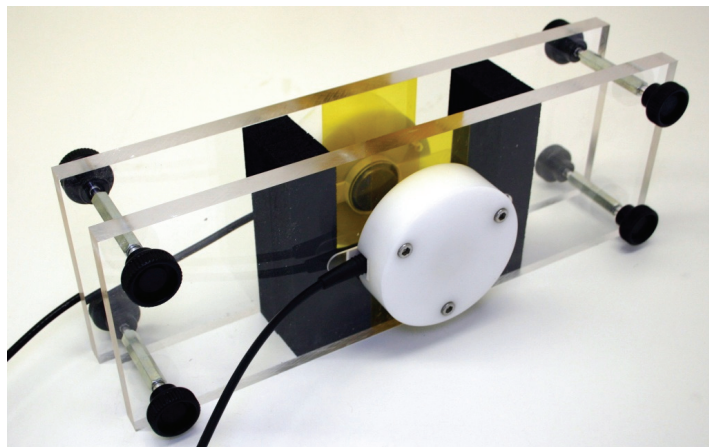


FRESHCON^{DUO}

V4.00

User Manual

Rev. 4.00, September 2012



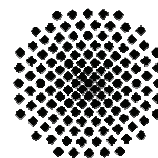
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 **SMARTMOTE**
MONITORING & TESTING

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1 Introduction

The *FreshCon 4.00* system was developed by the University of Stuttgart and TTI GmbH – TGU Smartmote to analyse the setting and hardening of any kind of materials (especially fresh cement concrete and fresh mortar) by using the ultrasound-analysis. Currently it consists of the following components:

- Industrial personal computer
- USB data acquisition device (USB-Multifunction-Oscilloscope 4262 with Arbitrary Waveform Generator)
- Pulse generator (PIEZOMECHANIK HVP 1000)
- USB pulse trigger module (Smart^{PULSE})
- At least two ultrasonic broadband piezoelectric sensors (Panametrics V 601 or comparable)
- Different cables for connecting the devices
- An optional temperature device (National Instruments 9211 with USB-9162 carrier)

The software for this system was developed with the program **LabVIEW 2011** (programming language G). The *FreshCon 4.00* system allows simultaneous data acquisition and online-analysis. For enhanced analysis functions with already recorded data there is an offline version *SmartPick 1.70* available.

2 High-voltage precautions

The high voltage pulser provides output voltages as high as 1000 Volts under normal operating conditions, so extreme caution must be employed when using the FreshCon system. The FreshCon system should only be used by individuals who are thoroughly skilled in high voltage laboratory techniques. The following precautions should always be observed:

1. Keep exposed high-voltage wiring to an absolute minimum.
2. Wherever possible, use shielded connectors and cabling.
3. Connect and disconnect loads and cables only when the high voltage pulser is turned off.
4. Keep in mind that all cables, connectors, oscilloscope probes, and loads must have an appropriate voltage rating.

Do not attempt any repairs on the system components, beyond the fuse replacement procedures described in this manual. Contact Smartmote's technical support if some of the system components require servicing.

3 Regularity Notes

The FreshCon system and its components are developed mainly for using it for scientific research in laboratory environments.

The components of the FreshCon system are enclosed in robust chassis and use a filtered power entry module (where applicable). The main output signal is provided on a shielded connector that is intended to be used with shielded coaxial cabling and a shielded load. Under these conditions, the interference potential of this instrument is low.

If interference is observed, check that appropriate well-shielded cabling is used on the output connectors. Contact Smartmote for advice if you are unsure of the most appropriate cabling. Also, check that the sensors used are adequately shielded. It is necessary to use components, which are shipped with the FreshCon system only.

If any of the connectors on the high voltage pulser are unused, they should be covered with shielded metal “dust caps” to reduce the interference potential and to reduce risk of injuries.

This instrument does not normally require regular maintenance to minimize interference potential. However, if loose hardware or connectors are noted, they should be tightened.

Contact Smartmote if you require assistance.

3.1 Declaration of Conformity

The Piezomechanik GmbH, Berg am Laim Str. 6, D-81673 München/Munich, Germany declare under their sole responsibility that the product

HVP 1000/50 (resp. HVP 1000/20)

to which their declaration relates, is in conformity with the following standards:

EN61000-6-3 and EN61000-6-1 (or other EN standards or national standards to which the product relates).

Following the provisions of the Electro Magnetic Compatibility Directive 89/336/EEC and the Low Voltage Directives 73/23/EEC.

And is in conformity with the safety standards EN 61010-1 (Safety requirements for electrical equipment for measurement, control and laboratory use), EN 60950 (Safety of information technology equipment).

We TTI GmbH - TGU Smartmote, Pfaffenwaldring 4, D-70569 Stuttgart, Germany declare under our sole responsibility that the products

Smart^{Pulse} and the

FreshCon PC

to which this declaration relates are in conformity with the provisions of the Electro Magnetic Compatibility Directive 89/336/EEC and the Low Voltage Directives 73/23/EEC.

Pico Technology, James House Colmworth Business Park, St Neots, United Kingdom declare under their sole responsibility that the product

PicoScope

to which their declaration relates complies with part 15 of the FCC rules.

The National Instruments Germany GmbH, Ganghofer Str. 70b, D-80339 München/Munich, Germany

declare under their sole responsibility that the products

NI 9211 and

NI USB-9162

to which their declaration relates, is in conformity with the following standards:

EN61326-2-1 Class A emissions; industrial immunity.

EN55011 Group 1 Class A emissions.

AS/NZS CISPR 11 Group 1 Class A emissions.

FCC 47 CFR Part 15B Class A emissions.

ICES-001 Class A emissions.

4 Software installation

For the installation of the software several programs and drivers from different manufacturers are necessary.

FreshCon 4.00.exe needs a *LabVIEW* 2011 runtime engine, if this runtime engine is not installed on the computer an error will occur.

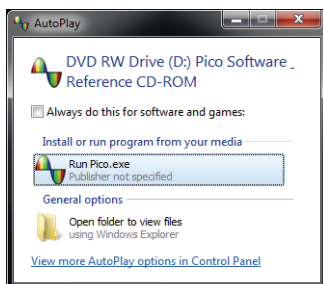


4.1.1 LabVIEW 2011 runtime engine installation

For installation of the runtime engine run the file

- *LVRTE2011f3std.exe*

and follow the instructions.



4.1.2 USB-Picoscope software installation

For the installation of the USB-Oscilloscope software do not connect the oscilloscope to the PC. Insert the Pico CD into the CD-ROM drive, the CD should start automatically. Click the

- *Run_Pico.exe*

and follow the instructions on the screen and in the *Quick Start Guide* manual of the *PicoScope*. After installation of the software the PicoScope can be connected and tested according to the manual.

4.1.3 USB driver installation for the Smart^{PULSE} device

For the installation of the USB driver for the Smart^{PULSE} device do not connect the device yet. First execute the

- *CDM20824_Setup.exe*

that is saved in the FTDI folder. A command window will appear. After the installation is completed the Smart^{PULSE} device can be connected to the USB port of the PC.



4.1.4 National Instruments 9211A USB temperature device driver installation

For the installation of the driver for the National Instruments 9211A USB temperature device run the

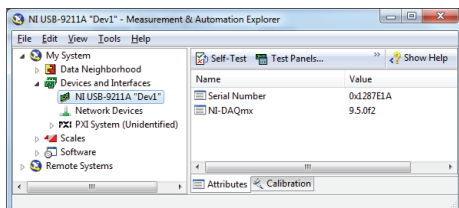
- *NIDAQ950f2.exe*

and follow the instructions. Note that even if you have no temperature device the driver must be installed.

If you want to use the temperature device connect it to an USB port of the PC, then open the

- *MAX (Measurement and Automation Explorer)*

and check if there is a NI USB-9211A configured as Dev1 found. If there is no device found then use the *Refresh* item in the *View* menu of the *MAX*.



4.1.5 Installation of the FreshCon Software

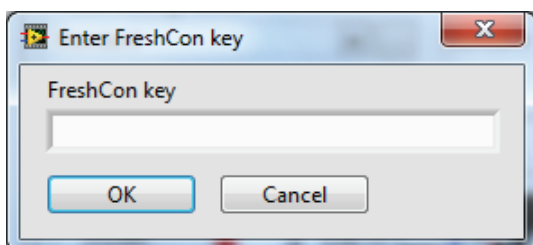
Copy the

- *FreshCon 4.00* folder

with all files from the *FreshCon* DVD to the hard disk of your computer and make sure that no file is write-protected.

4.2 FreshCon license

Each FreshCon 4.0 system is protected by a software key belonging to the serial number of the USB-Multifunction-Oscilloscope 4262, which will be delivered together with the system. If you want to use a different USB-Multifunction-Oscilloscope 4262 together with the FreshCon software a new FreshCon key is necessary, please contact SmartMote to get a new key code. The key code can be entered manually in the dialogue or the *FreshCon.key* file can be replaced by a new one.



4.2.1 FreshCon Software key dialogue

If the item **FreshCon license...** from the *Help* menu is selected, the *Enter FreshCon key* dialogue opens. Enter the key provided by Smartmote and press OK.

5 System assembly

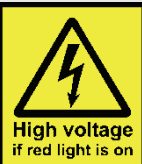
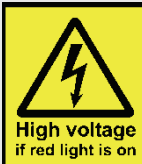
Each measurement is controlled by the software *FreshCon 4.00*, which operates the DAQ-device (**DataAcQ**quisition device) and the Smart^{PULSE} connected by USB to the PC. The DAQ-device (USB-Multifunction-Oscilloscope 4262) is used for logging data of two input channels simultaneously. The data acquisition is triggered by the Smart^{PULSE} device.

