DANISH TECHNOLOGICAL INSTITUTE

Simulation and Verification of Form Filling with Self-Compacting Concrete

Lars Nyholm Thrane	Danish Technological Institute, Concrete Centre
Peter Szabo	Technical University of Denmark, Dep. of Chemical Engineering
Mette Geiker	Technical University of Denmark, Dep. of Civil Engineering
Henrik Stang	Technical University of Denmark, Dep. of Civil Engineering
Claus Pade	Danish Technological Institute, Concrete Centre

DANISH TECHNOLOGICAL INSTITUTE

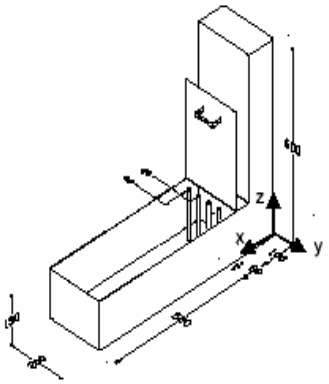
Objective

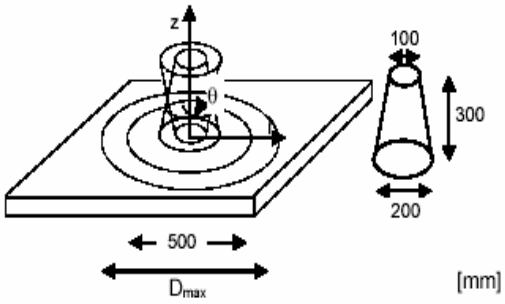
To verify a single fluid approach for simulation of SCC Form Filling

Nordic Concrete Day 2005

DANISH TECHNOLOGICAL INSTITUTE

Approach - Part 1





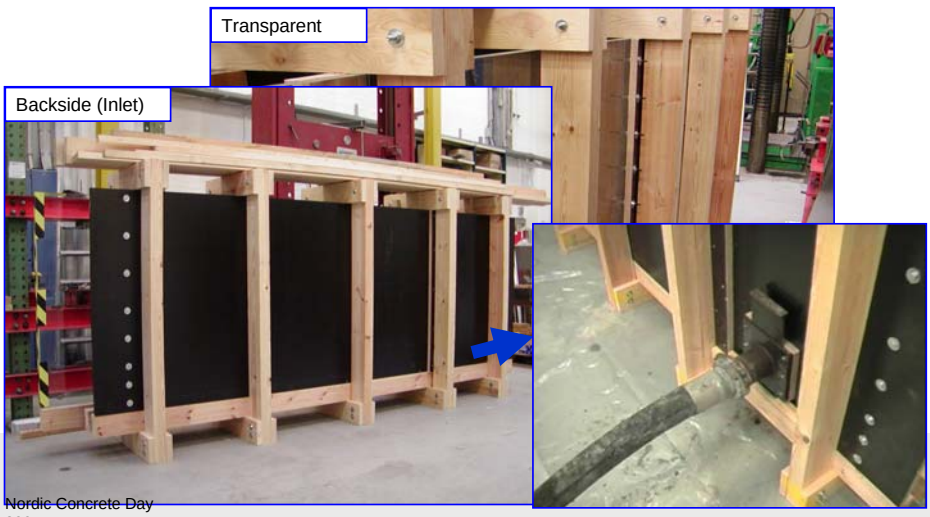
Mass: $(\nabla \cdot \mathbf{v}) = 0$

Momentum: $\frac{\partial \rho \mathbf{v}}{\partial t} + \nabla \cdot (\rho \mathbf{v}\mathbf{v}) = -\nabla \cdot \boldsymbol{\sigma} + \rho \mathbf{g}$

$\boldsymbol{\sigma} = p\boldsymbol{\delta} + \boldsymbol{\tau} \qquad \boldsymbol{\tau} = 2\eta\dot{\gamma} \qquad \eta = \eta_{pl} + \frac{\tau_0}{\dot{\gamma}}$

