„Simulation-based optimization of steel fiber reinforced concrete“

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Rheologische Messungen an Baustoffen
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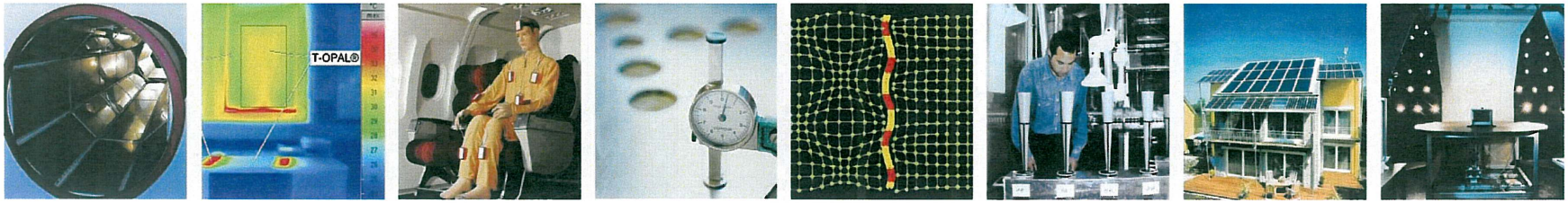
Auf Wissen bauen



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Motivation and Objective

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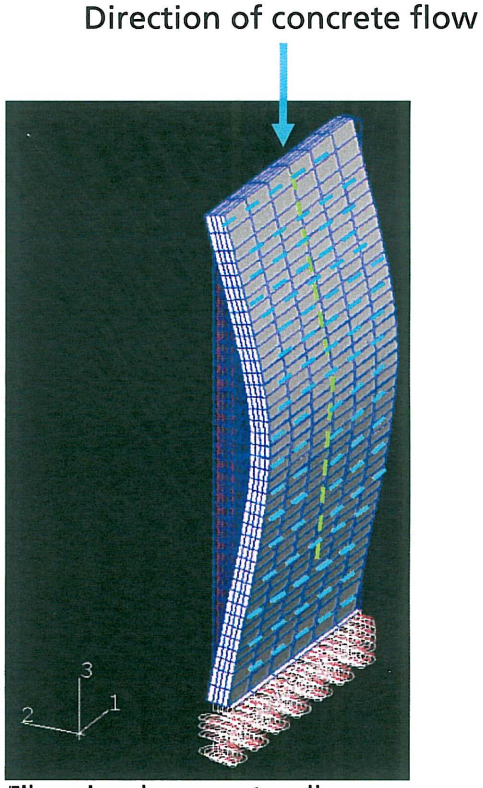
Motivation

- Until now there is no economic tool existing for the prediction of the steel fiber orientation and distribution in fiber reinforced concrete
- Fibers in concrete elements can be distributed statically unfavorable or be lacking at critical places

Objective

- Simulation of position, orientation and amount of steel fibers in self compacting concrete elements in the planning phase
- Designing steel fiber reinforced concrete components with statically appropriate distribution and orientation of fibers



Fibers in a basement wall

Project approach

Approach

- Classification of simulation tasks
  - Setting cement paste and concrete constitutions e.g. different rheological properties
  - Defining suitable test methods for the calibration of simulation
- Analysis of rheological properties
  - Identification of rheological properties of cement paste and concrete
  - Determination of stress and yield stress at different constant shear rates
- Development of the numerical methods
  - Formulation of a suitable modeling for the viscous stress in the cement paste and concrete based on the rheological data
- Validation of simulation results

Results

Measurements and simulations

Measuring rheological properties of cement paste

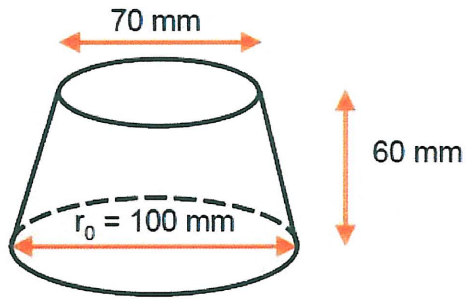
Used methods for testing rheological properties of cement paste