With version 4.00 of the FreshCon system we have introduced a system setup that only requires a PC with MS Windows XP (or MS Windows 7) and two USB ports. One USB port is used for the Smart^{PULSE} device, the other one for the USB-Multifunction-Oscilloscope 4262. Due to the fact that the new DAQ device now has 16 bit amplitude resolution and an enhanced range of preamplification settings the preamplifier used in the former versions of the FreshCon system is no longer required. If the optional temperature device is used another USB port is needed.

The Smart^{PULSE} device is designed to simultaneously trigger the data acquisition of the USB-Multifunction-Oscilloscope 4262 and the high voltage pulser HVP 1000. The pulse duration is selectable by the FreshCon software. Therefore, please connect the "Trigger Out DAQ" BNC output connector to the "EXT" input connector of the USB-Multifunction-Oscilloscope 4262 as well as the "Trigger Out Pulser" BNC output connector to the "MOD.IN" input connector of the HVP Pulser.

The USB-Multifunction-Oscilloscope 4262 has got two input connectors (A and B) for directly connecting two transducers. The sockets and the experimental setup will be explained in the following. Up to now it is recommended to follow these instructions accurately. Otherwise miscellaneous results can occur.

To the *PIEZO* sockets of the high voltage pulser one of the transducers for each container has to be connected. If two measurement containers are to be connected and your system is not equipped by factory with two *PIEZO* sockets you additionally have to use the T-type BNC connector provided with the system.

	Danger: It is strongly recommended to switch of the high voltage pulser if it is not in use!	
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Note: Be careful when connecting the cables to the apparatus, because when the *PIEZO* output of the pulser is connected with any other device than the transducer, it could cause severe damage to the appropriate device! So it is strongly recommended to check all connections before starting the system. It is recommended to switch on the high voltage pulser last.

Note: The transducers provided with the FreshCon system are designed to operate with input signals in a range of at most 900 Volts! So never use voltages greater than 850 volts to prevent damage of the transducer!



Fig. 1: System components (components might look different due to user specific customization)

6 Software setup

6.1 The main window

After start up at first the main window (**Fehler! Verweisquelle konnte nicht gefunden werden.**) appears. The main window has a title bar, a menu bar and some controls to operate the program. In the title bar the name and version of the program as well as the last project name is displayed.

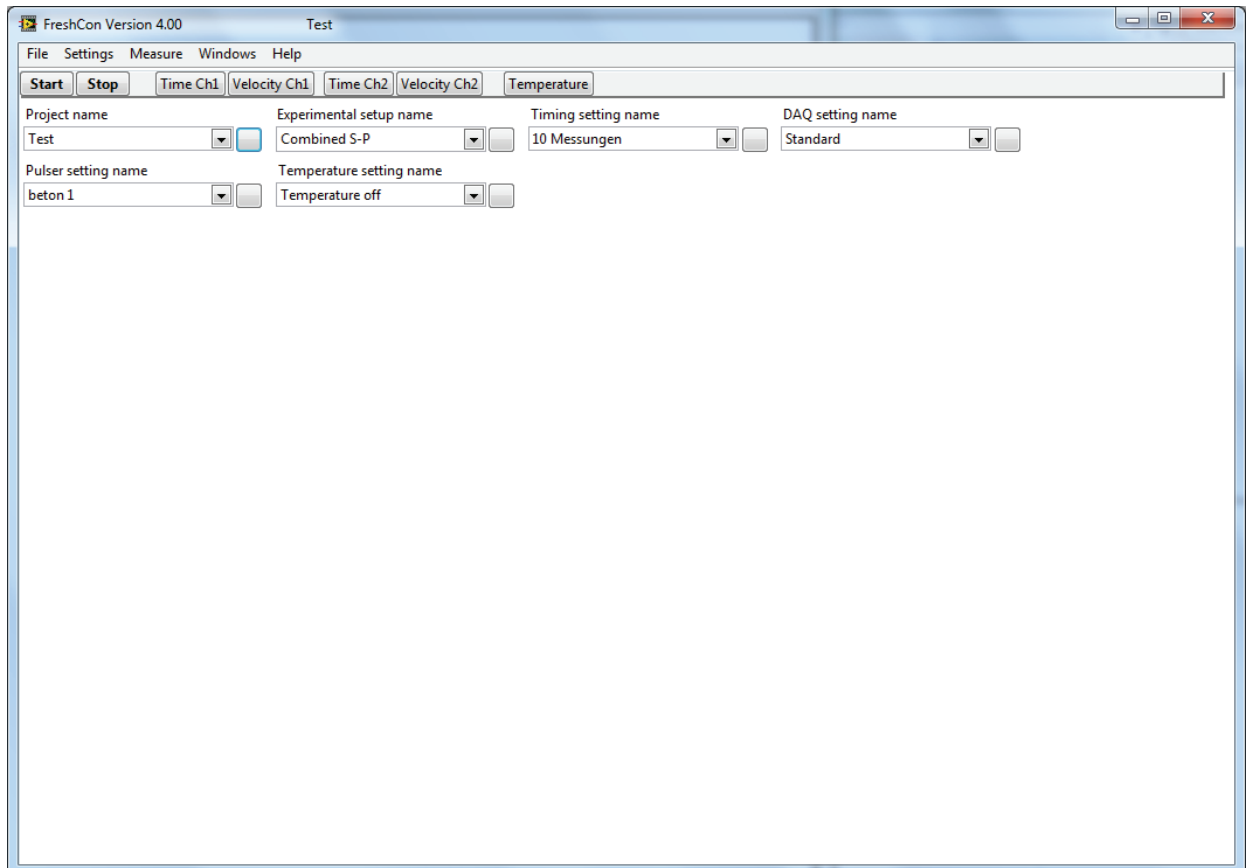


Fig. 2: The main window of the graphical user interface (FreshCon software)

6.2 The menu bar

The menu bar contains several basic items for the configuration and execution of the program. Five menus

- File
- Settings
- Measure
- Windows
- Help

can be found in the menu bar. The *File* menu contains the items

- Project...
- Quit program.

The *Settings* menu contains the items

- Experimental setup...,
- Timing...,

- DAQ...,
- Pulser...
- Temperature....

The *Measure* menu contains the items

- Start
- Stop.

The *Windows* menu contains the items

- Time channel 1
- Velocity channel 1
- Time channel 2
- Velocity channel 2
- Temperature.

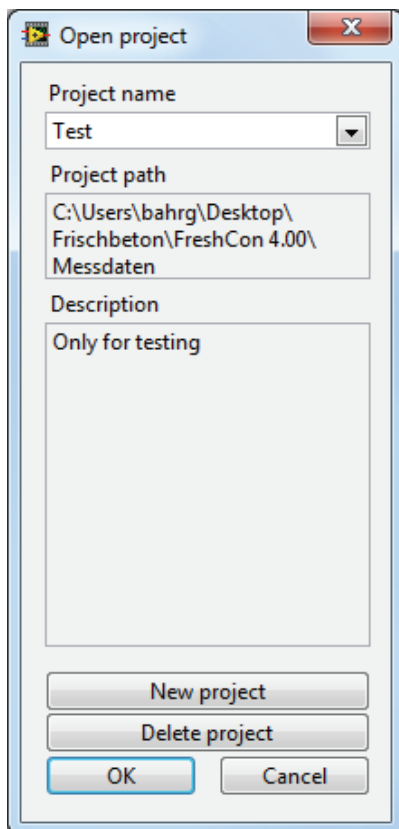
The *Help* menu contains the item

- FreshCon license...

The most important items of the menu bar are also available via controls in the upper part of the main window and can be used alternatively to the menu items.

6.3 The *Project...* item

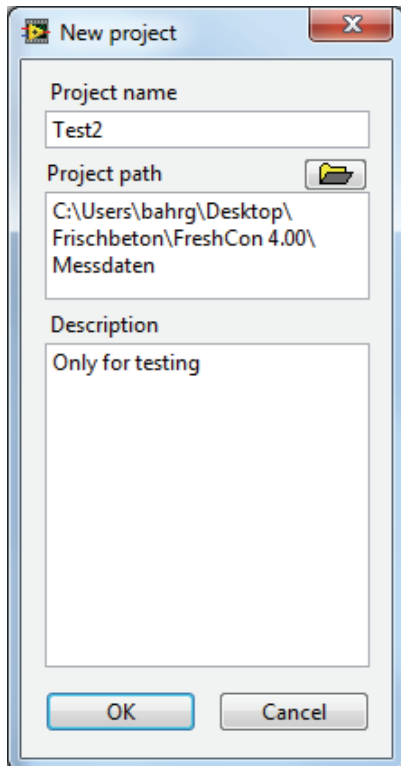
If the **Project...** item from the *File* menu is selected, the *Open project* dialogue appears. There is a drop-down list box labelled *Project name* where an already existing project can be selected.



6.3.1 The *Open project* dialogue

A project is a folder on the hard disk where all files related to a measurement like data files and setting files are stored in an adequate way (ASCII format). In the text boxes *Project path* and *Description* the path to the project and a description is shown.

Finally the *Open project* dialogue can be closed by using the *OK* or the *Cancel* push button.

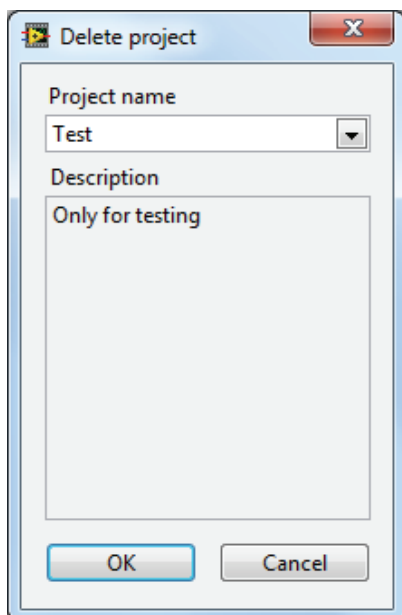


6.3.2 The New project dialogue

With the push button *New project* the *New project* dialogue is opened. A new project can be generated by entering a name in the text box *Project name* and by selecting a valid Project path with the *Open Folder button* near the *Project* text box. Additionally a description to the project can be entered in the *Description* text box.