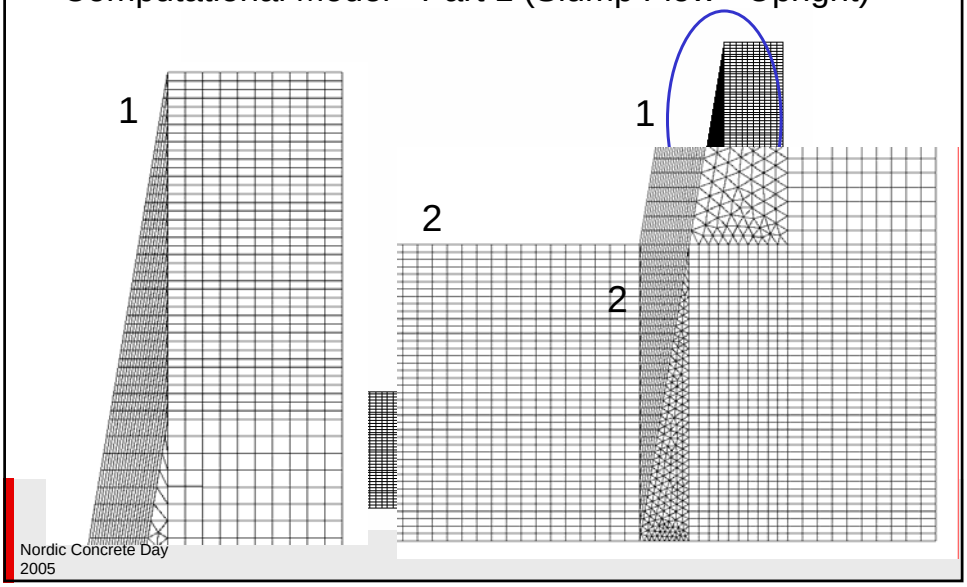
DANISH TECHNOLOGICAL INSTITUTE

Approach – Part 2: l = 3 m, w = 0.3 m, h = 1 m



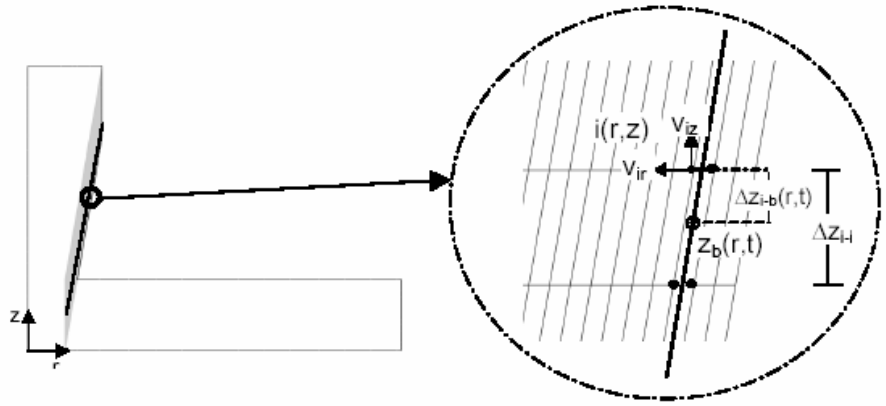
DANISH TECHNOLOGICAL INSTITUTE

Computational Model - Part 1 (Slump Flow - Upright)



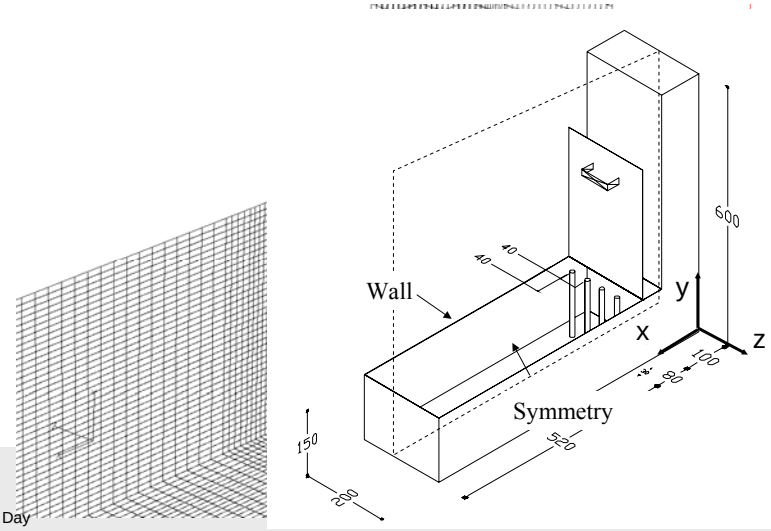
DANISH TECHNOLOGICAL INSTITUTE

Computational Model - Part 1 (Slump Flow – Upside down)