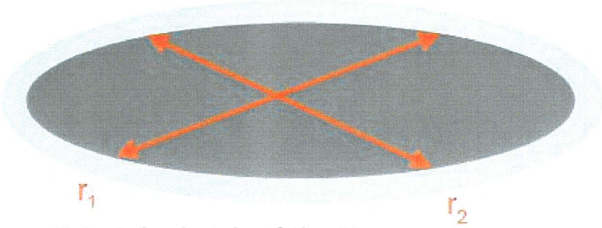
- Slump flow test with Haegermann cone
- Progress of stress τ at different shear rates *D* with Haake VT 500

Viscometer Haake VT 500

Viscometer features

- Controlled rate viscometer
- Stationary outer cylinder
- Rotating inner cylinder





Principle sketch of the Haegermann cone

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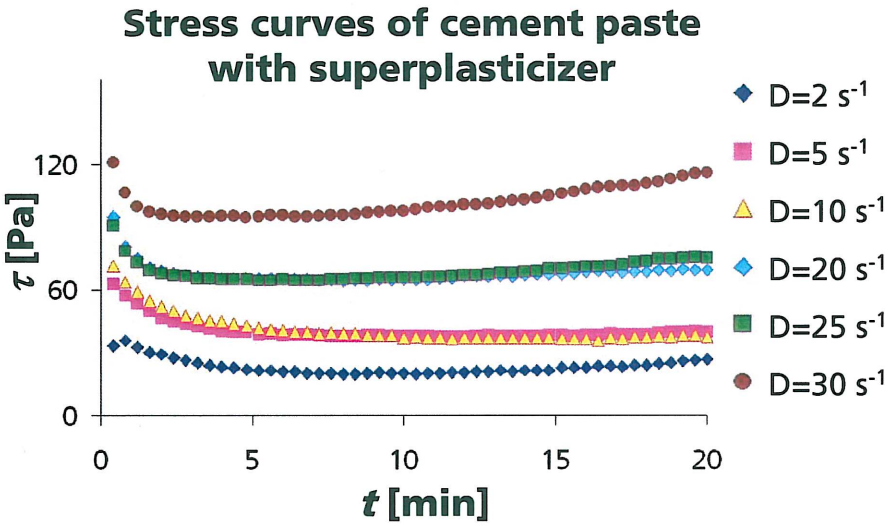
Evaluation of the flow properties of cement paste

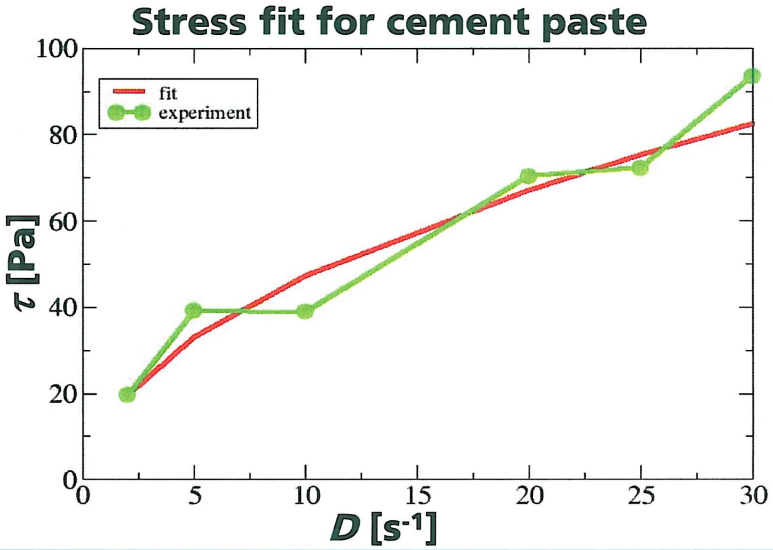
Stress curves of cement paste

- High shear energy necessary at the beginning
- After around 4 minutes stress stays nearly constant
- Due to hydration of material, stress is increasing at the end of experiments



Stress fit for cement paste from experimental data

- Experimental stress values from constant part of stress curves
- Calculated model can be described by a combination of the Bingham and Herschel-Bulkley-model



