# Schleibinger Curling- or Bending-Drain

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# 1 Introduction

All mortars are changing their volume from the moment the binder particles came in contact with water until several months and years. In most practical application this expansion and shrinkage must be minimized. Many theoretical models are describing the cause of this effects, but specially the mechanism in the first hours are not completely understood yet. One demanding prerequisite for controlling the shrinkage of mortars are measurement instruments that are able to measure shrinkage and expansion from the early beginning of hydration and setups that are able to simulate environmental conditions in the field application.

Up to now shrinkage and expansion of building materials is measured by simple mechanical instruments like cantilevers. Therefore a certain strength of the material is necessary.

There is a survey given about more modern sensors and instruments measuring also the early shrinkage before the setting point. Beneath others a contactless LASER based measurement method with a coneformed formwork is presented avoiding the problems shown above.

## 1.1 Taxonomy of Shrinkage Measurement Systems

As long as a material is in the fluid state shrinkage is not causing a problem. The only thing you have to keep in mind is, that a length change on each site of a 1 cubicmeter cube of 1/1000 is already a volume change of about 3 liters.

When the material is setting and/or is in contact with a material that has no shrinkage or expansion, strain inside the material or in the contact zone will appear. As soon as this tension will be over the actual tensile strength of the material, the material structure will be damaged, usually by the occurring of cracks.

Therefore its obvious not only to measure the free shrinkage but also the strain that occur. It's called measurement of the blocked or restrained shrinkage. The tensile strength and the materials volume is changing most in the first hours after mixing, so restrained and free shrinkage should be observed as early as possible in the hydration process.

The process of crystal grow itself is influenced by the environmental conditions like temperature, humidity, freeze thaw cycles, penetration of gas, or salty or acid liquids. This environment must be kept constant to detect the shrinkage of the material itself. But on the opposite the length change may be an indicator for the resistance against an environmental attack on the material. For example for detecting the alkali silica reaction or for indicating the freeze/thaw resistance of concrete.

Figure 1 shows free shrinkage over the time in a general way. We must distinguish 3 ranges of of material strength for using different measurement techniques:

- fluid (F)
- starting of setting (S)
- hardened material (H)

These 3 ranges may be subdivided depending on the material geometry and environmental conditions. For example:

- rigid volume, no evaporation

- low volume, high surface, high evaporation
- high or low temperature
- periodical temperature changes
- humidity gradient
- temperature gradient

The appropriate shrinkage measurement instruments are also shown.

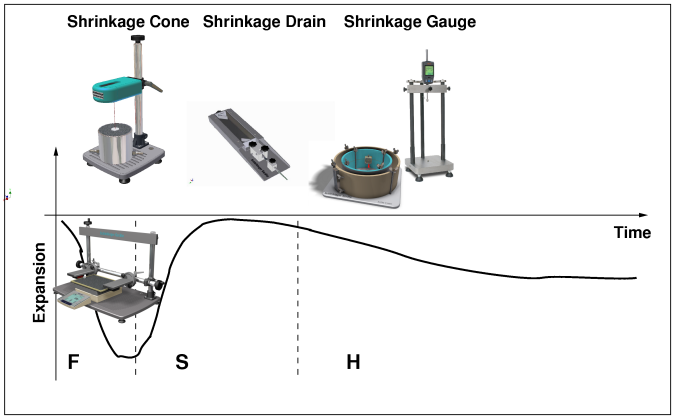


Figure 1: Shrinkage over time

Schleibinger is offering the whole range for measuring shrinkage of constructing materials.

- The Schleibinger Shrinkage-Cone and the Schleibinger Thin - Layer - Measurement System are the ideal instrument for measuring the very early shrinkage and expansion of building materials like paste, mortar, plaster etc. A toucheless laser sensor allows data acquisition suddenly after filling the cone-formed specimen container or the thin layer formwork.
- The Schleibinger Shrinkage Drains are working in a similar way. Here the shrinkage or expansion is measured with a movable anchor .
- The Schleibinger Bending Drain measures not only the length change, but also the curling of the specimen. Here also the influence of floor heating is simulated.
- The Schleibinger Shrinkage Ring according to ASTM C1581 is measuring the forces occurring at restrained shrinkage.

# 2 Theory of Operation

## 2.1 The Schleibinger Bending Drain

The Schleibinger Bending drain, not even measures the length change of the specimen, but also the height change. It is described in the standard EN 13892-9: “Methods of test for screed materials, Part 9: Determination of shrinkage and swelling” as "Curling profile Apparatus".See [1].

The specimen in the drain is fixed by to bolds 4 and 5. The length change of the specimen is measured by a sensor 12. The height change by a sensor 10. The heating unit mounted in the bottom of the drain is free programmable.

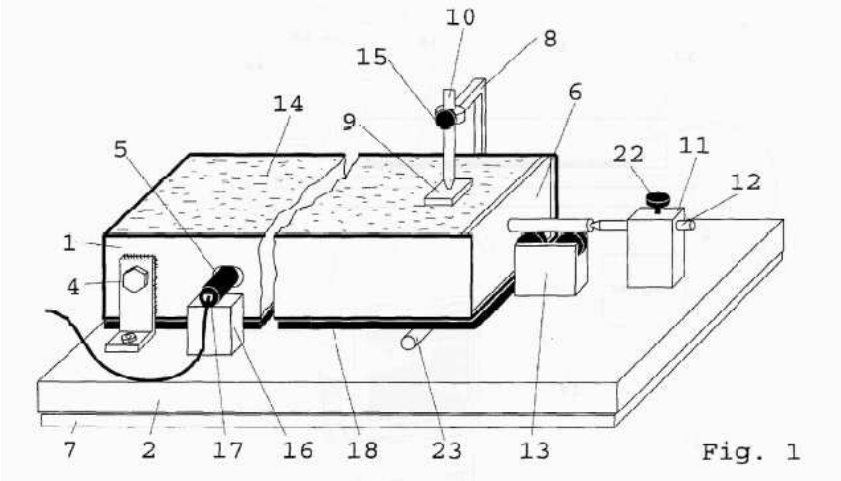


Figure 2: principle schematic of the bending drain

# 3 Handling

## 3.1 Bending Drain

Install the shrinkage-drains, as far as possible, in an air conditioned room. The length change ratio of steel and concrete is about $12\mu m/Km$ . The real working error of the complete measurement system is $< 1\mu m/K$. Please mount the bending drains on a vibration free table, ore set it on a wall-mounted platform.

### 3.1.1 Filling the drain

Please set the end plate into the drain. The distance to the LVDT may be fixed with four spacers. This spacers are supported by springs. Pull them out and turn it for fixing it in the zero position. Please look at figure 3. First lay in the compressible rubber-sheet made of Neoprene. You can adjust the length of the foil by stretching it a little bit. This may be used several times. If you like you may use additional some usual household foil to save the rubber sheet and to avoid friction. Before filling the drain, seal the gap between stamp and drain with the delivered grease. The the ball formed nut must be in contact with the length change sensor.

