area of concrete quality control needs proper surveillance by reliable and – as far as possible – objective measurements. The ultrasonic technique yields a possible solution. Variations of amplitude, velocity and frequency with the age of the material can be observed during the hardening process. The ultrasonic method developed at the Institute of Construction Materials is able to extract automatically certain parameters of US waves recorded continuously during the setting and hardening of mortars. The resulting curves describe the material behaviour and are related closely to the hydration process of mortar. These curves are linked to the elastic properties and give a comprehensive picture of the stiffening process in a way that was not accessible before. Future applications in industrial laboratories have to show what kind of benefits are brought up by recording the material properties of suspensions during hardening. Anyway, it is obvious that this technique gives a clearer and more detailed insight than the standard procedures measuring only a single parameter at certain stiffness stages. The key to this new method is the automation of the testing procedure using LabVIEW virtual instruments.

2. AIMS

Conventional methods for the evaluation of the setting and hardening process of mortar or concrete mixtures are the Vicat-needle test, the penetrometer test or the slump test. The disadvantages of these methods are the lower reproducibility and the lower accuracy of the measurement. They are unable to measure the material parameters continuously, and only one material parameter can be measured with these equipments. The ultrasonic technique represents an improvement in the determination of material properties during the stiffening process.

The hydration of the cement-matrix results in the change of cementitious materials from a suspension to a solid. During this phase-transition the wave velocity, the amplitude, and the frequency spectrum of an elastic wave also vary [Biot, 1956]. These parameters can easily be determined by an ultrasonic transmission method developed at the Institute of Construction Materials at the University of Stuttgart and was patented under number 198 56 259.4 [1999] at the german patent office in Munich.

Knowing the travel path of the waves, the wave velocity results from the onset time of the signals. The energy can be calculated by the square of the signal amplitudes and the frequency content of the signal can be computed by using the Fast-Fourier-Transform technique. One has to keep in mind that there are, of course, also several other parameters that can be used. Even though a single wave parameter could be sufficient to characterize the material, evaluating more than one increases the reliability of the method.
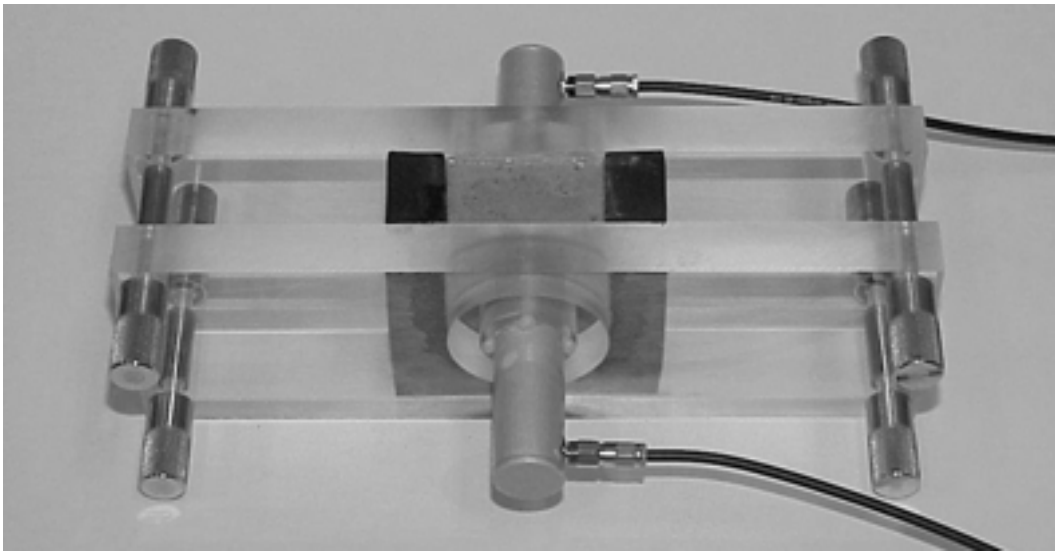

Fig. 1: An ultrasonic emitter and transducer are coupled to the mould made of PMMA sheets and a cuboid rubber foam block with U-shaped cutting bolted together.

The testing device consists of a mould with an ultrasonic emitter and transducer. An ultrasonic generator produces the ultrasonic impulse as reported earlier [Herb et al., 1999]. Figure 1 pictures the mould consisting of rubber foam and PMMA sheets. An A-D-conversion card (ELSYS, 12 Bit, 20 MHz) in a PC processes the signals. The typical duration of a measurement is 24 hours with a data acquisition interval of 10 minutes.