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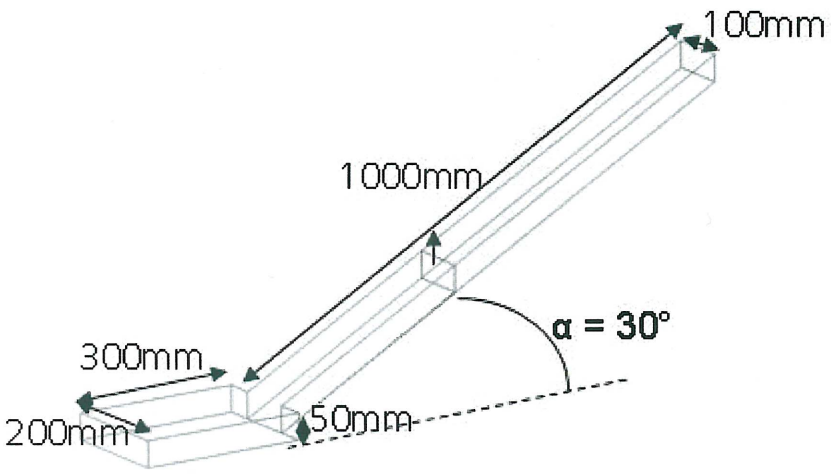
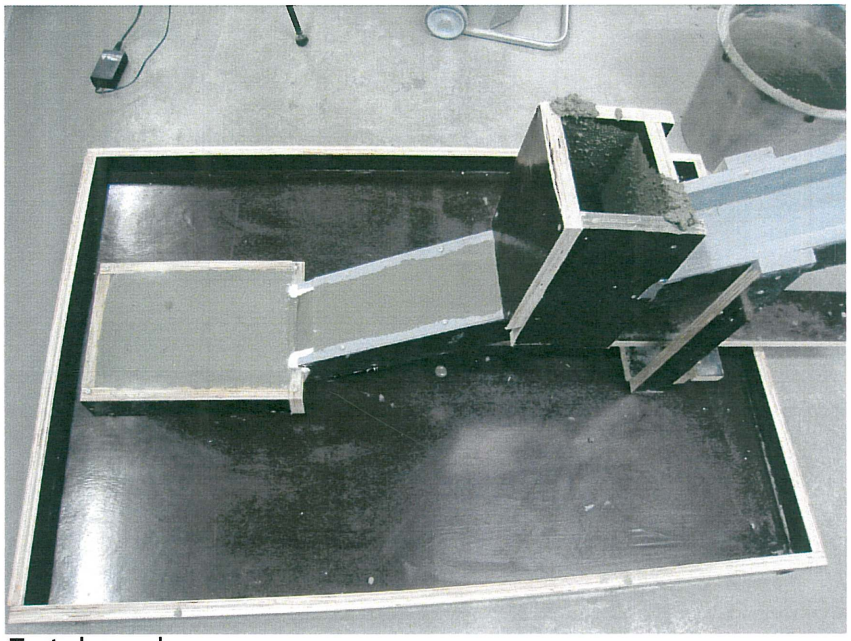
Evaluation of flow behaviour in formworks

Testing geometry

- Test channel
- Obstacles can easily be installed
- Slope of 30° causes the flow