DANISH TECHNOLOGICAL INSTITUTE

Computational Model – Part 1 (L-Box)



DANISH TECHNOLOGICAL INSTITUTE

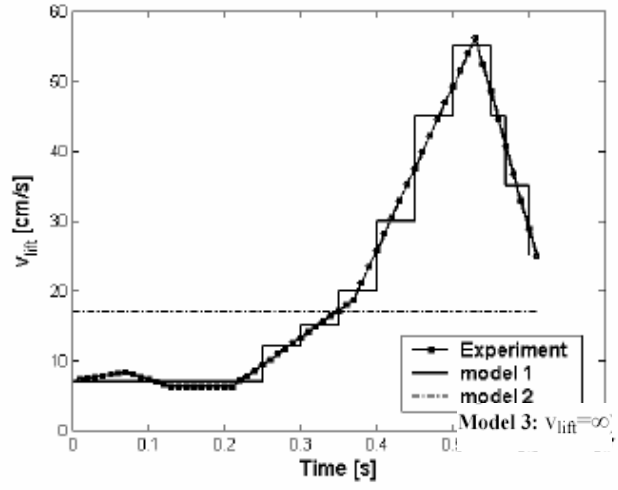
Experimental – Part 1

1. A self-compacti

BML Viscometer

Slump Flow Test:

L-Box



DANISH TECHNOLOGICAL INSTITUTE

Experimental – Part 1

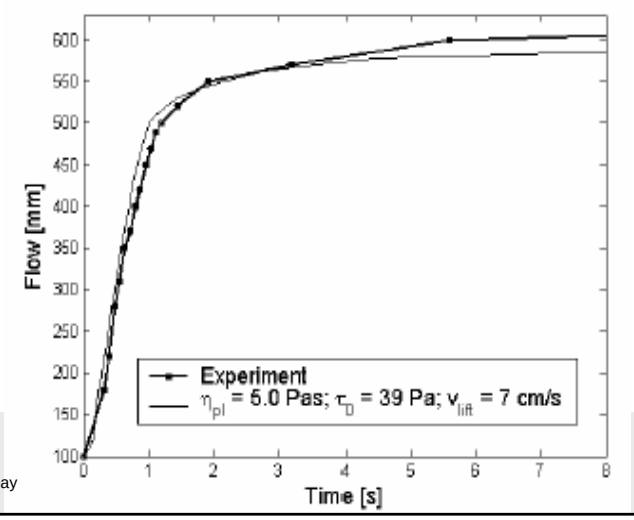
2. A self-compacting concrete

Slump Flow Test: v_{lift} = 4 cm/s – Upright

L-Box: v_{lift} = 29 cm/s

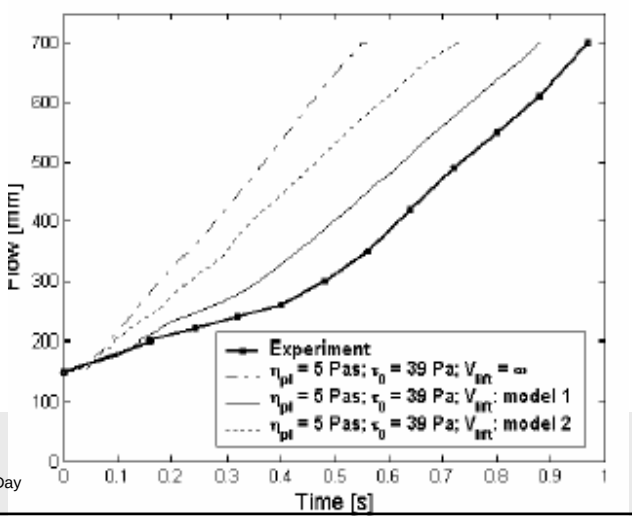
DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (Slump Flow - Mortar)