If the specimen has a certain strength and is not flowing anymore you may set the spacers to zero position as you may see in figure 4.

Now mount the vertical LVDT in the LVDT support. Fix the mounting screw with a maximum torque of 0.25 Nm.

Now place the plastic plate (9) on the top surface of the specimen, below the support for the vertical height change sensor. Now mount the horizontal LVDT in the LVDT support. Fix the mounting screw with a maximum torque of 0.25 Nm. Place the tip of the sensor very carefully onto the plastic plate. If the material is still to soft do this later. Otherwise you will press the plate into the mortar, by the LVDTs spring.

For temperature measurement a Type K thermocouple may be connected to the Bending Drain. You may embed the sensor into your specimen. After the measurement you may cut off the sensor wires. You can reuse the sensor. Remove the insulation from the cable on a length of

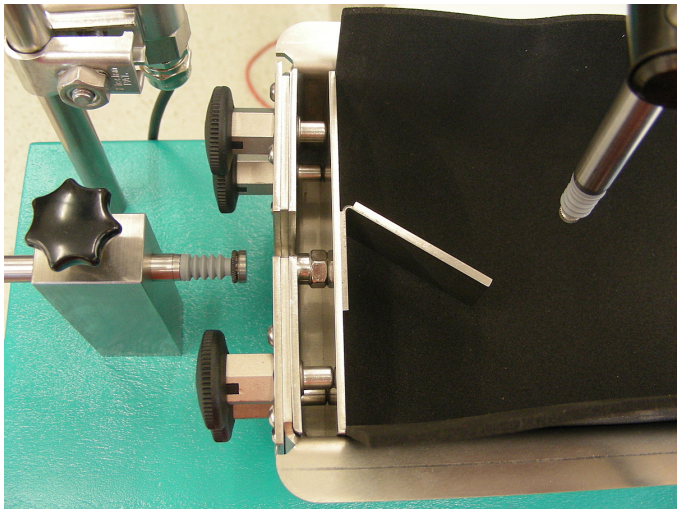

Figure 3: The spacers in the position : *filling*

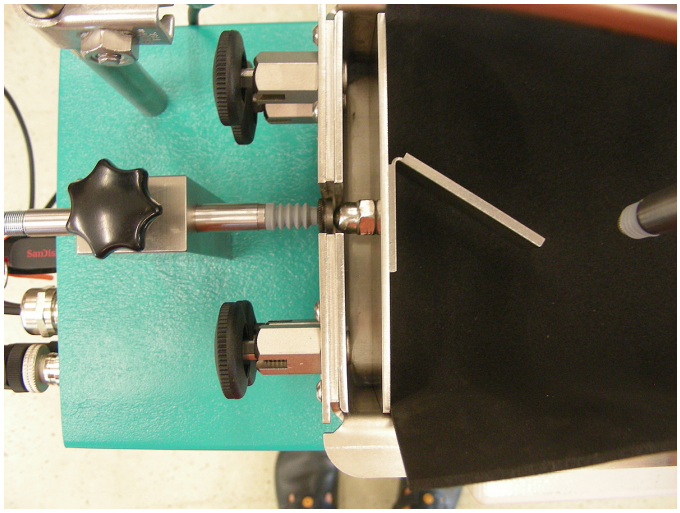

Figure 4: The spacers and the horizontal LVDT in the position *measuring*

10 mm. The drill both cables together to get a new sensor tip. More infos about thermocouples at: Wikipedia

Please start now your browser software. Select the address of the data-logger. Set the offset of the LVDTs to zero. (figure 17).

#### 3.1.2 Removing the Specimen

If the measurement is finished, please remove the LVDTs first. Remove the support for the vertical LVDT. Then open the both screws at the support (4). Remove the bold 4 and 5. The valves may be still in the specimen. The specimen may now to be removed. If the specimen is glued to the drain wall, remove it with some soft hammer strokes. Then remove carefully the stamp and the both valves. from the specimen.

The drain is made of stainless steel. It may be cleaned with diluted phosphoric-acid. Don't us chloride solvents.

## 4 Hardware Installation

### 4.1 Requirements

The shrinkage-cone, the TLMS, the bending drain, the shrinkage drain and the shrinkage ring are delivered with a data-logger. The data logger records the measurement values more then 40 weeks autonomous. The data-sets are stored non-volatile in the data-logger. The logger is equipped with a network interface. It may be integrated in your local intra-net as well as into the world-wide Internet. As user interface you need a PC with an actual Internet browser software like (Firefox 24+, Internet Explorer 9+, Microsoft Edge, Chrome 25+, Opera 15+, ...). You can use any PC from Win95..Windows10 as well as Linux ore MacOS. Even a tablet running Android or iOs is possible. The PC must be equipped with an Ethernet network interface running the TCP/IP protocol. The data-logger need a free fix IP address, but also activating a DHCP service is possible. For using it without a network, take a cross-wired Ethernet cable (Cat5, RJ45) During the measurement you need no running PC. The configuration is described in detail in section 5. Beneath the http protocol you may also readout the data with the file-transfer protocol (ftp). The username for the ftp protocol is `ftp`, the pasword also `ftp`.

For debugging purposes you may also login with the telnet protocol. Here username and password are `tel`.

### 4.2 Installation of the Data-Logger for the Bending-Drains

- The data logger for the bending drain is integrated into the bottom of the drain.
- The data-logger will be delivered with an internal 100V-240V ~, 50..60Hz power supply. Connect the power supply with the 3 pin plug to the bending drain. After some seconds the data logger is running and the LED indicator should blink.
- The network cable is connected to the RJ45 plug beneath the mains connection of the data logger. We recommend to use a network-switch if you integrate the data-logger in your intra-net.
- Configure the network interface as described in chapter 5.

- The USB stick delivered with the Bending Drain may plugged in for readout the measurement data. Please use only the USB drives delivered from Schleibinger. Please don't connect any other USB device like keyboards, USB hard disks, cameras or similar. The measurement data are stored inside the Bending Drain. Select the appropriate command in the Web browser software to copy the data to the USB memory stick.