Principle sketch test channel



Test channel

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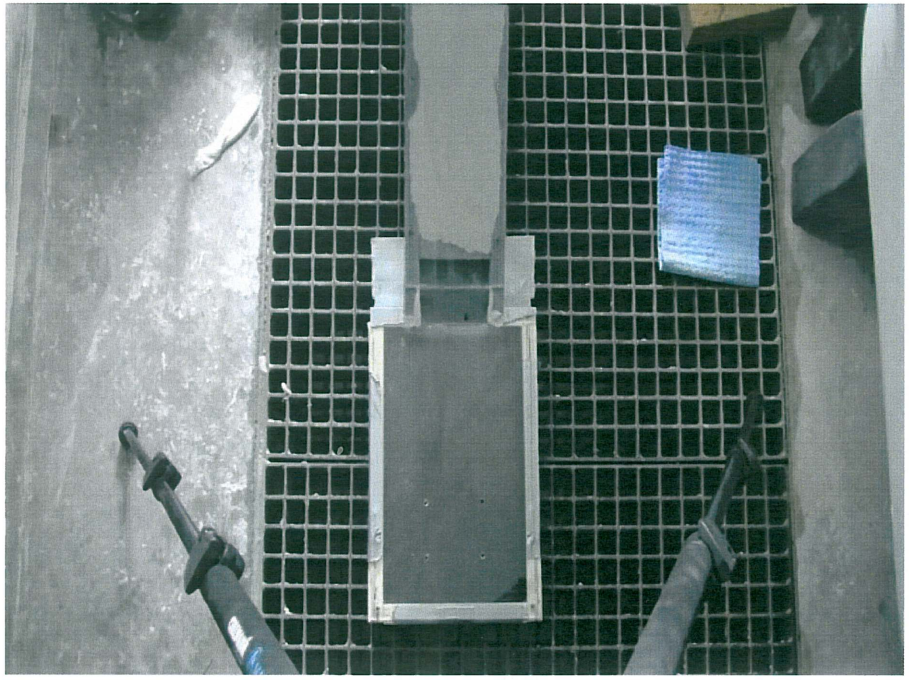
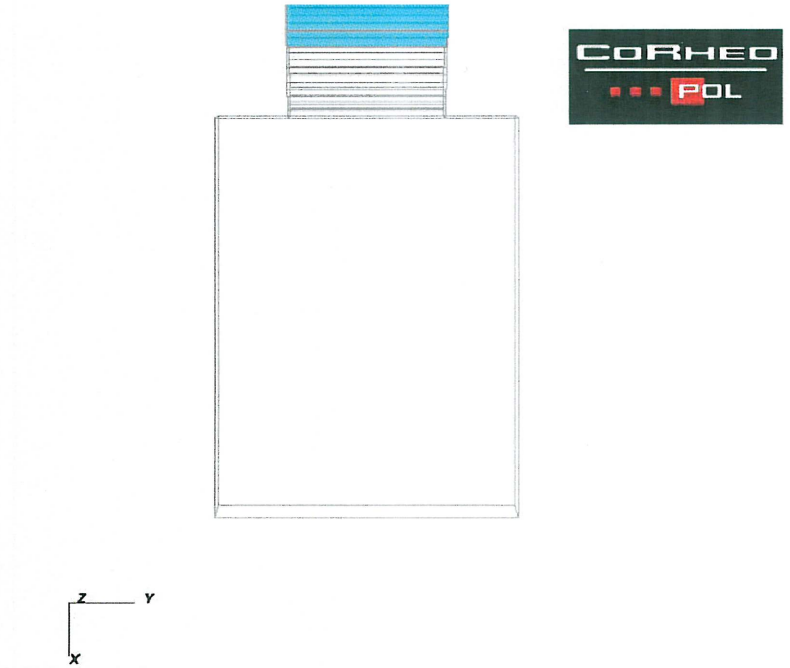
Simulation and experiment





Comparison between film and simulation

- congruence of filling time between simulation and experiment
- similar flow pattern of the material in the simulation

3D-Simulation of steel fiber distribution and orientation

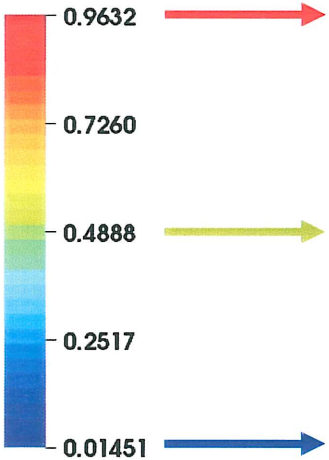
Used simulation type

- Computational Fluid Dynamics (CFD)

Simulation input

- Fibers have no effect on the flow
- Fiber content up to 1 Vol.-%
- Linear steel fibers, length of 10mm, diameter of 0.3mm
- Fluid parameters according to slump test
- Filling time of the formwork in the experiment

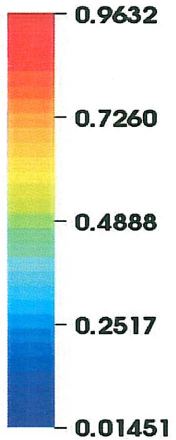
3D-Simulation of steel fiber distribution and orientation