With the *OK* or with the *Cancel* button the *New project* dialogue is closed.

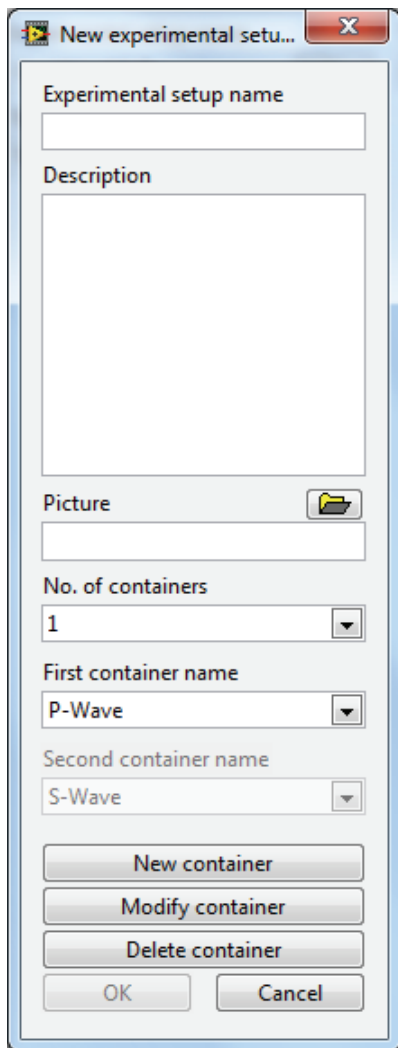
Note: After initial installation of the *FreshCon 4.00* software it is necessary first to create a new project with a valid project path.



6.3.3 The Delete project dialogue

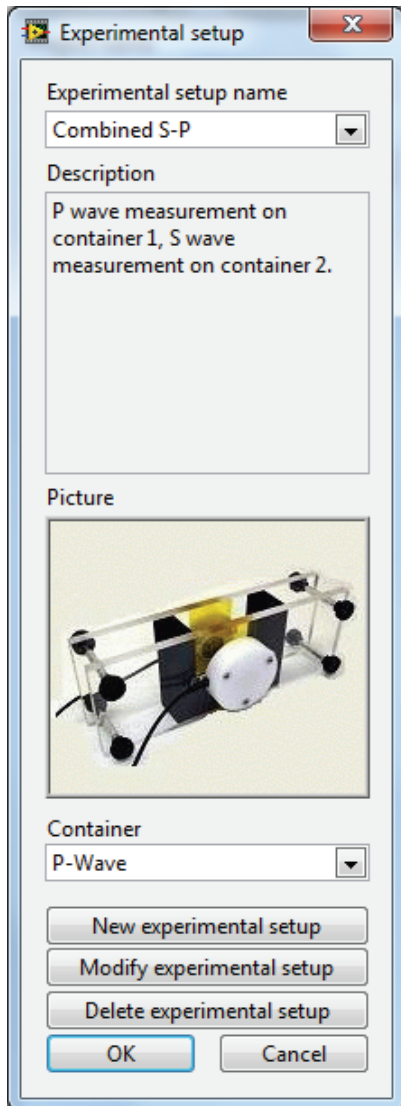
To delete existing projects the *Delete project* button in the *Open project* dialogue must be used. The *Delete project* dialogue will appear where an existing project can be selected with the drop-down list box and deleted with the *OK* button. Note that all associated data and setting files will be removed from the volume. Of course the *Delete project* dialogue can also be closed without deleting files by using the *Cancel* button.

6.4 The Experimental setup... item



6.4.1 The New experimental setup dialogue

With the *New experimental setup* button the associated dialogue window is opened. Similar to the *New project dialogue* a setup name and a description can be entered. Additionally a picture can be selected if there is one available. The picture must be a "jpg"-type and must be saved in the *FreshCon* folder. With the *No. of containers* drop-down list box one or two containers can be selected, depending on this selection the system measures only on one channel or on both channels. With the two drop-down list boxes *First* and respectively *Second container name* the correct container can be selected. If there is no suitable container a new container can be created with the *New container* button or an already existing container can be modified with the *Modify container* button.



6.4.2 The Experimental setup dialogue

With the **Experimental setup...** item from the *Settings* menu the *Experimental setup* dialogue can be opened. There is a drop-down list box labelled *Experimental setup name* where an already existing experimental setup can be selected. With the *New experimental setup* button a new setup can be created, while with the *Modify experimental setup* button an already existing setup can be modified. The *Delete experimental setup* button allows deleting an already existing and no longer used setup. Each of this buttons opens a dialogue window to operate the system.

There is an already existing experimental setup named

- **Combined S-P**

that is well suited for a two channel measurement with two containers.

6.4.3 The New container dialogue

The picture on the left shows the window of the *New container* dialogue. Each container has a unique container name and two sensors that can be selected from the *First sensor* and from the *Second sensor* drop-down list box. The distance between the two sensors respectively between the PMMA plates of the container must be measured and entered in the *Distance [m]* numeric control. Also the delay time and the reference energy should be measured for correct analysis and entered in the associated control. It will be explained later how to make a correct calibration of a container.

There are already existing two predefined containers named

- **P-Wave** and
- **S-Wave**

that are well suited for a two channel measurement.

6.4.4 The New sensor dialogue

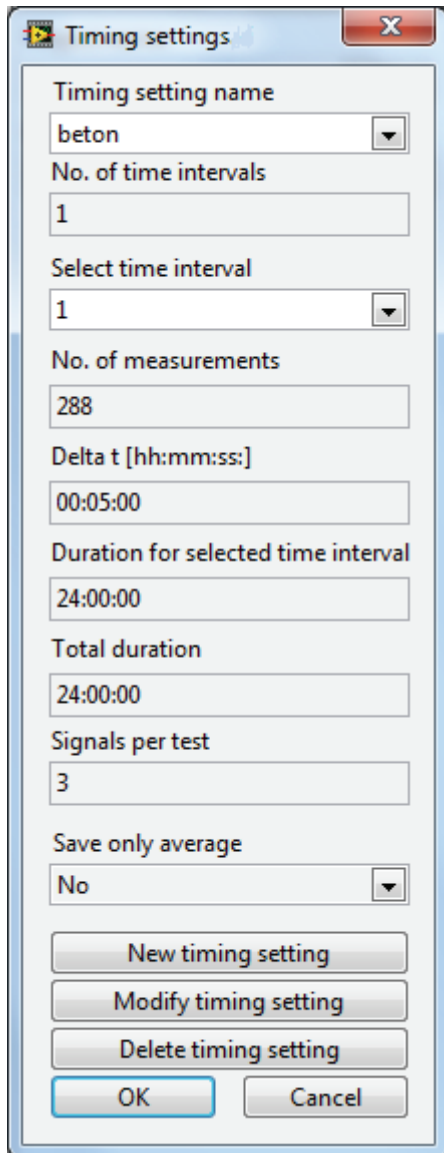
If the actually used sensor does not exist in the drop-down list box of the *New container* dialogue a new sensor can be created or an existing sensor of the *New container* dialogue can be modified. With the *New sensor* button the associated dialogue is opened. A unique sensor name and if necessary a serial number for that sensor can be entered in the text boxes. After a new sensor was created it can be used in the *New container* or *Modify container* dialogues.

6.4.5 The Delete sensor dialogue

Sensors as well as containers that are no longer needed can be deleted from the system with the *Delete sensor* respectively *Delete container* dialogue. Please note that you should not delete a container that was/is used in an experimental setup and that you should not delete a sensor that was/is used by a container.

6.5 The Timing... item

With the **Timing...** item from the *Settings* menu the *Timing* dialogue can be opened.



6.5.1 The Timing setting and dialogue

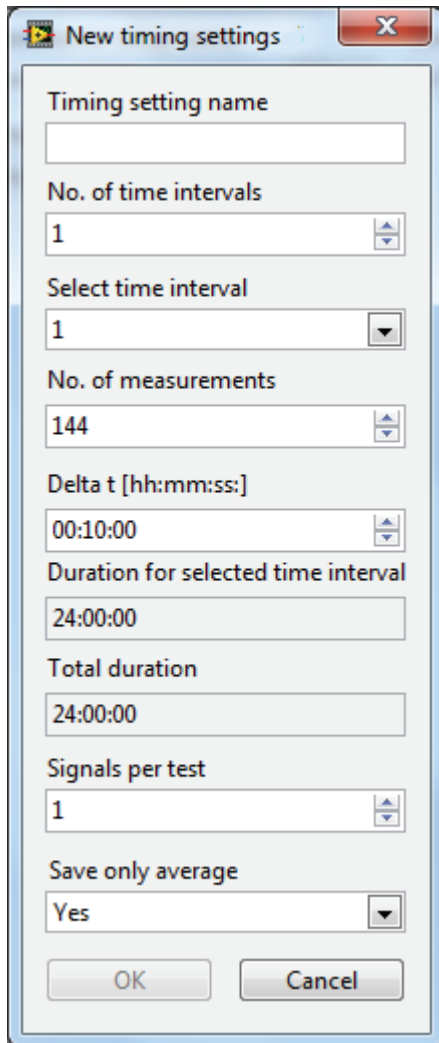
There is a drop-down list box labelled *Timing setting name* where an already existing timing setting can be selected. With the *New timing setting* button a new setting can be created, while with the *Modify timing setting* button an already existing setting can be modified. The *Delete timing setting* button allows deleting an already existing and no longer used setting.

There is an already existing timing setting named

- **beton**

that can be used for all standard mixtures without any accelerator or fast hardening cement.

Depending on the mix to be tested it may be useful to modify the settings or to create new settings for each individual test.