For details see figure 5

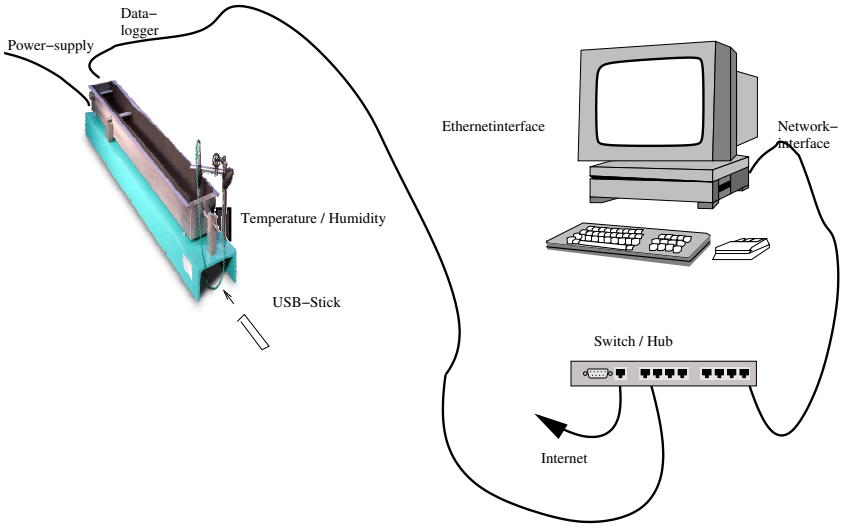


Figure 5: Connection of the Bending-Drain

### 4.3 Thermocouples

As option thermocouples may be connected to the data-logger or the strain gage amplifier of the Shrinkage Rings for measuring the specimen temperature.

A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots, where a temperature differential is experienced by the different conductors (or semiconductors). It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit. Thermocouples are a widely used type of temperature sensor for measurement and control. Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. The main limitation with thermocouples is accuracy; system errors of less than one degree Celsius (°C) can be difficult to achieve.

Please use only Type K thermocouples with the Schleibinger data logger. Otherwise you will get wrong results!

There are different types of thermocouples on the market. Type K (chromel / alumel) is the most common general purpose thermocouple with a sensitivity of approximately $41\mu V/C$ (chromel positive relative to alumel when the junction temperature is higher than the reference temperature). It is inexpensive, and a wide variety of probes are available in its -200 °C to +1350 °C range.[1]

[1] Text partly from: Wikipedia contributors. "Thermocouple." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 31 May. 2015. Web. 5 Jun. 2015.

After the measurement you may simply pull out the thermocouple from the specimen. If its not possible cut it off. You may reuse it by removing the insulation at the cable head and drill the both cables with several windings together again.

# 5 Configuring the Network access

The Schleibinger data logger, the Slabtester and the CDF machine are equipped with a *100 BaseT* network interface. It can be integrated within a local Intranet or globally into the Internet. The network configuration can be done with the program Chiptool (it can be found at the product CD-ROM delivered with the equipment, sub directory Beck-chiptool).

Example Default Settings:

```
Device: Data logger for the shrinkage cone
Customer:  Miximaxi AG
Serial Nr: 201312324
MAC-ID: 00:30:56:90:7D:C3
Hostname: Scone_201312324
[]   Obtain an IP-Address automatically
[]   Use the following IP-Addresse: IP addresse:.......
Subnet mask:.......
```

## 5.1 How to do the network configuration between the data logger and a PC

You have two options, below described number 1 is the one set by default - obtain an IP-Address automatically.

### 5.1.1 Working with a symbolic Server Name

Connection of the data logger into a local network with DHCP- and DNS-Server is the simplest and fasted method.

- Connect the data logger with your local network (switch) using the network cable which was delivered with the device and switch on the data logger (24V adapter)
- Enter the host name into the address line of your browser - see symbol 1 in screenshot 6 (see default settings)


Figure 6: Accessing the data logger with a symbolic server name

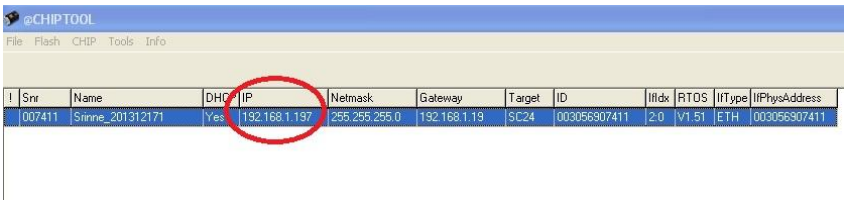


Figure 7: Readout the IP address to the data logger with the program chiptool


Figure 8: Accessing the data logger with a fix IP address

A DHCP-Server assigns a free IP address to the data logger. You can access the data logger via the default host name using the DNS - see picture 6.

Hint: DHCP server are scanning the network from time to time assigning a IP address and a symbolic name to all computers in the network. This procedure may last some time. So please wait some minutes until you try to access the data logger with its symbolic name.

### 5.1.2 Working with a fix IP address

If the hostname-method/DNS-server doesn't work or supported in your network, you can access the data logger via the assigned IP address. You can determine the IP address of the data logger with the above mentioned program chiptool.

Your network administrator has to make sure that the data logger always gets the same IP address from the DHCP server. Into the address line of your browser you enter the IP address assigned by the DHCP server instead of the host name. See figure.

If there is no network or you are not allowed to connect a measurement device into your local network, you can connect the Schleibinger data logger directly to a PC, e.g. with an older notebook. Most of the PCs are configured in a way, that they take an IP address automatically assigned by the DHCP server. In case of a direct connection between data logger and PC, both peers are missing the DHCP server. You have to use static IP addresses in this case.

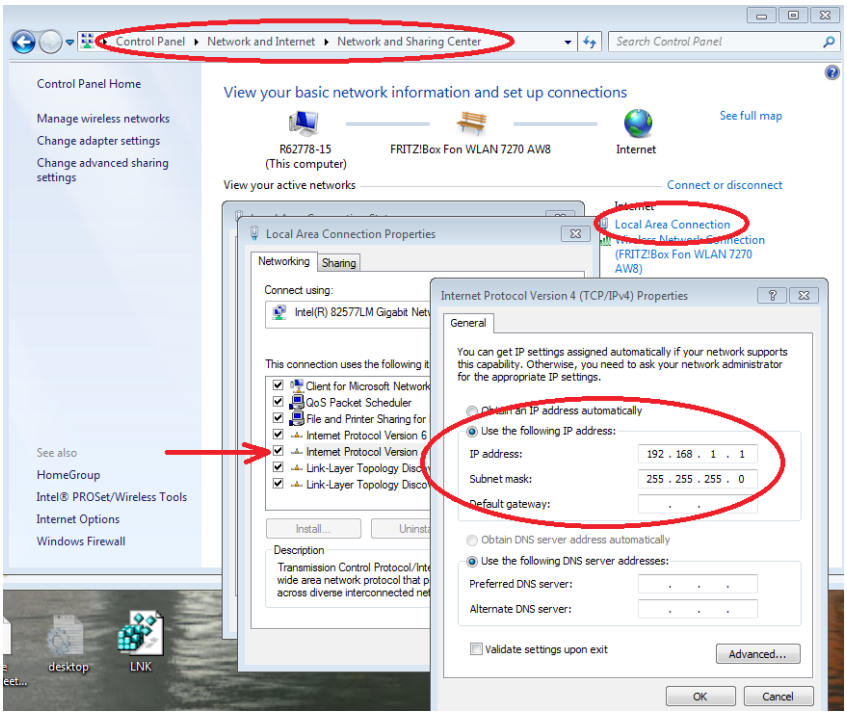


Figure 9: Configuring the PC for a direct connection between the PC and the data logger

## 5.2 Setting a static IP-address on a Windows computer

Open `Control Panel` → `Network and Internet` → `LAN-Connection` → `Properties` and set a static IP-address from the so called private area e.g. `192.168.1.1` and a sub net mask `255.255.255.0`. Gateway doesn't has to be set. See figure 9

## 5.3 Setting a static IP address on the data logger

Connect the data logger and the PC where you have just set the static IP address. The best with a cross-wired Ethernet cable (Cat5, RJ45)- not delivered with the equipment, and start the program chiptool. The program is searching for the data logger and if the PC is configured correctly and the right connection cable is used, appears the Schleibinger device in the window of the program. Click with the right mouse button on the entry within the window and chose IP configuration. A little window appears. Set a static IP address from the same private area as well (but different to the one on the PC) e.g. `192.168.1.2` and the same sub net mask. Finally click on `Config`.