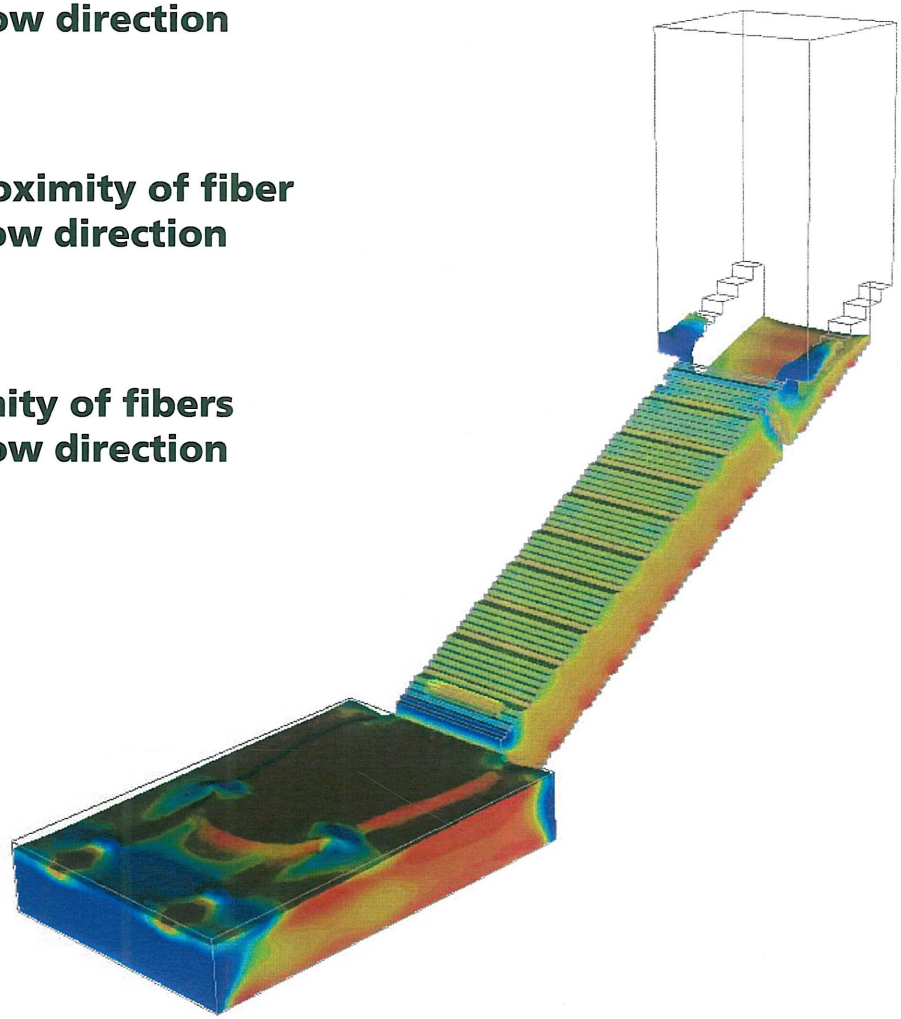


= 96, 32 % **High approximity of fiber oriented in flow direction**

= 48, 88 % **Medium approximity of fiber oriented in flow direction**

= 1,45 % **Low approximity of fibers oriented in flow direction**





Simulation of steel fiber orientation in flow direction at the surface

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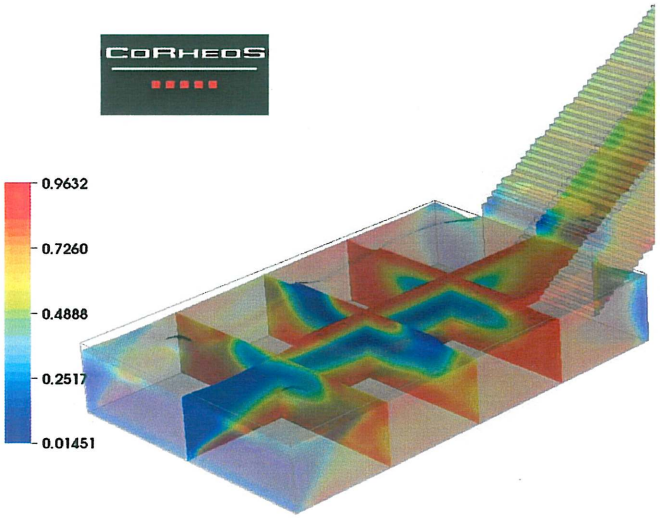
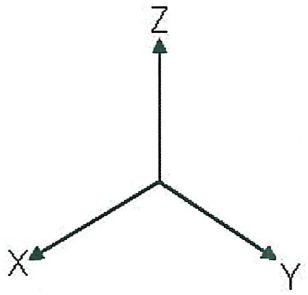
3D-Simulation of steel fiber distribution and orientation