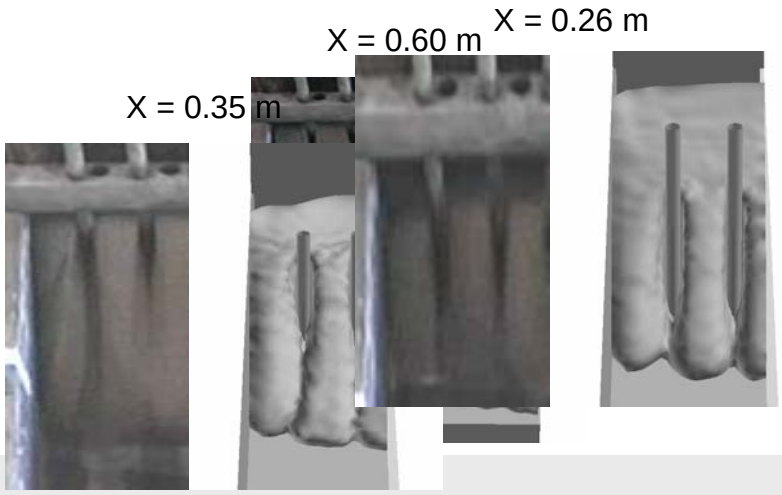
DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (L-Box - Mortar)



DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (L-Box - Mortar)



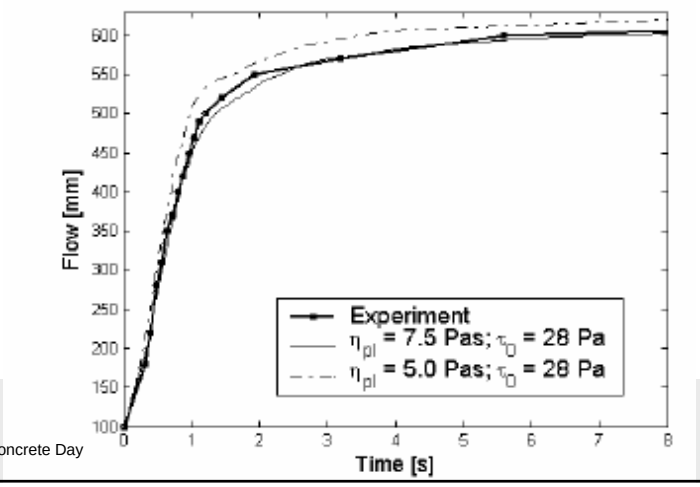
Nordic Concrete Day 2005

DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (L- Box - Mortar)

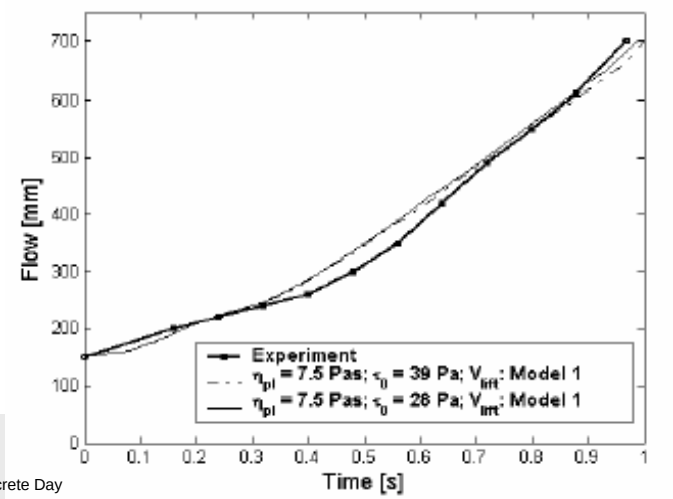
DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (Slump Flow - Mortar)



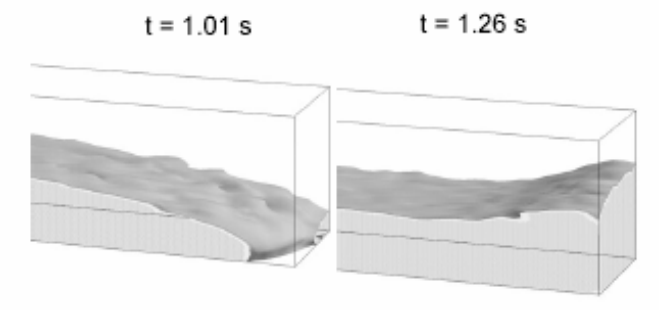
DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (L-Box – Mortar)