If you enter the just set IP address of the data logger into the address line of your browser, the main page of the data logger should appear.

Please ask your network administrator how to integrate best the data logger into the network infrastructure.

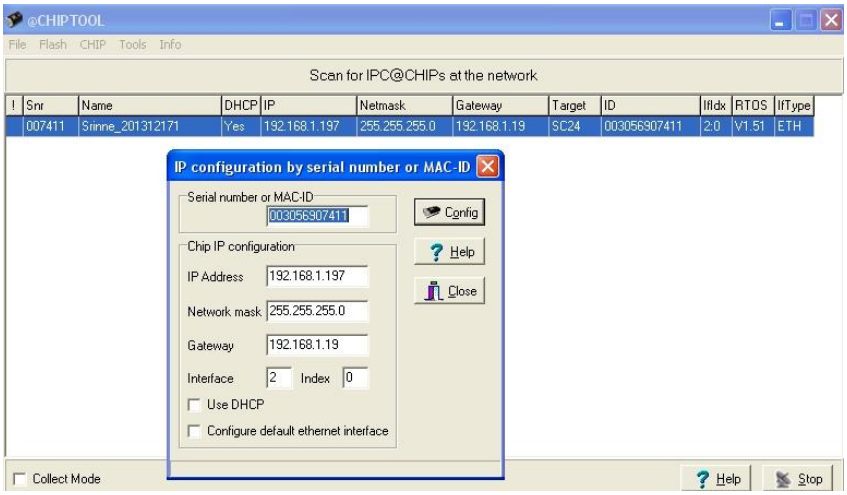


Figure 10: Configuring the data logger for a direct connection between the PC and the data logge with the program chiptool

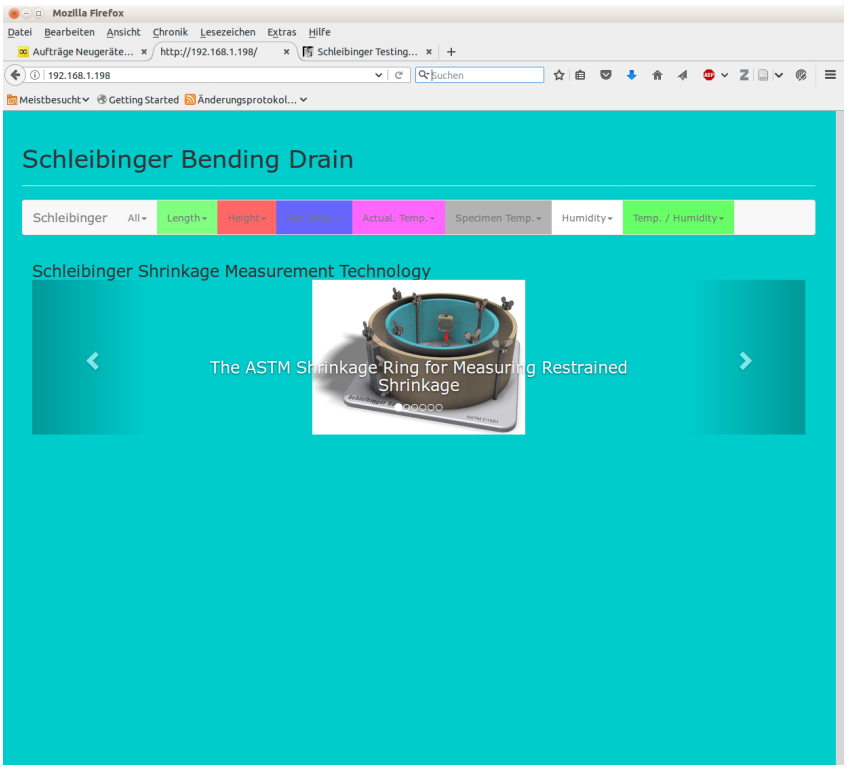


Figure 11: Start screen

# 6 The Software

The software is quite similar for all four shrinkage test systems.

## 6.1 Recording Data

As soon the data-logger get power, data acquisition starts. This is shown by the blinking LED at the front-side of the data-logger. The PC is only required for setup and data transfer.

## 6.2 Software Handling with your Web-Browser-Software

To communicate with the data logger start at your PC your web browser software. Input at the address line the IP address of your data logger for example 192.168.1.40

The following start screen will appear in your browser (fig.: 11).

In the header you see on the left the drop down menu `All`. In this menu you may control all things regarding all channels in the same way. For example starting the measurement, set up of the real time clock, showing all data numerical and graphical.

All other drop down menus right of the `All` menu are concerned with each single channels, like the LVDT's, Temperature sensors etc. Depending on the installed options this may be varying (see fig. 12).

Starting a measurement works as follows:

Select your channel in the header-line.

Set the LVDT of the shrinkage drain to the middle of the measuring range. Check this by displaying the raw values with:

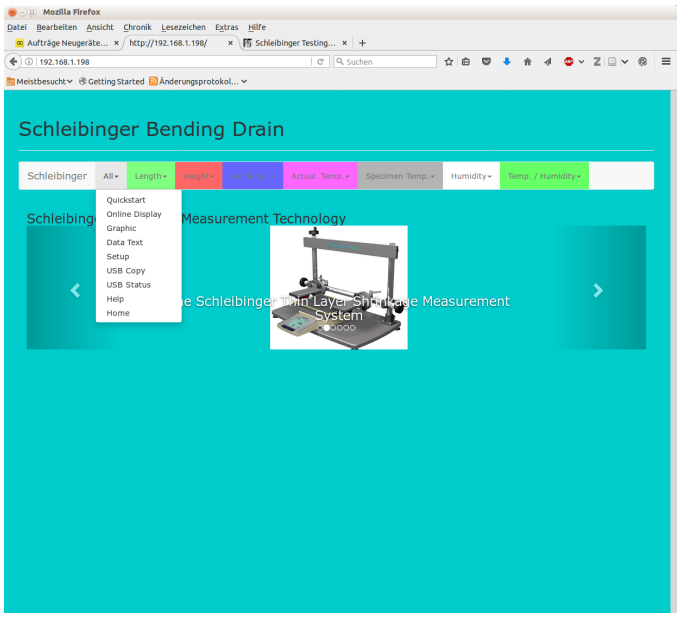


Figure 12: Main menu

`All -> Online Display -> Start.`

The raw value should be between 7000 and 8000. (figure 13)

The vertical LVDT for measuring curling may be placed later, when the surface of the specimen has a certain stiffness. For starting the measurement we recommend the `Quickstart` as described in chapter 6.3

Now go to `Offset` and then press the button `Offset=0` . The actual value is set to zero (fig.14 ).