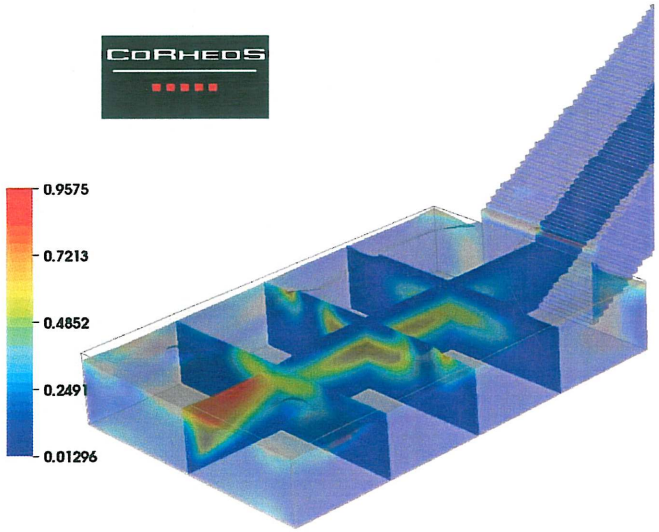
Result

Orientation of fibers mainly **in** flow direction

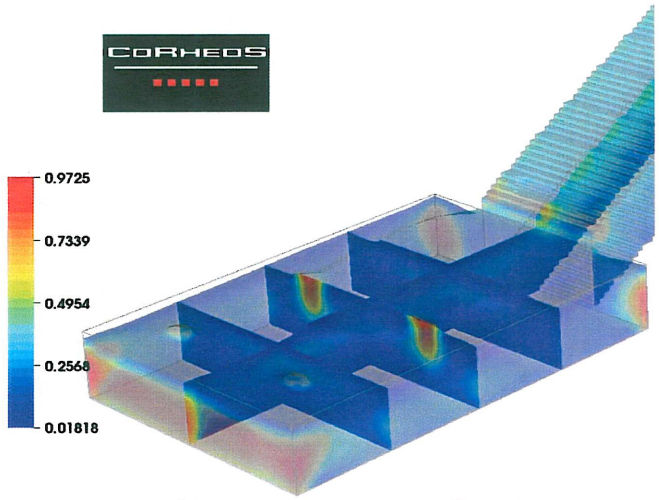


Simulated fiber orientation in **x**-direction





Simulated fiber orientation in **y**-direction



Simulated fiber orientation in **z**-direction

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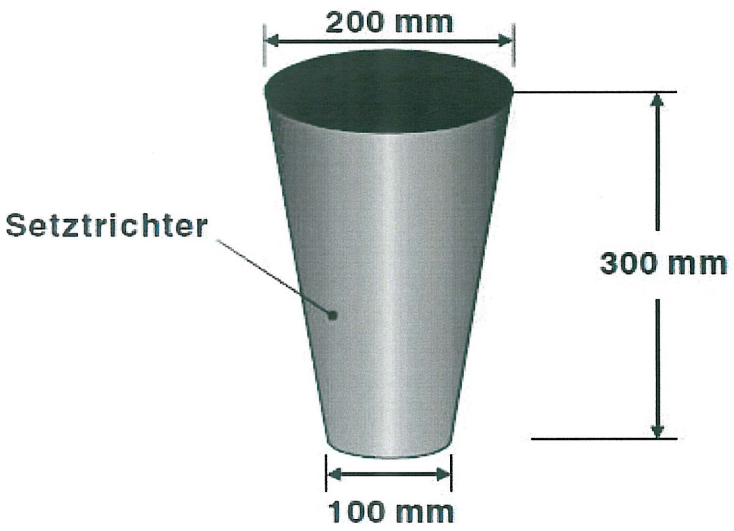
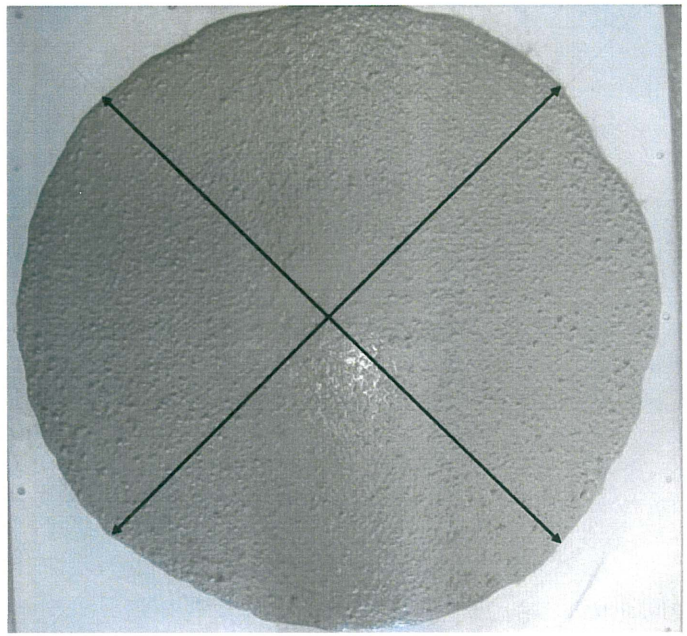
Testing rheological properties of concrete with fibers