New timing settings

Timing setting name

No. of time intervals

Select time interval

No. of measurements

Delta t [hh:mm:ss]

Duration for selected time interval

Total duration

Signals per test

Save only average

OK Cancel

6.5.2 The New timing setting dialogue

With the *New timing setting* button the associated dialogue window is opened. A timing setting name can be entered here. With the *No. of time intervals* control up to five time intervals can be selected, each time interval can have a different number of measurements and a different time steps Δt . The duration of the selected time interval is calculated by the number of measurements and the time step Δt and displayed by the indicator *Duration for selected time interval*. The total time that is displayed by the indicator *Total duration* is the sum of the durations of each time interval.

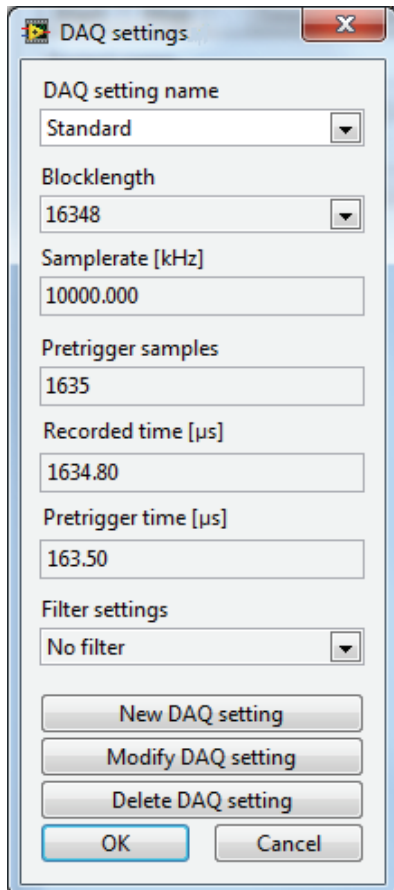
With the numeric control *Signals per test* there is an averaging function available, e.g. three single measurements are made one after another in a short time and the average of the three measurements is calculated. To reduce the data volume the control *Save only average* can be set to *Yes*. If this function is set to *No* there will be a folder in the result path(s) where all single not averaged measurements for each testing time are stored separated in folders labelled with the number of the test.

Note that the recording and averaging of the single signals need some time so if this feature is used the time step setting Δt should not be set too short, otherwise it may be possible that the measurements cannot follow the time step settings.

6.6 The DAQ... item

With the **DAQ...** item from the *Settings* menu the *DAQ* dialogue can be opened.

Note: If filter settings are changed the system must be readjusted with the calibration procedure.



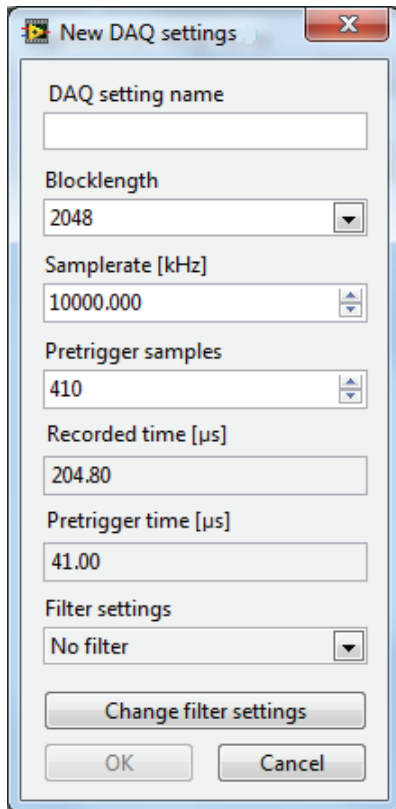
6.6.1 The DAQ settings dialogue

In the *DAQ* dialogue the time base settings for the data acquisition board that define the size and the frequency resolution of each measurement can be changed. There is a drop-down list box labelled *DAQ setting name* where an already existing *DAQ setting* can be selected. With the *New DAQ setting* button a new setting can be created, while with the *Modify DAQ setting* button an already existing setting can be modified. The *Delete DAQ setting* button allows deleting an already existing and no longer used setting.

There is an already existing *DAQ setting* named

- **Standard**

that can be used for most mixes to be tested.

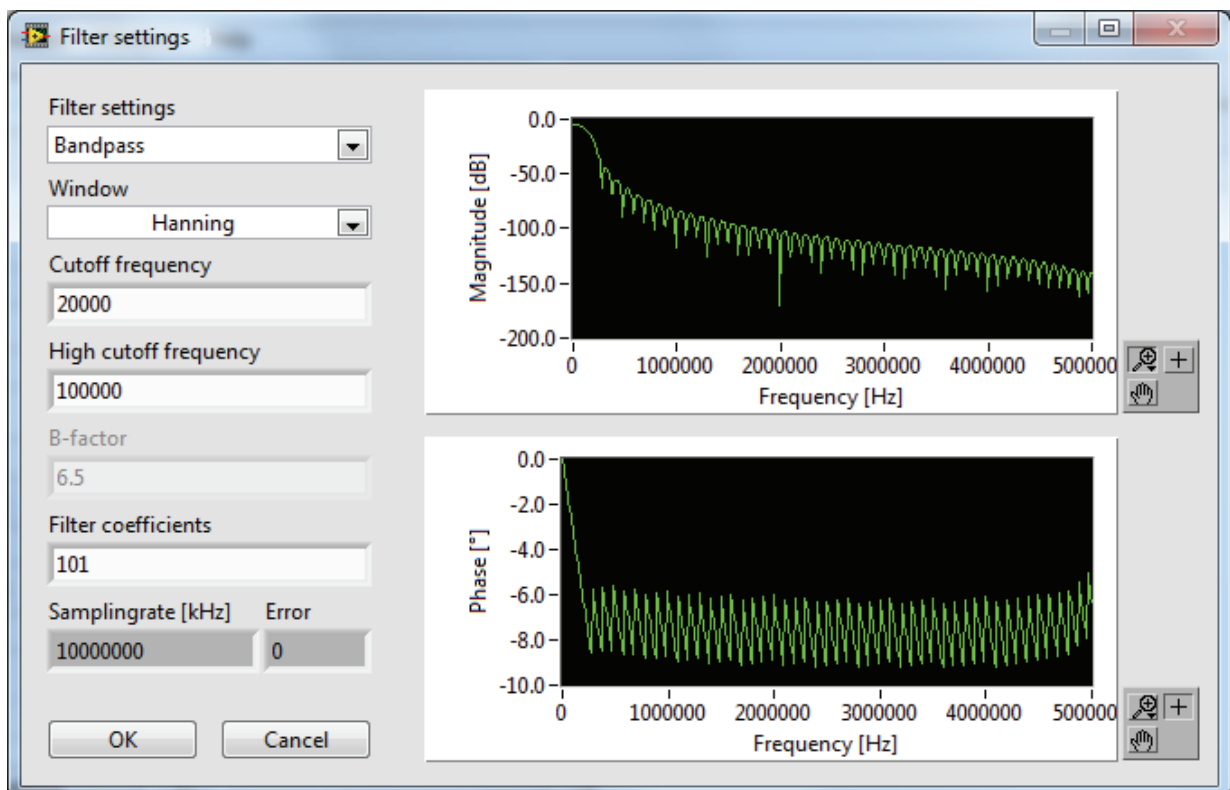


6.6.2 The New DAQ settings dialogue

With the *New DAQ setting* button the associated dialogue window is opened. A *DAQ setting name* can be entered here. With the *Blocklength* drop-down menu the number of samples that are recorded for each measurement can be changed. The *Samplerate* drop-down menu defines the sampling rate while the *Pretrigger samples* drop-down menu defines the number of samples recorded before a trigger signal occurs. A suitable value for the pretrigger setting is about ten percent of the whole blocklength. Please also note that the automatic signal onset picker requires 1000 samples as pretrigger.

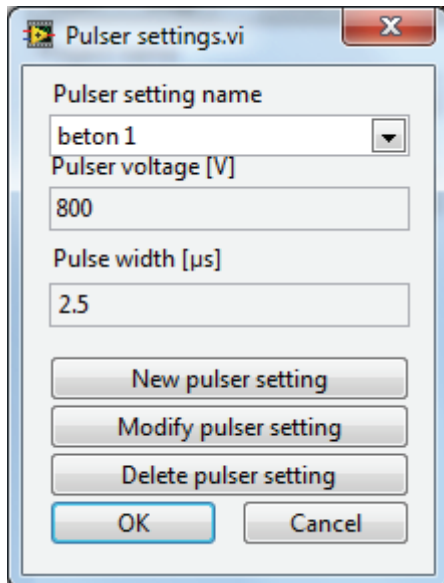
The *Recorded time* of the measurement in μs is calculated by the reciprocal of the sampling rate multiplied with the block length, whereas the *Pretrigger time* in μs is calculated by the reciprocal of the sampling rate multiplied with the Pretrigger samples. The DAQ-device of the FreshCon system is up to now able to work with a maximum sample rate of 10 MHz.

With the *Change filter settings* button a digital FIR filter (finite impulse response) can be used. A dialogue window *Filter settings* opens when the *Change filter settings* button is pressed and the filter settings can be adjusted. The filter algorithm is an FIR windowed coefficients algorithm. The filter type can be selected with the *Filter settings* drop-down list, low-pass, highpass, bandpass, bandstop and no filter are available. With the controls *Cut-off frequency*, *High cut-off frequency*, *B-Factor* and *Filter coefficients* the filter response can be tuned. The amplitude and phase response are displayed in the associated graphs.



6.7 Pulser... item

With the **Pulser...** item from the *Settings* menu the Pulser dialogue can be opened.