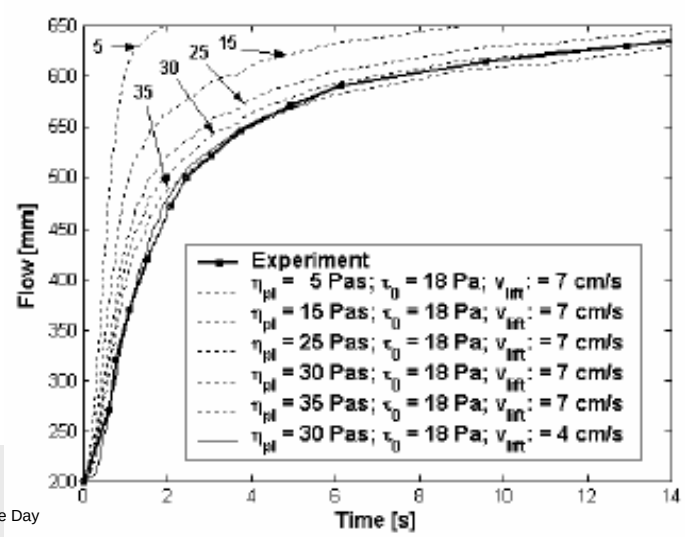
DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (L-Box - Mortar)



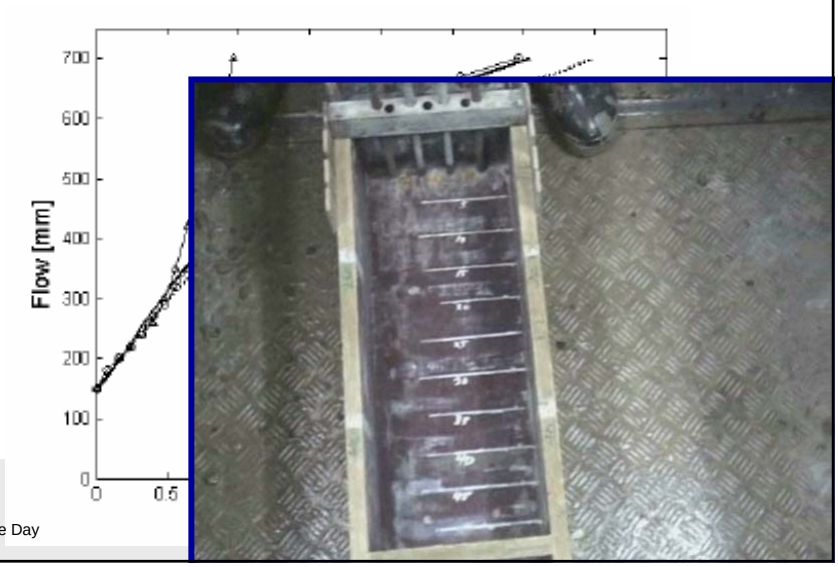
DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (Slump Flow - Concrete)



DANISH TECHNOLOGICAL INSTITUTE

Results – Part 1 (L-Box – Concrete)



DANISH TECHNOLOGICAL INSTITUTE

Conclusion: Part 1

- Results show consistency between simulations and experiments for both the L-box and slump flow test for a given set of rheological properties when including moving boundaries and a reasonable agreement between rheological parameters determined in a viscometer and those applied to simulate flow is obtained.
- This indicate that the applied simulation approach could be valid for full-scale simulations.

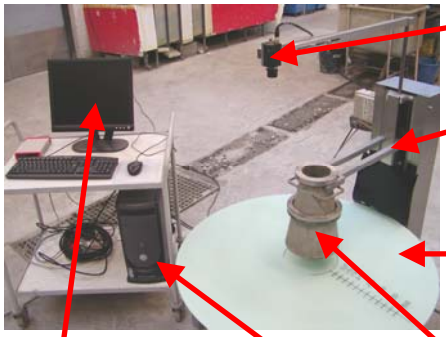
DANISH TECHNOLOGICAL INSTITUTE

Supplementary

- For assessment of rheological properties based on the test methods, complete control of the lifting velocity and a detailed and accurate monitoring of the transient flow behaviour are required.