Now go to `Measurement Start`. Optional you can give a name to the measurement, pressing `Start` resets the time counter to zero and starts recording. (fig.15 )

Now go to `Measurement Data-Reset`. All old records will be cleared. (fig.16 )

## 6.3 Quickstart

Quickstart is a comprehension of the point Data-Reset, Offset-Zero and Measurement Start. All these commands are integrated for all channels in the quickstart option.

Attention: All data of all channels will be erased!

## 6.4 Temperature Profile Input

For the bending-drain you may define a temperature profile for the floor-heating. Select the channel `Set Temp.` then select in the menu bar `Profile Input`. For using this menu point Java-Script must be activated in your Internet browser.

You can edit a table with time in hours and minutes and a temperature for each time-point. The first line must be 0 hours and 0 minutes. The minimum time is 1 minute. If you like to repeat the temperature profile several times, you may input the number of cycles. If you don't like to start the heating immediately please give in a start date and time. Please

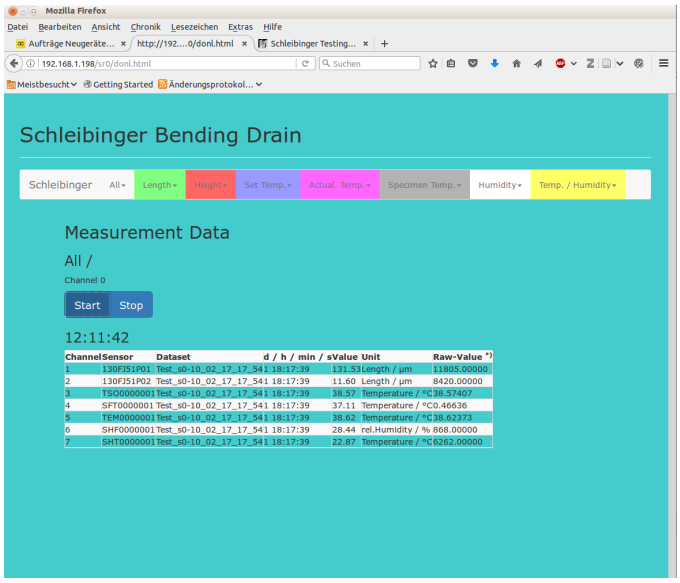


Figure 13: Measurement values in a numerical format

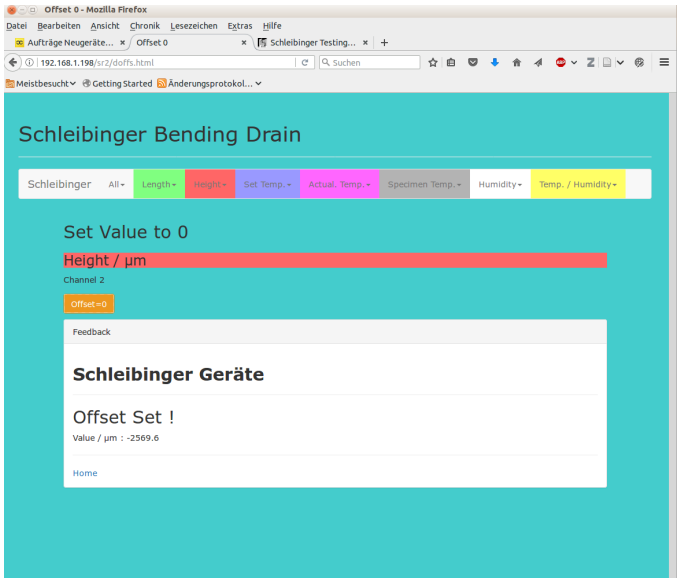


Figure 14: Offset zero

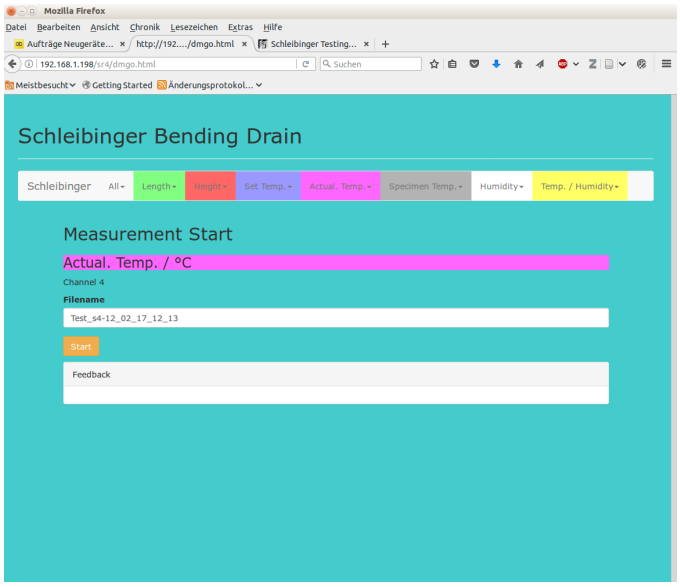


Figure 15: Measurement start

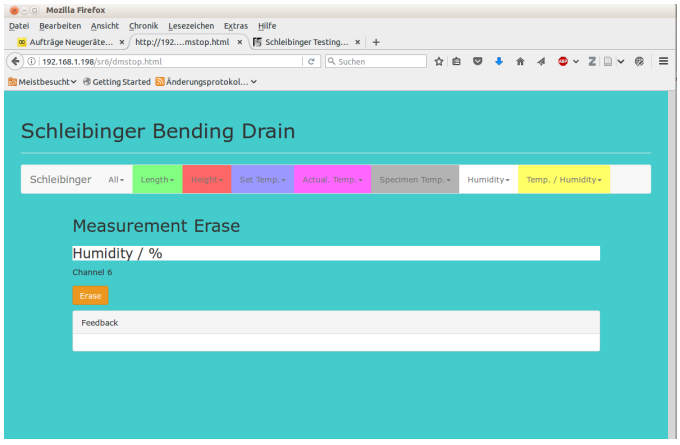


Figure 16: Clear dataset

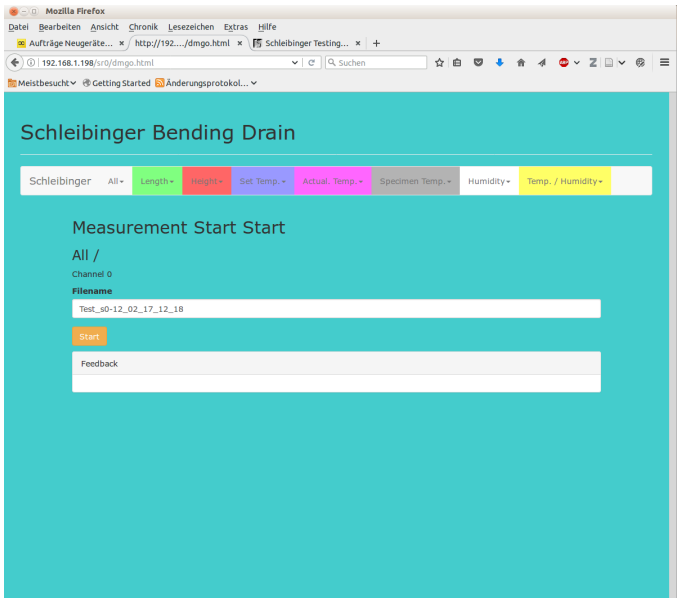


Figure 17: Quickstart

put in the complete date and time including the seconds. You may press the button now to see the actual date and time in the input field. If the date and time is in the past, the profile is started immediately after the Quick-Start. You may see the profile graphically in the upper part of the window. If you like to add more input lines press the button `Insert Line`. If you like to remove a line press the `X` button at the end of the line.

A temperature of 0 switch off the heating unit.

With `Save Profile` you can store the profile. This can last some seconds. Please don't leave this page before a confirmation window appears. You may change the profile during a measurement, but a changed profile is not used before you start a new measurement with quick-start, or before you switch on and off the data logger.