The velocity of a transmitted ultrasonic signal is a main parameter used for the evaluation of the stiffness of a material. For an accurate determination of the velocity the onset time must be known. To extract the onset times automatically an algorithm was developed and implemented in a software named *FreshCon*. A description of the software can be found in the patent mentioned above. The disadvantages of the software are the complicated initialisation of data acquisition boards and the time-consuming modification of program parts in C++.

Fig. 2: The start window of FreshCon gives access to the main features of the program.

LabVIEW is a graphical development environment specially developed for measurement problems, so that the implementations of new hardware equipments or new program options are made easy. The "building set" principle of the program makes a decentralized programming possible as well as the integration of program modules from one application to another. Therefore the revised version *Freshcon 2.0* was developed under LabVIEW.

During an experiment the amplitude of the transmitted signal changes in a range of 60dB. To avoid a permanent manual readjustment of the gain *FreshCon 2.0* automates the data acquisition and analyse the signals online. This enables the operator to control signal form, velocity, energy, and frequency content of the current signal and to react to measurement problems at an early stage.

3.   THE SOFTWARE

3.1   A short introduction in LabVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) from National Instruments is a development environment based on the graphical programming language G. The construction of a circuit diagram is typical for this programming language with a large number of graphical elements [Jamal et al., 1998]. These elements are wired with each other and visualize the dataflow.

LabVIEW relies on graphical symbols rather than on an abstract textual language to describe programming actions and can be used with little programming experience.

For data collection, analysis, presentation and storage the program contains comprehensive libraries. Traditional program development tools are also included in LabVIEW to make debugging and program development easier, like the simulation of the program execution to see how the program works, the setting of breakpoints or the single-step execution of the program.

LabVIEW programs consist of a front panel and a block diagram called virtual instrument (VI), existing. The front panel is the graphical user interface of the VI. Comprehensive knobs, push buttons, graphs, and other controls and indicators can be chosen from several palettes. The block diagram contains the graphical source code of the VI and shows the real executable program. The elements of the diagram are subroutines (subVIs), predefined functions, constants, and work structures like branchings, case differentiations, and loops or selfdefined subroutines.

The scheduler forms the connection between the VI and elementary operators. It also includes terminals that are associated with controls and indicators created on the front panel. The modular structure of LabVIEW allows the parallel development by several programmers. The implementation of self defined subVIs in other applications is possible. The integration of a new data acquisition board or another hardware component is unproblematic. It is only necessary to install the hardware driver for the new component and to use the existing subVIs on it.

In the following picture an example of the LabVIEW program structure is shown. The program calculates the sum and difference of two numbers. The block diagram stresses the advantages of a graphical programming language. One can easily follow the path the addition routine takes.
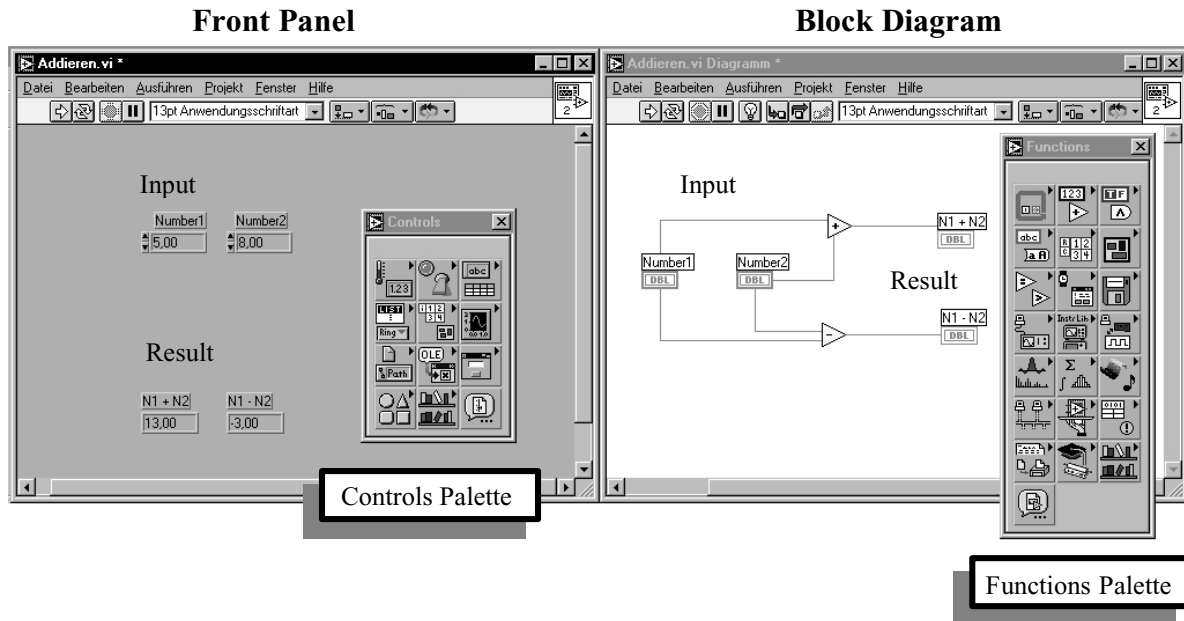
Front Panel   **Block Diagram**