Measuring the slump flow value of self compacting concrete

- Maximum aggregate size of 8mm
- w/c- ratio: 0,38…0,45
- Steel fiber volume: 0 …2,0 Vol-%



Principle sketch of „Setztrichter“



Slump flow test with self compacting fiber reinforced concrete

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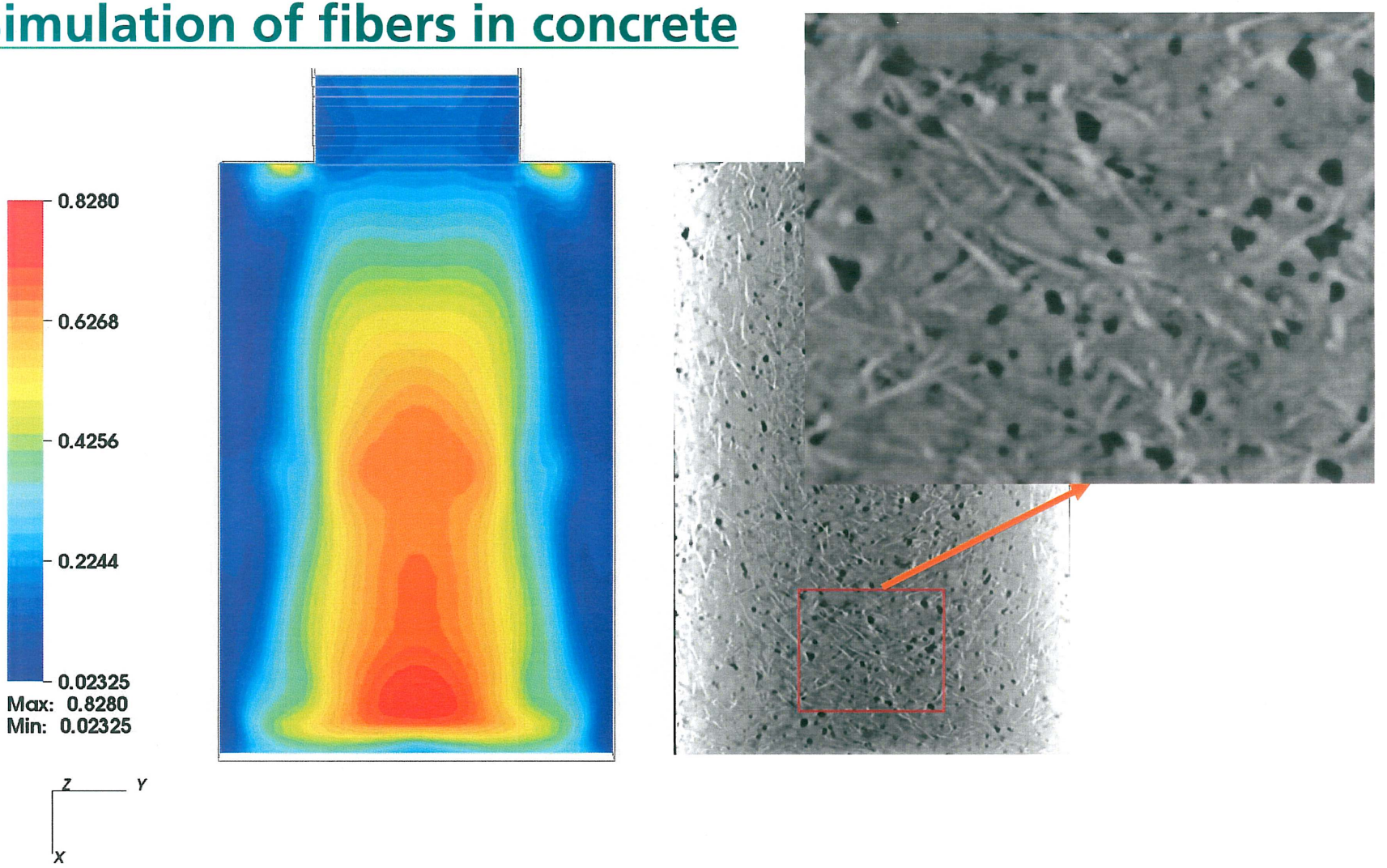
Simulation of fibers in concrete