## 6.5 Transferring the datasets

The measurement will be stored locally in the data-logger. The memory is non-volatile.

The easiest way for data transfer to the PC is your web-browser software.

### 6.5.1 Data Text

Go to `Data Text`. In the right browser window all measurement values will be displayed (fig. 19). In the first column you see the seconds, in the second one you see the measurement values. All columns are separated by tabs.

From this window you can copy the data to other programs like Excel using the clipboard. You may also directly open this file from your Excel program. Say in Excel `File Open` as filename us

`http://192.168.1.40/daten/data1.txt`

for the first channel `data2.txt` for the 2nd channel and so on.

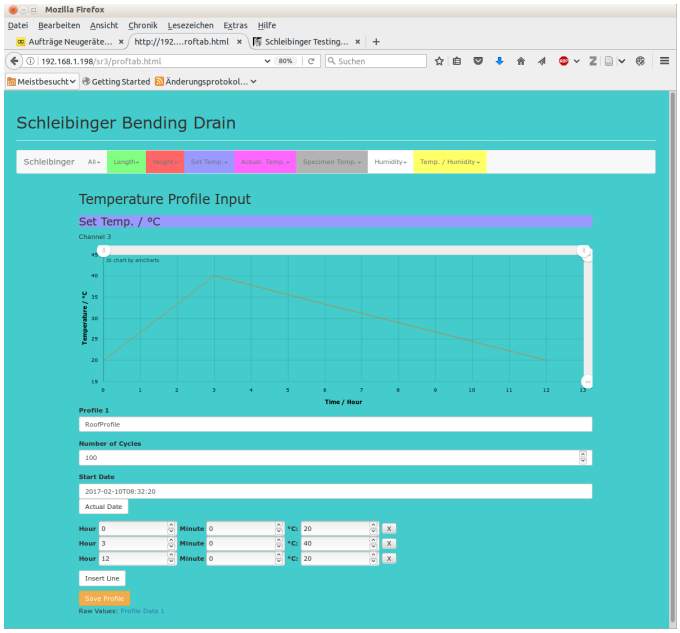


Figure 18: input of a temperature profile

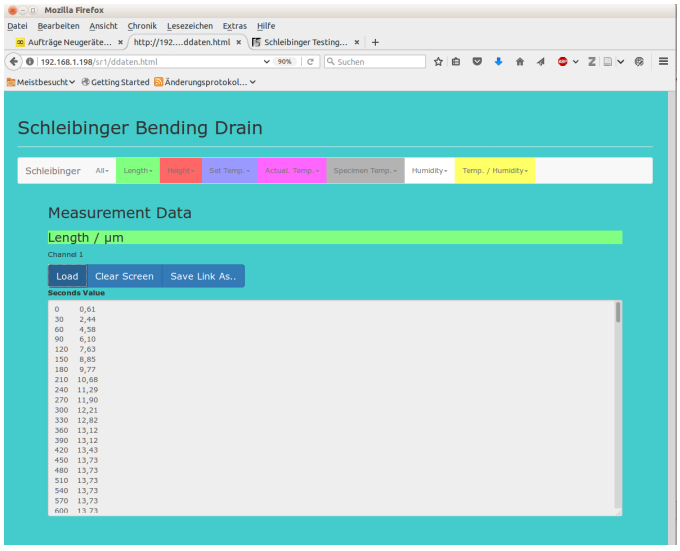


Figure 19: Measurement values as text file

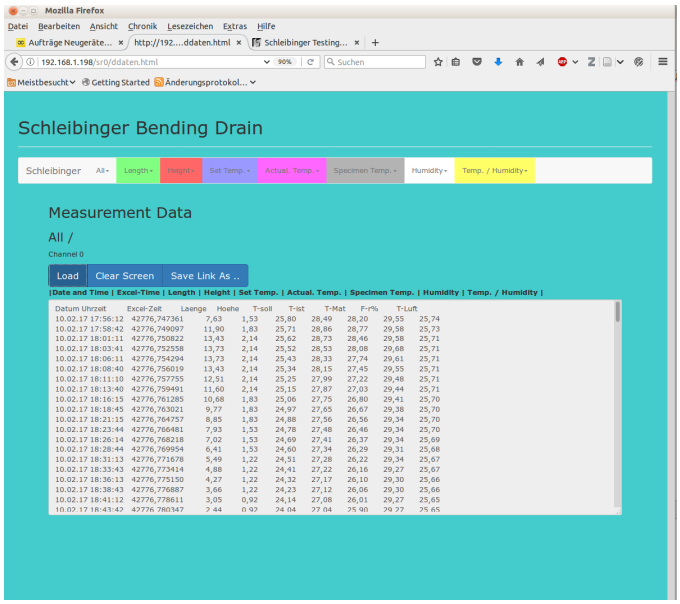


Figure 20: All channels values as text file

### 6.5.2 All Channels

Here a synoptic set of all data channels is stored. The format is as follows:

| Date | Time | Excel-Time | Channel 1 | Channel 2 |
|---|---|---|---|---|
| 12.08.04 | 10:40:32 | 38211,444815 | 3999,6 | -221,0 |

The Excel Time is the internal Excel time format. The digits before the comma show the number of days since January, 1st, 1900. The digits after the comma show the fractal part of one day. For example noon is 0.50000, 6 am is 0.2500. If you import a data set into Excel, you can format this column as date and time and you will see the correct date and time format in Excel. You may retrieve this file directly from Excel at the address

`http://192.168.1.40/daten/data0.txt`

There is a header written in the first data line. If you don't like this, or Excel has problems with the header, erase the file `pheader.txt` in the `par` subdirectory

### 6.5.3 FTP

The power user can also use FTP for data transfer. Login name is `ftp`, password is also `ftp` The datasets are in `/httpd/htdocs/daten`. Don't use the Internet-Explorer for this. Its is not according to the ftp standard. We recommend Filezilla (free software), wise-ftp ore similar programs.