Fig. 3. A demonstration of the LabVIEW program structure. The controls and functions palettes contain comprehensive predefined features.

3.2   DESCRIPTION OF *FRESHCON 2.0* AND FIRST RESULTS

When beginning *FreshCon 2.0*, the start window opens (figure 4), where the settings of the experiment can be made. It is possible to choose between two types of experiments. Type 1 describes a transmission system with two ultrasonic transducers and a steel ball shot on the wall of the mould and acting as an impactor. This option is not available at the moment but will be implemented later. For type 2 an ultrasonic emitter and transducer are used. In order to distinguish between the files corresponding to different experiments, one can add a characteristic prefix consisting of 3 digits or letters.

Furthermore, there is a possibility of setting test duration and test interval time. For better accuracy the program is able to average several measurements. These settings can be saved in configuration files; saved settings can be reloaded. The control panel, a part of the drivers included with the card, configures the data acquisition board. In this panel, the timebase, the settings of the input amplifier, the trigger modes, and physical units can be chosen.
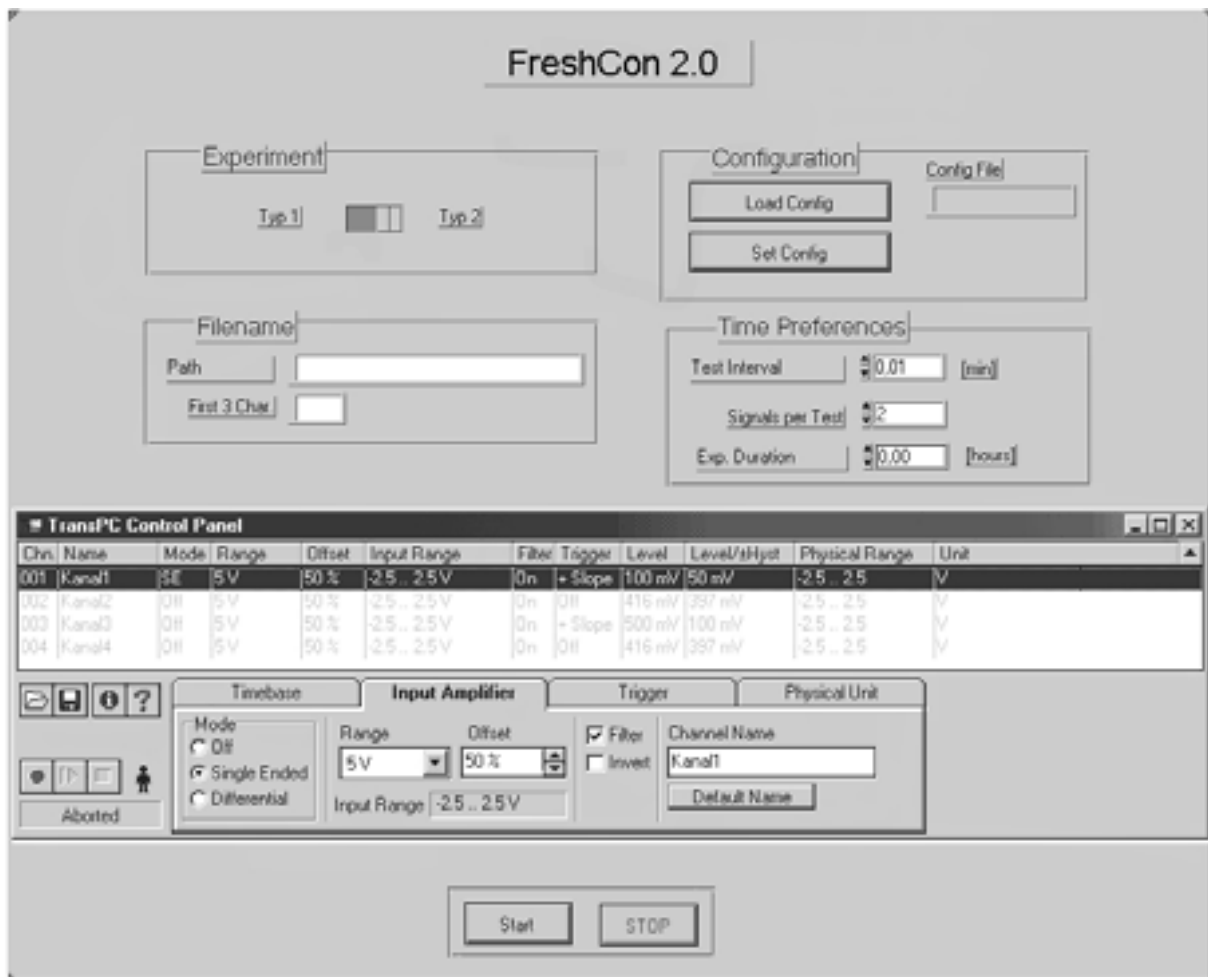
*Fig. 4. The start window of Freshcon 2.0 shows several configuration options
the user can choose from.*