6.7.1 The Pulser settings dialogue

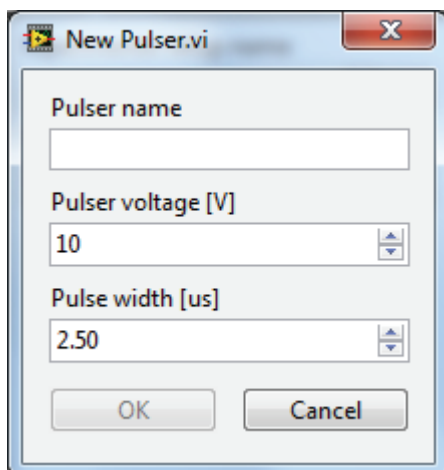
There is a drop-down list box labelled *Pulser setting name* where an already existing pulser setting can be selected. With the *New pulser setting*, *Modify pulser setting* and *Delete pulser setting* buttons a new setting can be created or an already existing setting can be modified or deleted.

There is an already existing pulser setting named

- **beton 1**

that can be used.

The pulser voltage must be manually set on the front panel of the *HVP 1000-50* with the aid of the ten-turn potentiometer, the control *Pulser voltage [V]* in the *Pulser* dialogue should be set to the same value then.



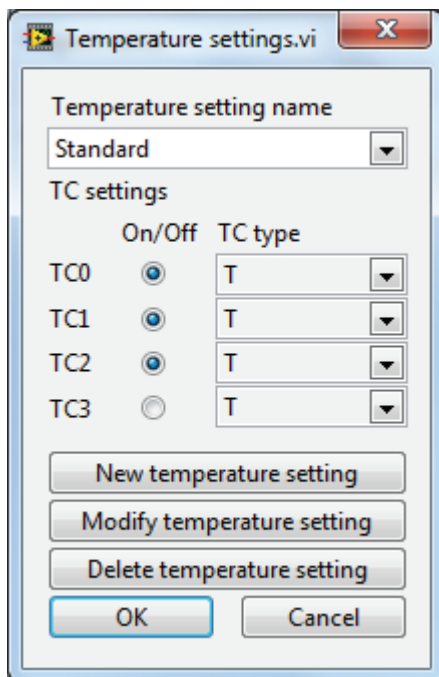
6.7.2 The New Pulser dialogue

In the *New pulser* or *Modify pulser* dialogue the pulse width of the external high voltage pulser *HVP 1000-50* can be set with the associated control. The minimum pulse width is given by 2.5 μs and the maximum by 16 μs . According to the experiments conducted in the course of the development of *FreshCon* a value of 5 μs seems to be suitable for almost all experiments. Higher values are only necessary for highly damping materials.

The pulser voltage must be manually set on the front panel of the *HVP 1000-50* with the aid of the ten-turn potentiometer, the control *Pulser voltage [V]* in the *New pulser* dialogue should be set to the same value then.

6.8 The Temperature... item

With the **Temperature...** item from the *Settings* menu the Temperature dialogue can be opened.



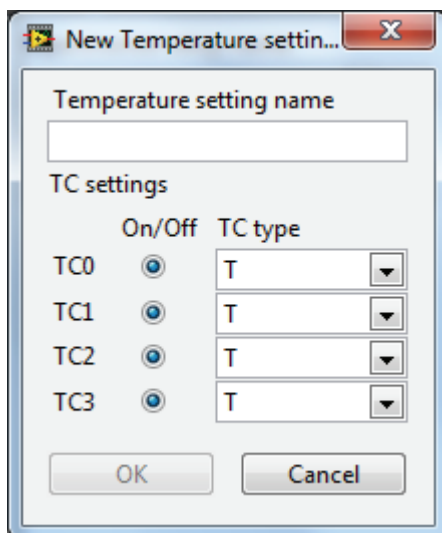
6.8.1 The Temperature settings dialogue

There is a drop-down list box labelled *Temperature setting name* where an already existing temperature setting can be selected. With the push buttons *New temperature setting*, *Modify temperature setting* and *Delete temperature setting* a new setting can be created or an already existing setting can be modified or deleted.

There are already existing temperature settings named

- **Standard** and
- **Temperature off**

that can be used.



6.8.2 The New temperature settings dialogue

In the *New temperature setting* dialogue up to four channels can be configured for temperature measurement. With the On/Off radio buttons the associated temperature channel can be switched on or off and with the drop-down list box *TC type* the correct thermocouple type can be selected. The standard type of the thermocouple is T. The different TC types depend on the materials of the conductor pair of the thermocouple. The *FreshCon* system is provided with thermocouples of type T.

There is an optional calibrated isolation container for the *FreshCon* system available, in which the predefined amount of 1575 g concrete or mortar mixture can be filled. The container is made for measuring the temperature without any external influences like the changing of the ambient temperature. For example, one can measure with one channel the temperature of the environment, with another channel the temperature of the mixture in the PMMA *FreshCon* container and last the temperature in the isolated container and compare them.

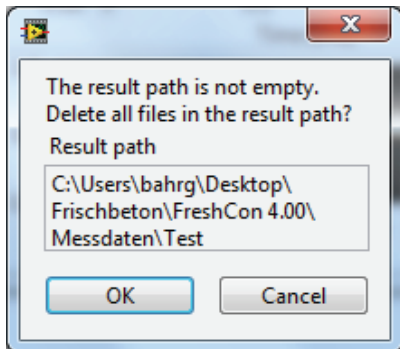
The temperature is written in an ASCII file in the result directory with the file extension .tem.

6.9 Starting a measurement

With the push button

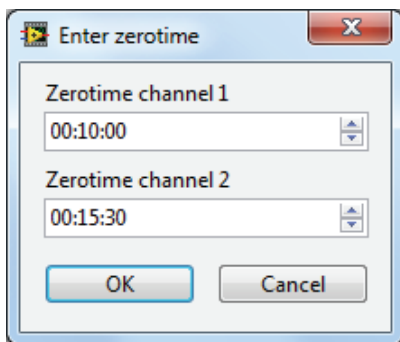
- **Start**

on the Main window or with the item *Start* from the *Measure* menu the measurement can be started.



6.9.1 Existing measurement data check

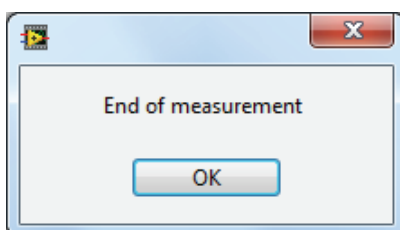
If the project path that was selected in the project settings is not empty a dialog appears asking to delete all files in the result path. With the *Cancel* button the start of the measurement will be aborted, but if the *OK* button is pressed all files in the result directory will be deleted and the measurement will start.



6.9.2 Zero time definition

Before the measurement starts another dialog will appear asking for an input of the zero time of channel 1 and channel 2.

The zero time is the time from adding water to the cement until starting the measurement with the *FreshCon* system. This time will be the initial time in the graphs for the calculated velocity etc. If only one channel is used, the zero time of channel 2 should be set to zero.



6.9.3 End of measurement

To indicate the end of the measurements a message is displayed.

Note: After starting the first measurement it is not any longer possible to change or modify the settings of the running experiment.

If the measurement is running it can be aborted with the push button

- **Stop**

on the Main window or with the item *Stop* from the *Measure* menu. If the measurement is not aborted a dialog window indicating the *End of measurement* will appear after the last measurement was done.

6.10 Displaying the results during a measurement

There are several windows to display the results of the measurement. These windows can be opened or closed before the measurement is started or while the measurement is running with the push buttons *Time Ch1*, *Time Ch2*, *Velocity Ch1*, *Velocity Ch2* and *Temperature* which are located on the Main window or via the corresponding items in the *Windows* menu.

If *Time Ch1* respectively *Time Ch2* is selected the associated window (Fig. 3) is shown. The time signal in the upper part of the window shows the amplitudes in volts recorded by the transducer over the signal length in milliseconds specified during the experiment. The red cursor position correspond to the automatically determined onset time of the p-wave. The blue cursor can be used for additional time measurements of the time signal. Both cursors can be changed manually; the X-position of the cursors is displayed in the indicators at the left side of the time signal.

Below the X-position indicators there is a LED bar with eleven LEDs corresponding to the eleven preamplifier ranges of the PicoScope 4262, whereas the most right LED belongs to the lowest (most sensitive) range and the most left LED belongs to the highest range. The LED that is lightened up corresponds to the actual selected range.



On the right hand side of the time signal, the cursor controls can be found. Clicking the zoom lens symbol gives various possibilities for changing the zoom in the time signal.

The cursor changes into a zoom tool. The cross symbol activates the standard cursor tool, which allows changing the set cursor positions. Selecting the hand symbol permits to shift the entire graph position within the given limits and without changing the zoom.

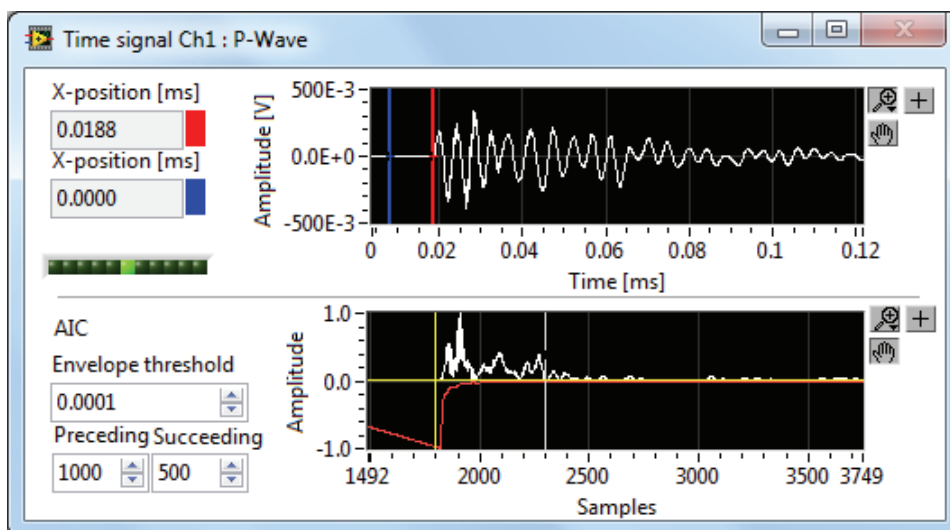


Fig. 3: The window *Time signal channel 1* (channel 2 is identical)

6.10.1 The p-wave onset picker

The picker for the determination of the p-wave onset is based on the Akaike Information Criterion (AIC)¹. It was adapted to ultrasonic signals by Kurz, Große and Reinhardt². The developed autoregressive AIC-picker first creates an envelope time function $E(t)$ via the Hilbert transform $\bar{R}(t)$ from the time signal $R(t)$ as

¹ AKAIKE, H.: *A new look at the statistical model identification*. IEEE transactions on automatic control, vol. AC-19, no. 6, 1974.