Fiber orientation in y-direction in a plane of a fiber reinforced concrete sample. Simulation (left picture) and CT-Shot (right picture)

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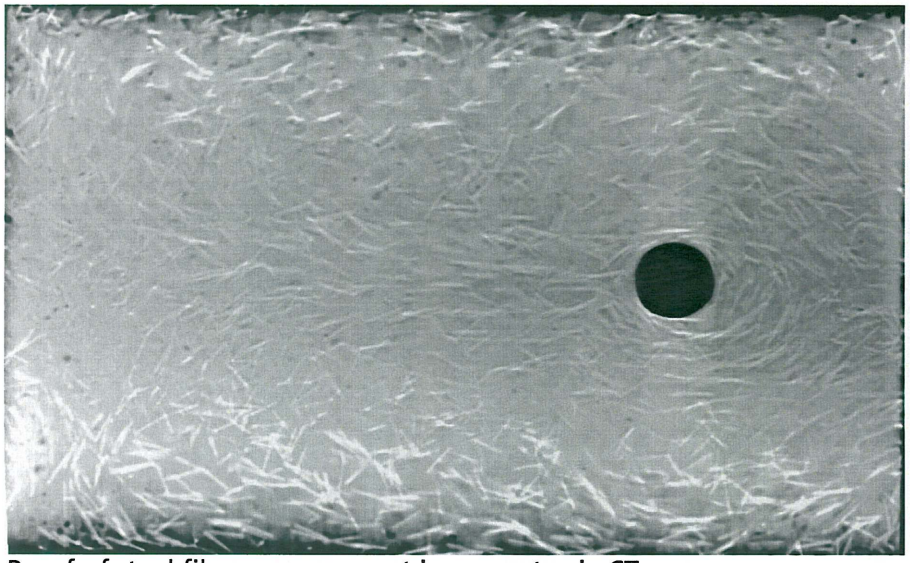
Validation of simulation

Verification of steel fiber distribution and orientation around obstacles by using two methods:

- Computer-Tomography (CT)
- Use of translucent hydrogel which replaces concrete



Proof of steel fiber arrangement in concrete via CT-scan

Orientation of steel fibers in hydrogel around an obstacle

Conclusion

Conclusion

- Simulation tool called "CoRheoS" for steel fiber distribution and orientation in concrete was established
- Simulation software works for cement paste or self compacting concrete (SCC) with linear steel fibers and particular formwork geometry
- Fiber arrangement around obstacles can be simulated
- The basics for a realistic simulation based presentation of steel fiber reinforced concrete elements was set
- User-friendly GUI (Graphical User Interface) for external users has been developed
- Appropriate methods for validation of fiber distribution have been established

Outlook

Outlook

- More tests are necessary to make the software marketable
- So far only self compacting concrete was used
- Impact of compression machines on concrete flow needs to be included in future works
- Use of fibers with different geometry would be important
- Upgrading of the software to simulate different formwork geometries
- Designing precast elements out of fibre reinforced concrete with reduced wall thickness but sufficient mechanical properties
- Designing and construction of a test building out of fiber reinforced components with the help of a precast factory