## 6.6 Channel Setup

Here you can configure some things.

You can select the sampling rate between 10s and 10 min. (see figure 23 )

If you define a limit smaller then $\inf$ then a new value will be recorded if the difference to the last value is bigger then the defined limit ore if

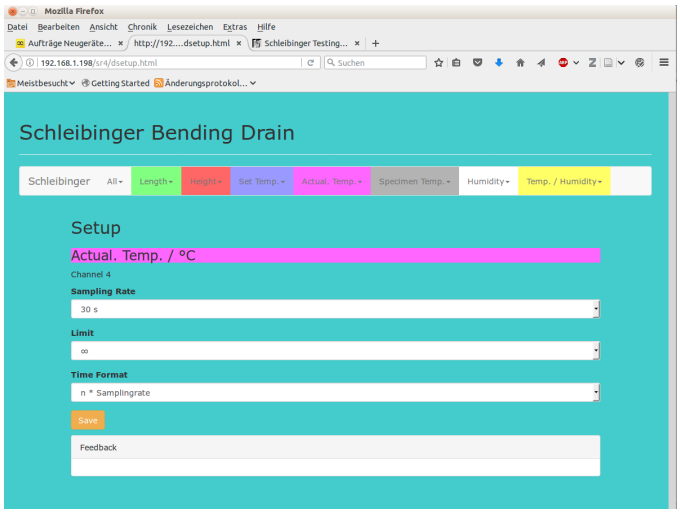


Figure 21: System setup

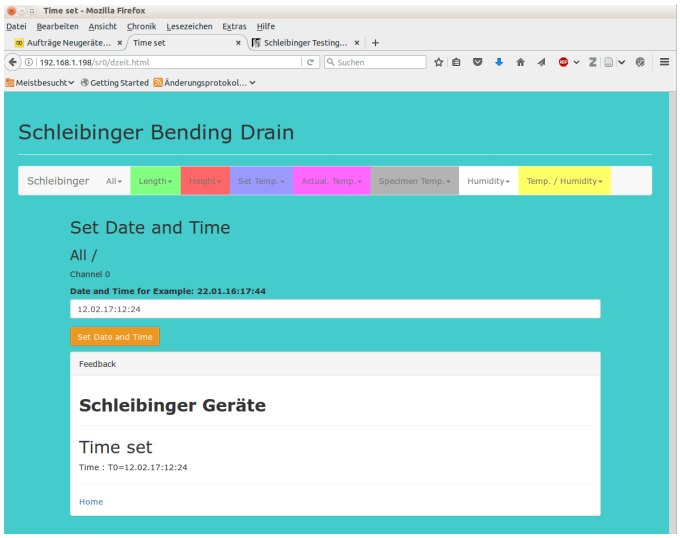


Figure 22: Setup of date and time

the sample intervals is reached. This setup is specific for each single channel.

If you define a sampling rate of for example 30s, the data logger will record data at: 30s, 61s, 90s, 119s . . . The reason for this jitter are small deviations in the response time of the several software processes running on this small computer. If you don't like this in your Excel worksheet please select hier `n*smaplingrate/s` otherwise slect `Time/s`.

### 6.6.1 All Setup

Here you can setup date and time. The displayed value is only a dummy value. Be careful, the European time format is used.

day.month.year:hour:min for example `26.03.03:12:11`. The hour format is from 0..24h. Press the `Set Date and Time` button as confirmation.

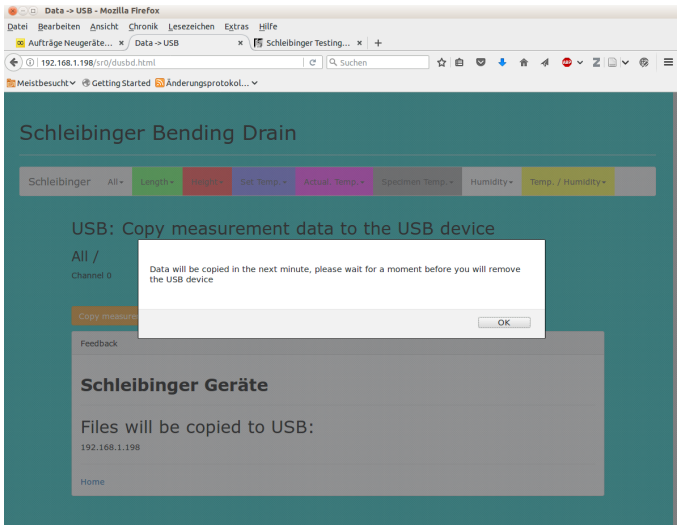


Figure 23: Copiing the measurement data to the USB device

## 6.7 USB

The Bending Drain has an USB port to copy the measurement data from the internal memory to the USB port. Please use the USB memory delivered by Schleibinger.

### 6.7.1 USB Copy

Please connect the USB drive. Wait some moments until the Bending Drain has recognized the USB drive. The select the menu point `All -> USB Copy`. All date from the internal memory are copied to the USB memory. The data are copied to the `\httpd\daten` subdirectory of the USB drive. If this subdirectory doesn't exist the data are copied into the root directory. The data files have the names `dataX.txt` where X stand for the channel number, starting with 1. The file `data0.txt` is a summary of all channels. The format of the files is described in chapter 6.5.

### 6.7.2 USB Status

Here you can test if the connected USB drive is recognized by the Bending Drain, and if the USB drive is ready.

## 6.8 Online-Data Graphical

You can display several channels in the same plot. In the next chapters you will find a more detailed explanation of this part of the program.

# 7 Plotting the Measurement Data in HTML5

The software is offering tow options to disply the the measurement data in a graphical way.

The first option is using a so called Java Applet. This is a small program, written in the Java programming language. To run such a program a Java Plugin must be installed in your Internet browser.

## 7.1 Browser Compatibility

Another option is using the new features offered by HTML5 Therefore you need a new browser software version like the Internet Explorer 9+, Firefox 2.x+, Safari 3.0+, Opera 9.5+ or Konqueror 4.x+. The software tool we are using is called FLOT and is running under the open MIT license.