DANISH TECHNOLOGICAL INSTITUTE

4C Automatic Slump Flow



B/W Video camera

Lifting device – Ball screw ensures accurate lifting speed of 7 cm/s

Base plate in hardened sand blasted glass on adjustable rubber feet

Everything mounted on ”rollers”

Monitor – one click and the analysis will proceed automatically

PC

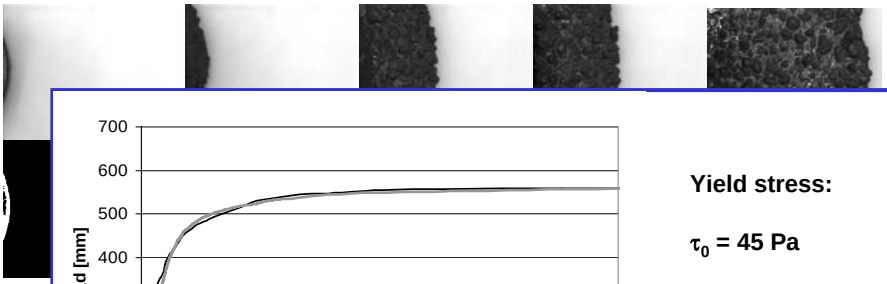
Upright Abrams slump cone with weight ring

DANISH TECHNOLOGICAL INSTITUTE

4C Automatic Slump Flow

Concept:

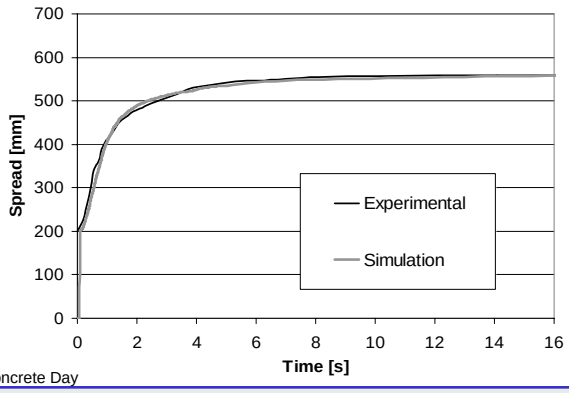
Raw image



Field

Spr

30 i



Yield stress:

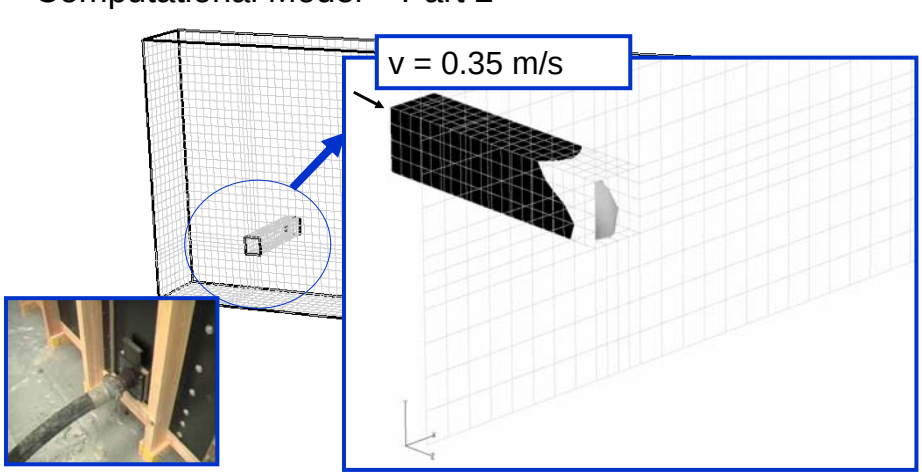
τ_0 **= 45 Pa**

Plastic viscosity:

η_{pl} **= 30 Pa s**

DANISH TECHNOLOGICAL INSTITUTE

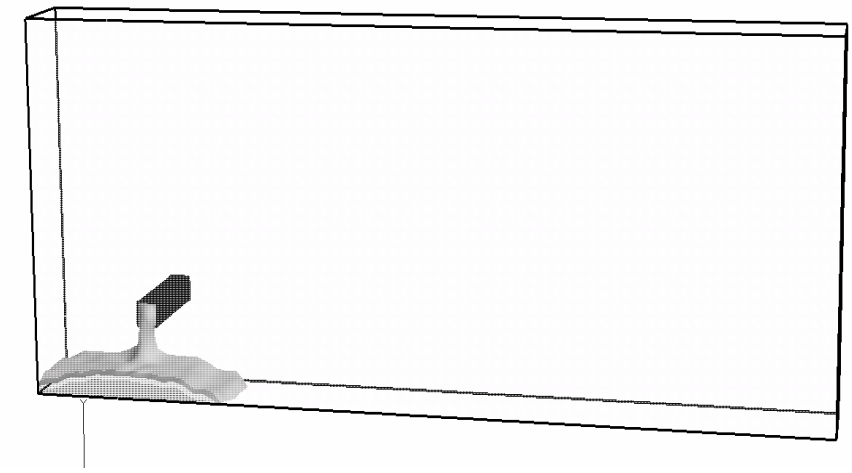
Computational Model – Part 2



Nordic Concrete Day
2005

DANISH TECHNOLOGICAL INSTITUTE

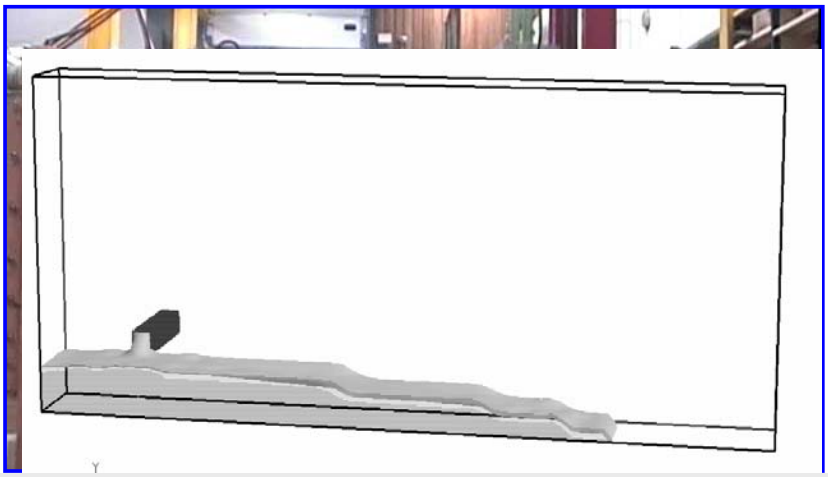
Results: Free Surface, Time = 6 s



Nordic Concrete Day
2005

DANISH TECHNOLOGICAL INSTITUTE

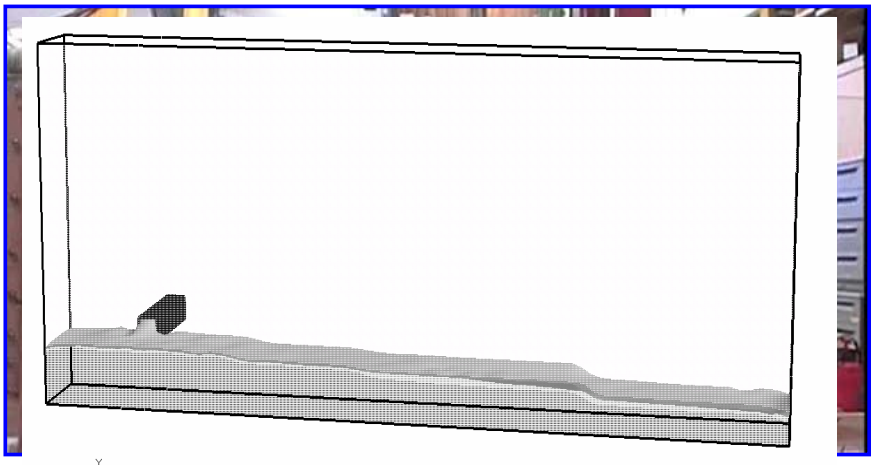
Results: Free Surface, Time = 36 s



Nordic Concrete Day
2005

DANISH TECHNOLOGICAL INSTITUTE

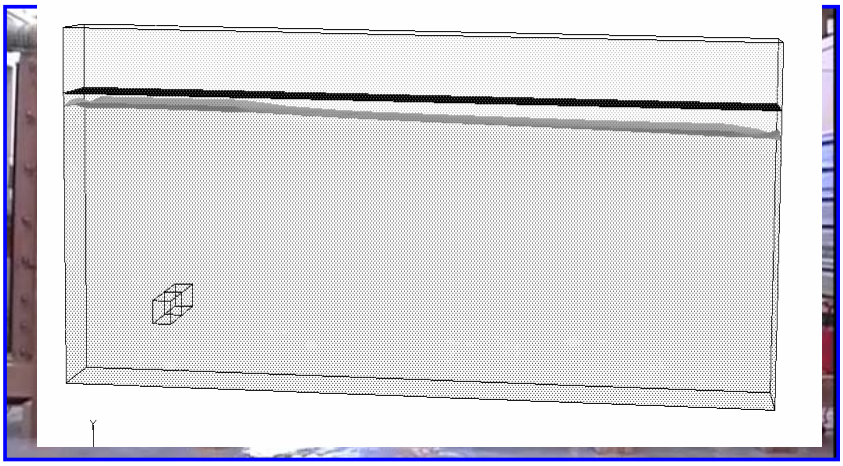
Results: Free Surface, Time = 60 s