² KURZ, J.H.; GROßE, C.U.; REINHARDT, H.W.: *Strategies for reliable automatic onset time picking of acoustic emissions and of ultrasound signals in concrete*. Ultrasonics, vol. 43, pp. 538 - 546, 2005.

$$\bar{R}(t) = \frac{1}{\pi} \cdot \int_{u=-\infty}^{\infty} \frac{R(u)}{t-u} du$$

$$E(t) = \sqrt{R(t)^2 + \bar{R}(t)^2}$$

where $\bar{R}(t)$ Hilbert transform
 $R(u)$ time signal
 u current timestep
 $E(t)$ envelope time function

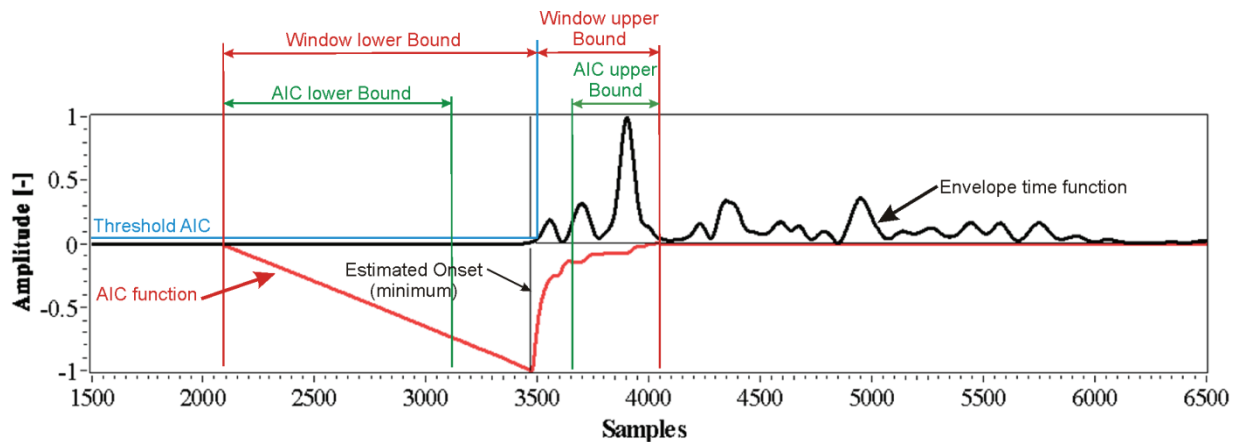
In the envelope time function, a simple threshold level set by the *Threshold AIC* is used to pick an onset window. The size of the window is specified by the parameters *Window upper bound* and *Window lower bound*. These parameters define a number of samples before and after the located time in the envelope time function corresponding to the AIC threshold level.

The AIC function $AIC(t_W)$ is then calculated for the selected window as

$$AIC(t_W) = t_W \cdot \log\left(\text{var}(R_W(t_W, 1))\right) + (T_W - t_W - 1) \cdot \log\left(\text{var}(R_W(1 + t_W, T_W))\right)$$

where $AIC(t_W)$ AIC function within the selected window
 t_W time within the selected window
 R_W time signal within the selected window
 T_W maximum time of the selected window
 $\text{var}(R_W(t_W, 1))$ the variance of R_W from the current value of t_W
 $\text{var}(R_W(1 + t_W, T_W))$ the variance of R_W between $1 + t_W$ and the T_W

On the basis of this AIC function a second window is cut in which *AIC lower bound* and *AIC upper bound* define the number of samples that where cut at the beginning and the end of the AIC function. Within the remaining window the point of the minimum is determined, which then equals the estimated onset time of the time signal (see figure below). This second cutting of the window is sometimes needed if certain noise (e.g. electromagnetic interference at the very early stage of concrete hardening) lead to multiple minima in the AIC function.



In *FreshCon V4.00* the p-wave onset picker is located in the lower part of the *Time signal channel 1* window, it shows the envelope time function (white) and its corresponding AIC func-

tion (red). The *yellow cursor* indicates the point where the specified threshold level is exceeded. The two *gray cursors* are related to the preceding and succeeding samples. To change the AIC parameters, either the values in the input boxes can be changed, or the cursors in the AIC graph can simply be shifted to the desired values.

To the right of the graph, cursor controls like described for the time signal can be found.

6.11 The Velocity window

If *Velocity Ch1* respectively *Velocity Ch2* is selected from the main window or the *Windows* menu the associated window (Fig. 4) is shown. The p-wave velocity is calculated from the *Distance* and the *Delaytime* defined by the container and the picked onset time for each time signal by the formula

$$V_p = \frac{\text{distance}}{\text{tonset} - \text{tdelay}}$$

and is displayed in the graph versus the time set in the timing dialogue. Distance, onstarttime, delaytime and the p-wave velocity of the actual measurement are additionally displayed in the indicator boxes at the left side of the graph.

To the right of the graph, cursor controls like described for the time signal can be found. Additionally there is a legend control where the color and the style of the curve can be changed by clicking on this control.

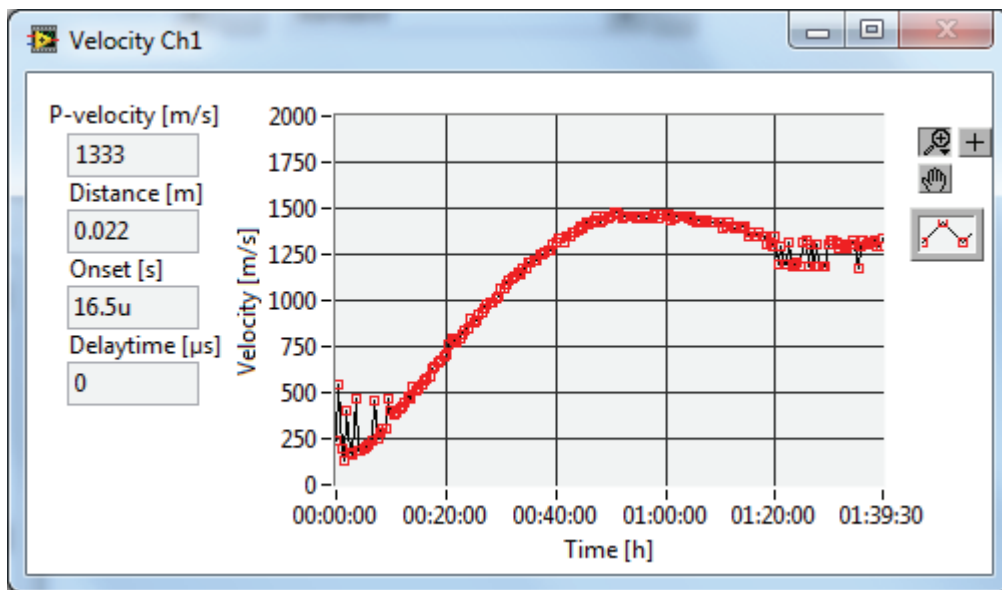


Fig. 4: The Velocity channel 1 window

6.12 The Temperature window

If Temperature is selected from the main window or the *Windows* menu the associated window is shown. The temperature values of the temperature channels selected in the temperature dialogue are displayed in the graph versus the time set in the timing dialogue. Fig. 5 shows a typical temperature plot where TC0 (blue plot) measures the temperature in the container and TC1 (red plot) measures the ambient temperature.

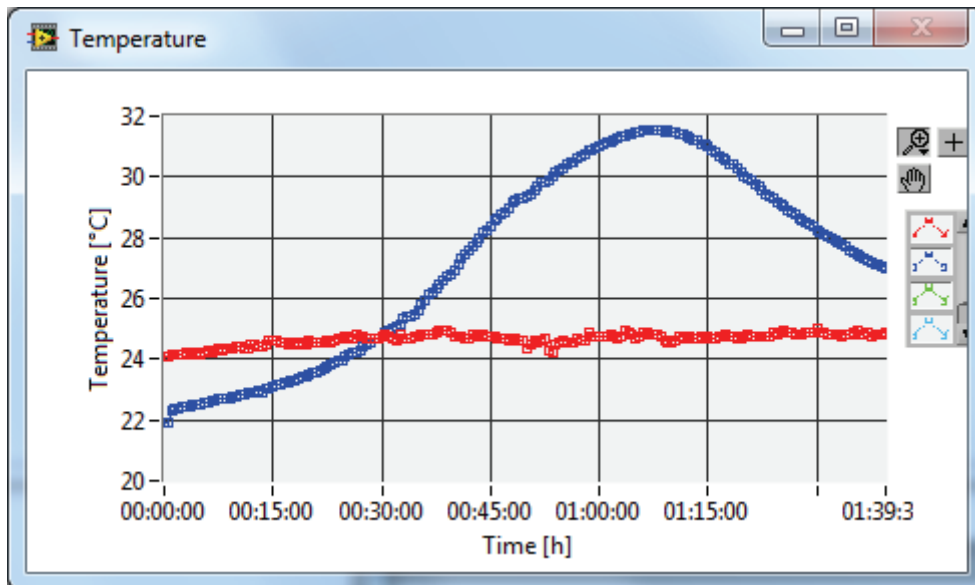


Fig. 5: The Temperature window

6.13 The settings file

The settings are stored as an ASCII-file in the result path, so it is possible for each user to have a look to settings of even older experiments. Such a file, labeled as *settings.txt*, is shown in Fig. 6. In this settings file all necessary settings are shown. Using this file it is also possible to change some parameters like the calibration parameters or the Zero time later.