Official supported are: Internet Explorer 9+, Firefox 2.x+, Safari 3.0+, Opera 9.5+ or Konqueror 4.x+. We urgently recommend Firefox 14.x or higher. Also Opera is working well. Many other browsers doesn't work, especially with Windows7 64bit.

### 7.1.1 Firefox

Firefox is working since version 2.x+ Also with Windows7 64bit and Linux.

### 7.1.2 Opera

For Opera you have to set a certain switch: Please input at the adress line:

```
about:config
```

Then you get a menu with a lot of options.

Please slect the button:

```
UserPrefs
```

There will be a submenu opened:

```
Allow File XMLHttpRequest
```

please selct this option.

Save the settings and restart the Opera browser.

### 7.1.3 MS Internet Explorer

Internet Explorer 6.0 doesn't work. Internet Explorer 8.0 may work after some confirmed popup windows. Internet Explorer 9.x running with Window7 Professional 64bit doesn't work.

### 7.1.4 Google Chrome

Doesn't work with Windows7 64bit.

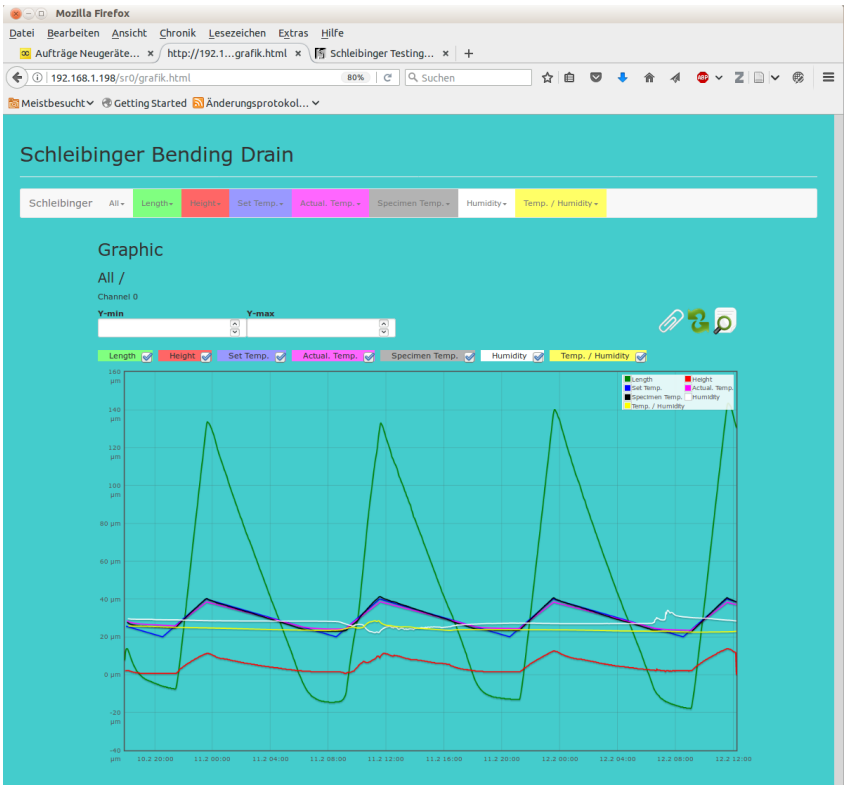


Figure 24: plotting a measurement curve in the Internet-Browser

## 7.2 User Interface

## 7.3 Channel Selection

In the upper area you may see check boxes where you may select the channels that should be shown. The color of the curves are the same then the background color of the channel names.

After selecting the required channels, you have to click on the icon with the two green arrows to reload and draw the data.

## 7.4 Zooming the Y-axis

The FLOT software is trying to find an optimal y-range for the data. You can select the range by putting in valid numbers in the min: and max: input fields.

## 7.5 Zooming the Time Axis

Please press the left mouse button and move the mouse over the region of interest in the time range. The background will change to light yellow. If you If release the mouse button again the plot will be refreshed. If you click on the magnifier icon the whole time range will be shown again.

## 7.6 Insert a Legend

Clicking on the paper-clip icon will open an input field for a text legend, shown in the graph.

### 7.7 Printing the Graph

Firefox: please use the print function of the browser. Select actual frame in the in the printing options dialog of the browser to print the graph without the menus around.

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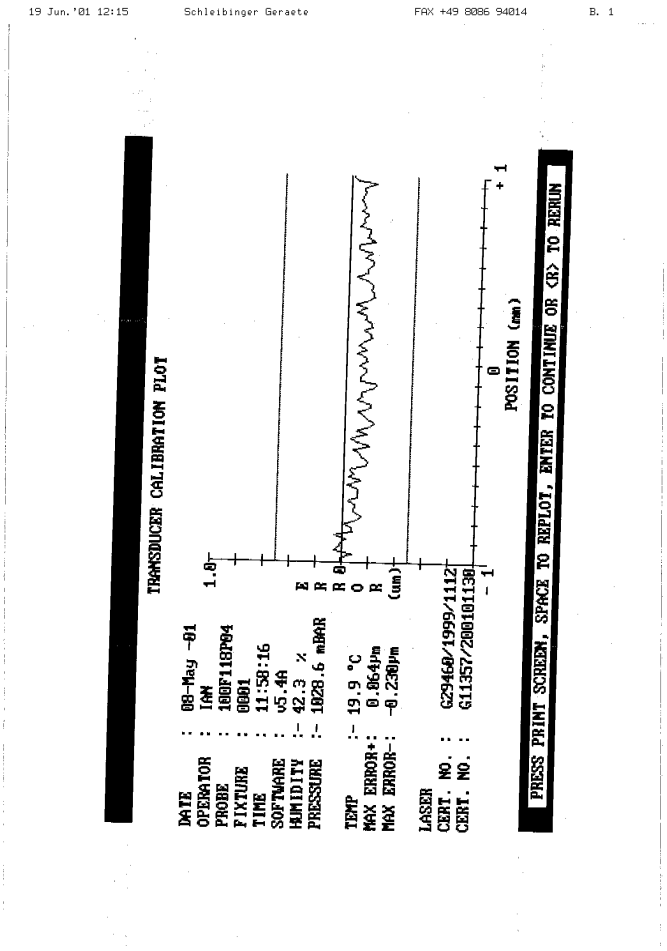


Figure 25: Calibration plot

# 9 Calibration Sheet Laser sensor

# 10 Calibration Sheet Temperature Sensors

## 10.1 Sensor 1

| Temperature 2 | |
|---|---|
| 26.1 | 35.4 |
| 25.34 | 34.6 |
| 2534 | 3460 |
| | C |

## 10.2 Sensor 2

| Temperature 2 | |
|---|---|
| 26.4 | 35.7 |
| 25.34 | 34.6 |
| 2534 | 3460 |
| | C |

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