After the "start" button is pressed the measurement begins and the analysis window opens. Figure 5 shows a screen shot of *FreshCon 2.0* during a measurement. The upper left graphic illustrates the transmitted curve. The amplitude axis conforms automatically to the peak of the signal. The time axis is adapted to the data length and the sampling rate.

The upper right window contains a diagram of the velocity and the relative energy vs. time. After every interval the program calculates a new data point, so that the operator can follow online the trend of the measurement. For the detection of the onset time a pick algorithm was implemented. At the moment it picks the first peak of the signal superior to a threshold level defined as 10% of the maximum of the total signal. But it is planed to replace this algorithm by a more effective one [Große et al., 1999]. The possibility of picking the onset time manually is also available. The energy is computed by the square of the signal amplitudes.

The frequency spectrum in the lower left graphic shows the Fast Fourier Transformation of the actual signal. LabVIEW offers a great number of predefined mathematical functions, which the programmer can easily integrate to a program. Programming such a file under C, C++ or any other development environment based on textual language would require a much larger effort. The 3-D plot is also a predefined feature of LabVIEW and shows the frequency content and the amplitude of the signals over the age of the material.

The analysis window described above has been programmed for experiment type 2. For type 1 the measurement requires two channels, one for the direct signal and the transmitted signal. For this test modus, an upgrading of the program is planned so that both signals can be shown simultaneously. Because of variations of the hitting sphere impulse form, the option of averaging over several signals will also be implemented.

At the end of the measurement the user can retrieve the whole signal data, the averaged data, the velocity and energy plots, and the frequency data. The analysis window can also be started as "stand-alone" for the offline evaluation of data improvement of onset determination is able.