The analysis software *SmartPick 1.70* reads this file for each project. And if, for example, the calibration parameters or the zero time picker were set wrong, it is possible to reset the parameters by changing them in the settings file.

```
FreshCon Version 4.00
Experiment Name Mortar
Filename      tst
Container Name Mortar
First Sensor  V101-1
Second Sensor V101-2
Distance [m]  0.0220
Delay Time [sec] 0.000E+0
Ref. Energy   1.000E+0
No. of Tests  240
Test Interval [min] 0.50
Intervals     240:30
Signals per Test 1
Zero time [min] 0.00
Pulser voltage [V] 800
Pulse width [us] 2.5
```

Fig. 6: The settings file

7 Calibration of the system

For correct analysis results it is recommended to make a calibration of the system. First the distance between the PMMA plates of the currently used container(s) should be measured exactly e.g. with a calliper.

The delay time can be measured by putting a calibration standard for p-waves between the two PMMA plates of the container instead of the mortar or the concrete material. However, also other calibration methods might be useful; if e.g. no standard is available it is also possible to put the PMMA plates respectively the sensor surfaces directly together. The coupled surfaces should be covered with glycerine or silicon grease to assure correct contact. The onset time measured in this way is exactly the time (dead time correction) the system needs for operation. Later this delay time will be subtracted from the onset time and so the real runtime of the signal through the specimen material is calculated for the velocity plots.

As in this *FreshCon* version no energy analysis is implemented the value for the reference energy should be set to exactly 1.

Note: The calibration is only valid for a certain test setup with a specific setting and so it is strongly recommended to record the settings of the devices to the calibration parameters. If any setting has changed, for example the voltage or the pulse width of the pulser these calibration parameters might change. This is especially true if filter settings are changed.

8 Measurement system setup

8.1 Test container preparation

The test containers provided with the FreshCon^{Duo} version are designed to operate with compressional wave as well as shear wave transducers. The main improvements of the new test containers are:

- Transducer encapsulation to provide better robustness
- Direct sensor coupling to the test mix through a ultrathin Polyimide foil for better coupling, less interference and signal distortion
- Flexible sensor fixing avoid decoupling due to early age shrinkage

In the following the test container preparation procedure is presented to obtain good test results. It is recommended to follow the instructions carefully:

1. Unscrew the test container and clean up the sidewall and the sensor surface with water and a fat-dissolving agent (agent should not dissolve PMMA) (see Fig. 7).
2. Take the Polyimide foil and glue it to the test container. Start with gluing from the bottom edge. If you come into the region of the sensor press the foil with a finger onto the piezo element (see. Fig. 11). The foil must be absolutely flat in the area of the piezo element. Try to avoid any air bubbles or wrinkles on the sensor surface. If the foil has full contact to the sensor use the nail of your finger to fix it properly.
3. Glue the foil onto the rest of the container. It does not matter if some wrinkles are in the foil or air bubbles are between the PMMA sidewall and the foil. It is only important that the foil is glued in a way that the transducer is protected from water from the test mix getting to the sensor.
4. Use a cutter to cut off the Polyimide foil at the edges of the PMMA sidewall and prepare the second PMMA sidewall the same way.
5. Assemble the test container by using the distance nuts (25 mm or 50 mm) and the rubber foam. Please note that the cables of the sensors should show in the same direction, because correct polarity of the shear wave transducers is important for the further analysis.
6. The test container is now ready for use.

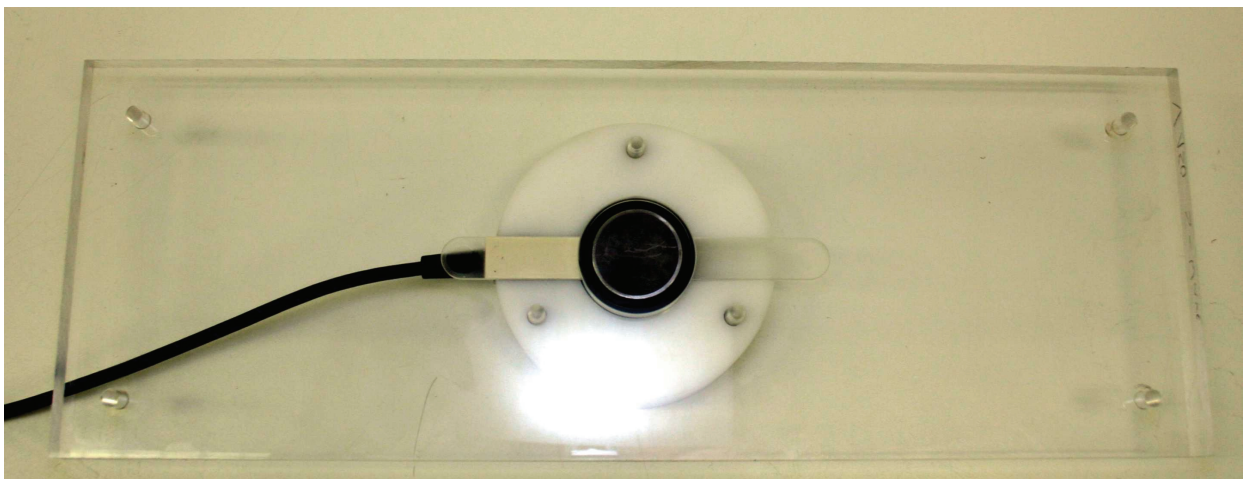


Fig. 7: Sidewall of test container with implemented sensor.

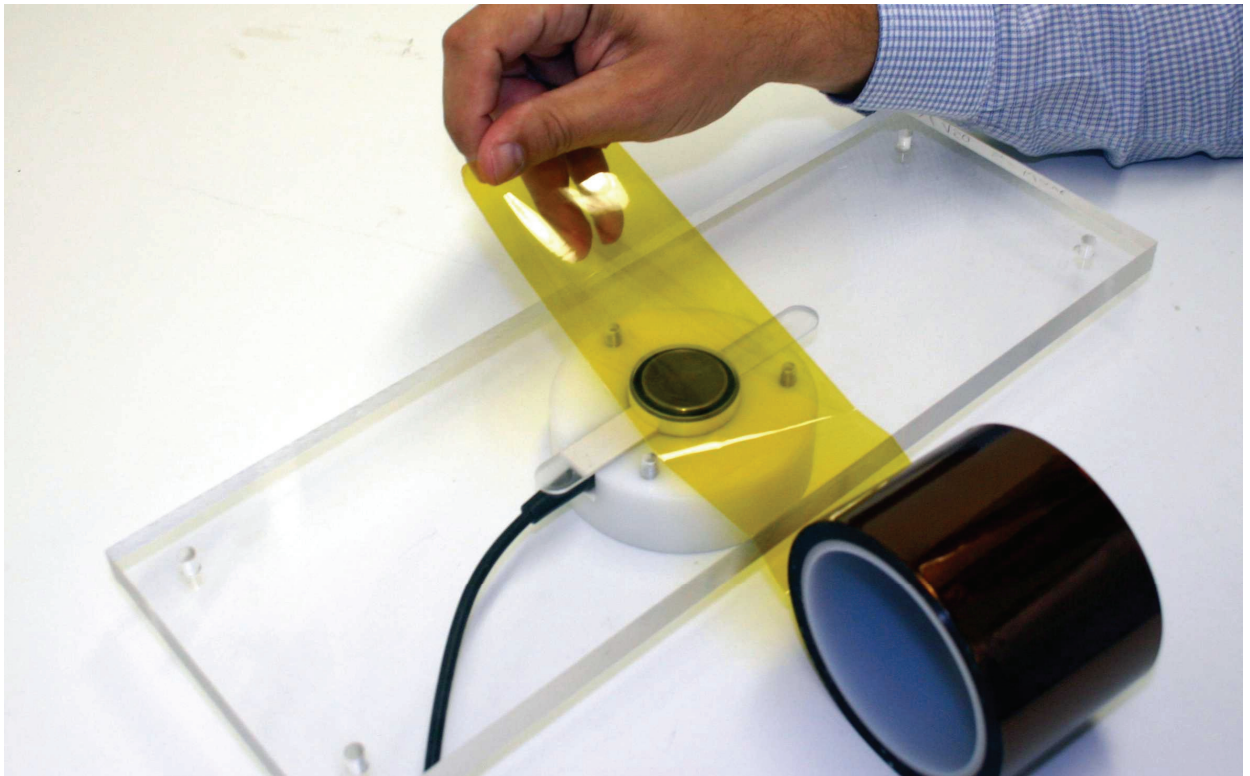


Fig. 8: Placing the Polyimide foil (1).

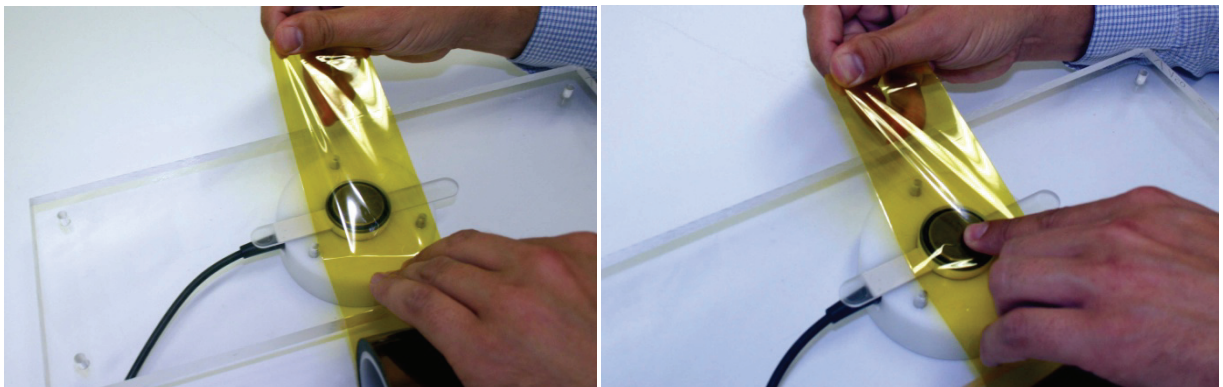


Fig. 9: Placing the Polyimide foil (2).