Figure 5 shows first results of a test measurement with a standard mortar. wave velocity and energy increase with the age of the specimen. The frequency plots align with former tests. For a better resolution of the frequency spectrum a zoom function is implemented, as well as a linear to logarithm switcher. The experiment makes clear that with *Freshcon 2.0* a fully automatic measurement is available. First tests permit the prognosis that the software is able to replace the first version of *FreshCon* and represents a continuous measurement technique for quality control of cementitious materials.
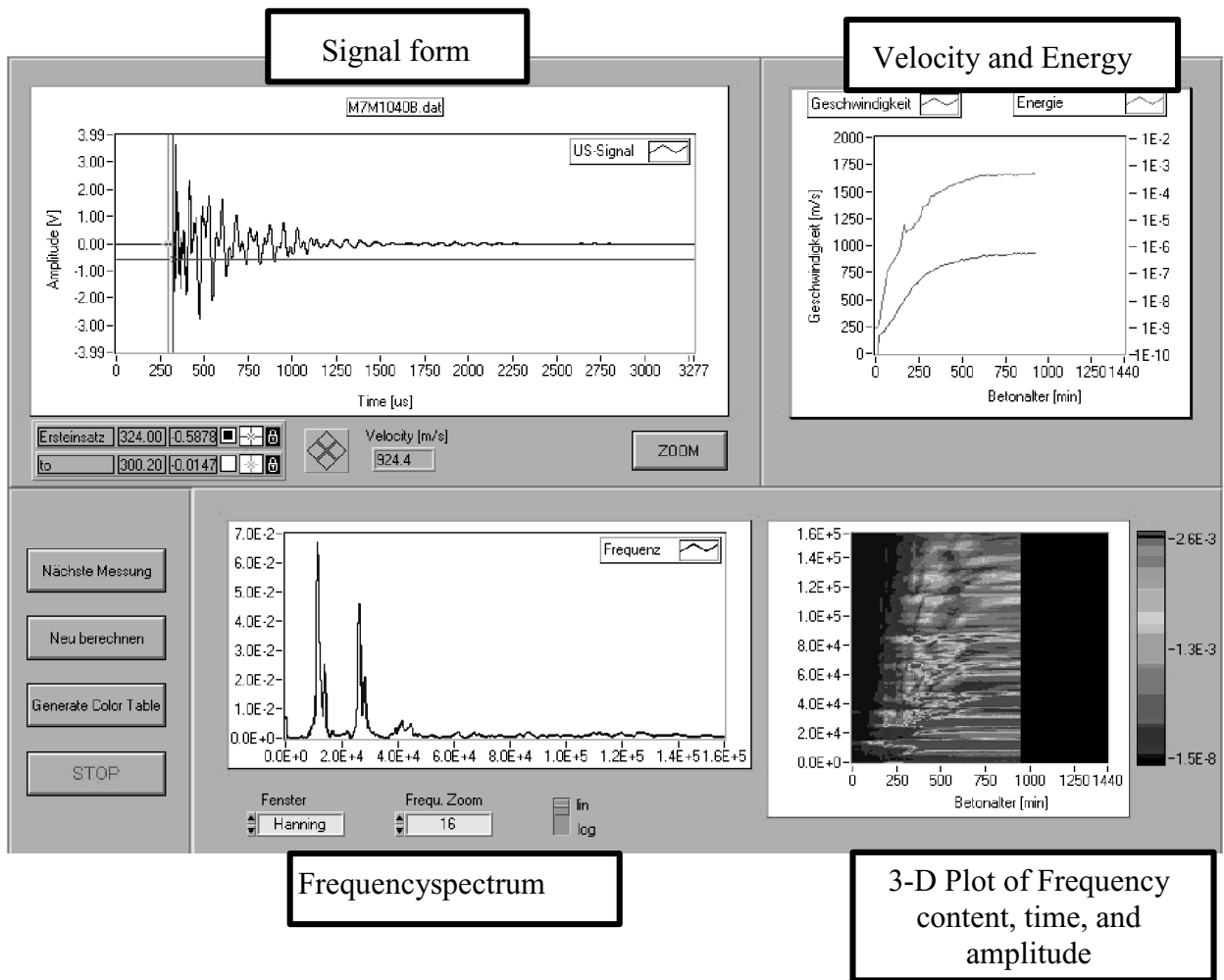
Fig. 5. The analysis window of FreshCon 2.0 during the measurement 940 minutes after compaction shows different details of the current signal as well as results of the whole measurement up to this moment.

4.   CONCLUSIONS AND OUTLOOK

FreshCon 2.0 is able to extract automatically certain parameters of transmitted ultrasonic waves recorded continuously during setting and hardening of cementious mortars. The parameters are used to calculate values which correlate indirectly with the elastic properties of the material and give a comprehensive picture of the stiffening process. These values can be controlled online, so that an intervention in the event of a hardware problem or setting errors is possible at an early stage. The detection of the moment when the material reaches a predefined state is also possible.

For further developments it is planed to implement experiment type 1 for the testing of concrete. The pick algorithm will be improved for a higher accuracy in the determination of the onset time. For a more compact testing system a PC card based ultrasonic impulse generator will implemented as well as the possibility of sending the test data or error reports via Internet to a remote user [Solbach, 2000]. For this the graphical development environment LabVIEW provides comprehensive features that allow an easy programming.

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