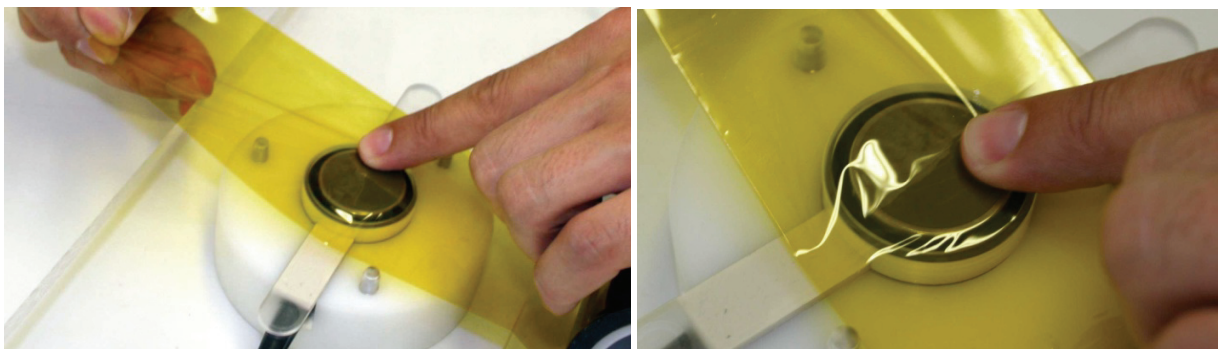


Fig. 10: Placing the Polyimide foil (3).



Fig. 11: Placing the Polyimide foil (4), avoid air bubbles.

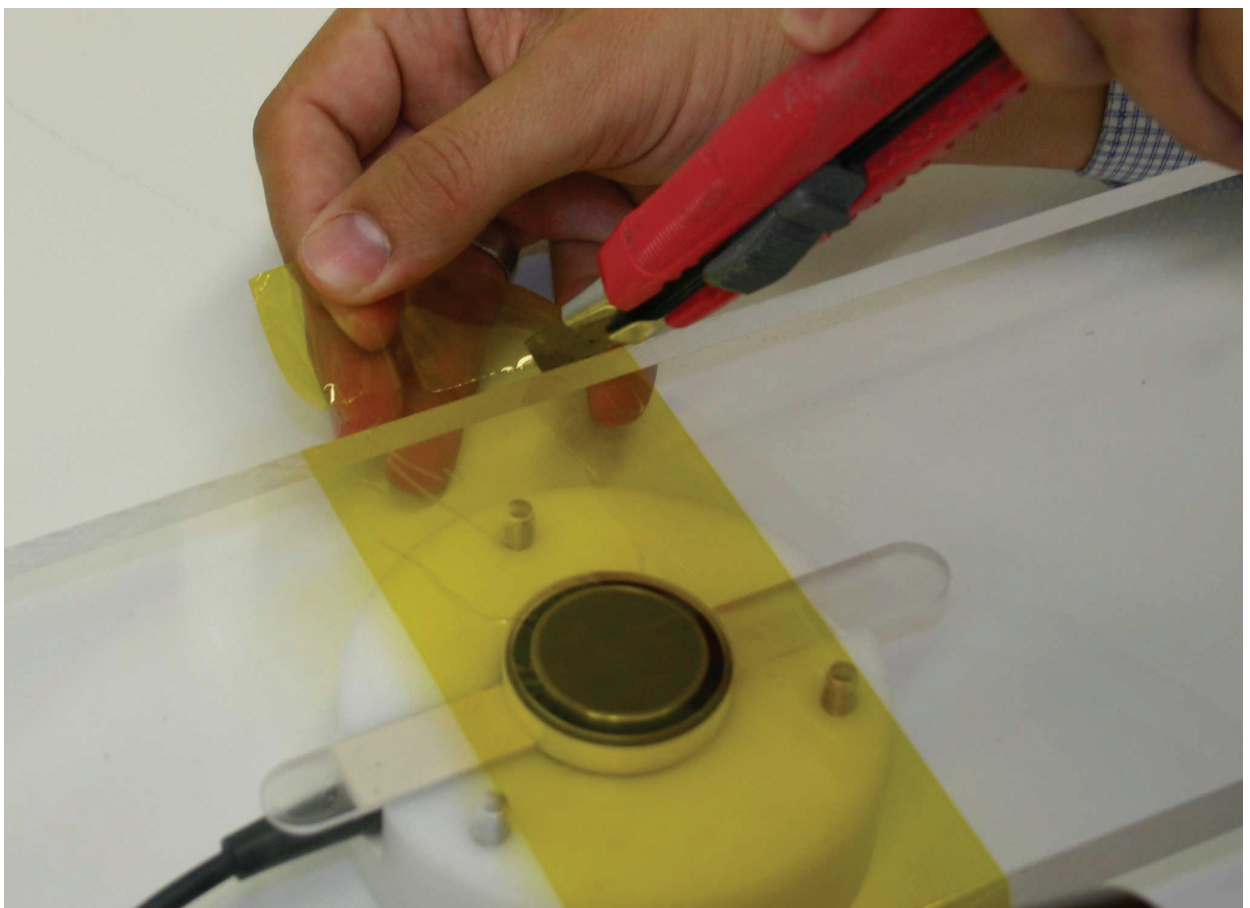


Fig. 12: Cutting the Polyimide foil.

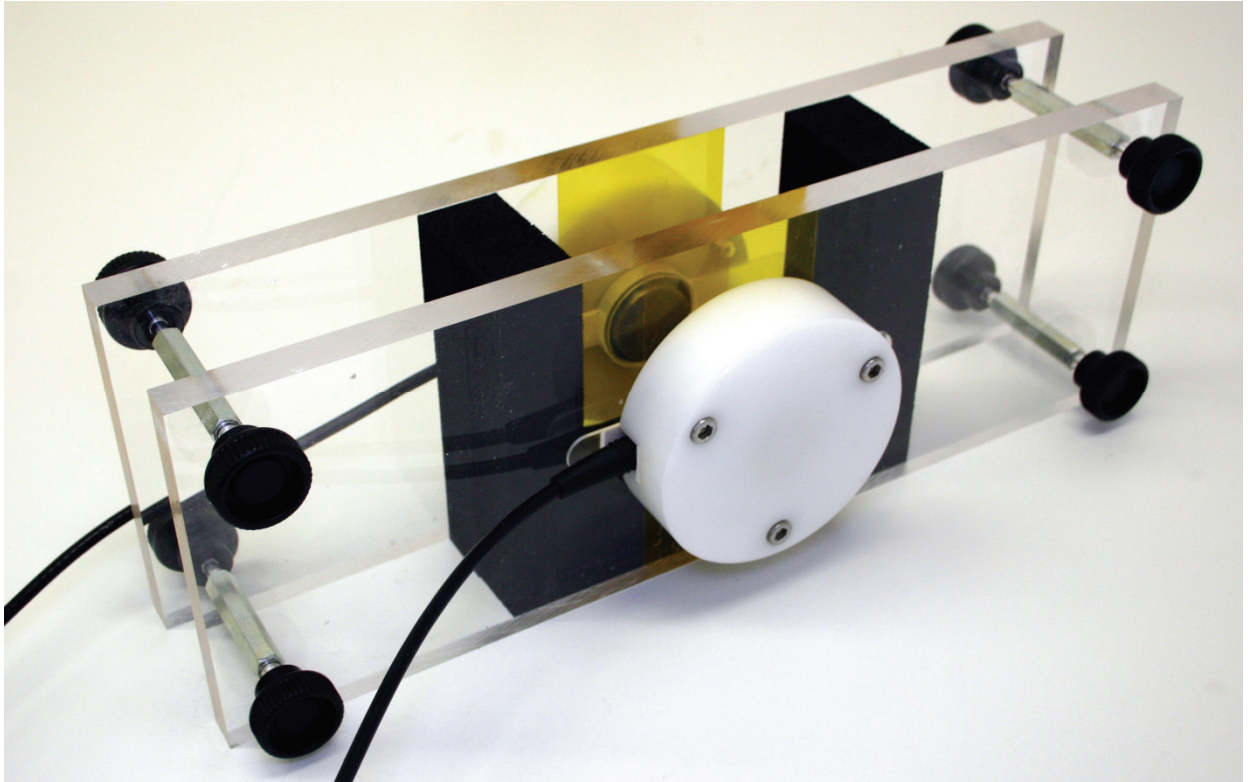


Fig. 13: Test container ready to use.

8.2 Test procedure

The following steps describe a procedure that is proven to be sufficient for testing most concrete mixes.

1. Clean the test container and check for damages of the Polyimide foil and correct coupling of the sensors. Place a very thin layer of formwork release oil onto the sidewalls and the rubber foam, but do not put it onto the sensor surfaces.
2. Close the test container with the screws.
3. Start the FreshCon software and make the initial software settings.
4. Prepare a mix to be tested.
5. Fill in the mix into the test container. Put the rubber foam pieces provided with the container on top of the mix. Do not forget to place the TC0 thermocouple in the middle of the material by putting it through the rubber foam.
6. Press down the rubber foam.
7. Start the measurement (for details see chapter 0).
8. When measurement is finished, strip the test specimen, measure the exact thickness of the test mix specimen and correct, if needed, the thickness for correctly calculating the velocities. If measured thickness is different from the initial value, velocities have to be calculated again with the correct value.

9 Appendix

9.1 Further developments

I would be glad to accept wishes and new ideas in respect to the further development of this program. The next experiments will show which further changes or enhancements are required anymore. Please do also refer detected software bugs to:

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