Nordic Concrete Day
2005

DANISH TECHNOLOGICAL INSTITUTE

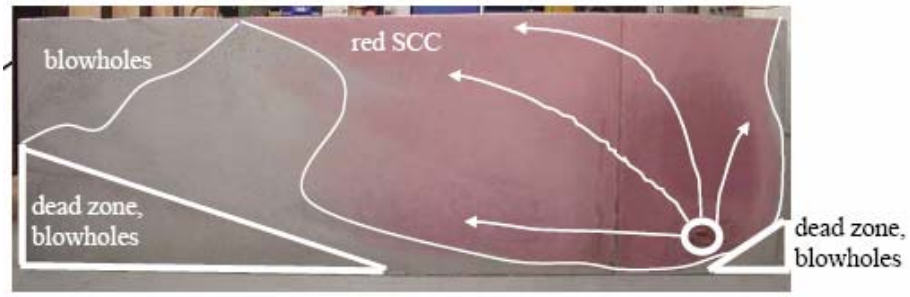
Results: Free Surface, Time = 360 s



Nordic Concrete Day
2005

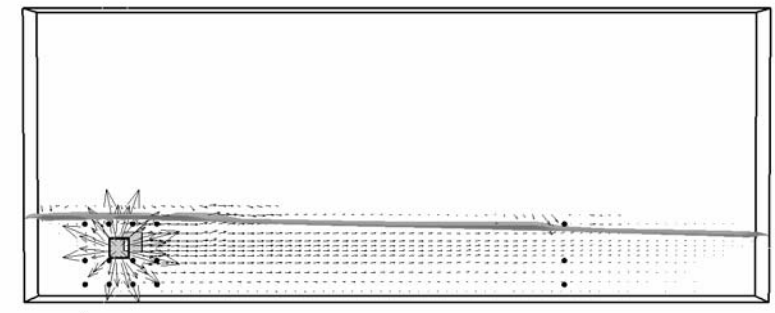
DANISH TECHNOLOGICAL INSTITUTE

Results: Flow Patterns, Experimental, Side of inlet



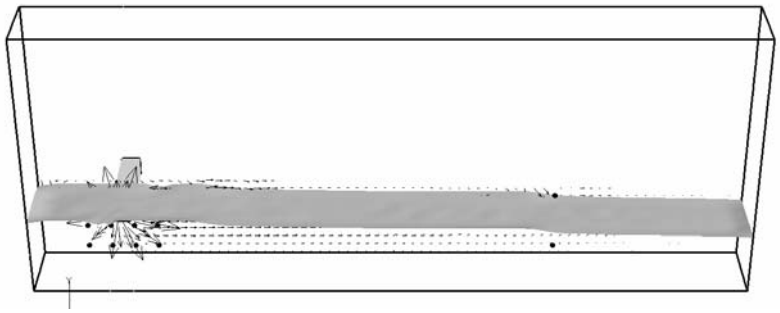
DANISH TECHNOLOGICAL INSTITUTE

Results: Flow Patterns, Experimental, Side of inlet



DANISH TECHNOLOGICAL INSTITUTE

Results: Flow Patterns, Experimental, Side of inlet



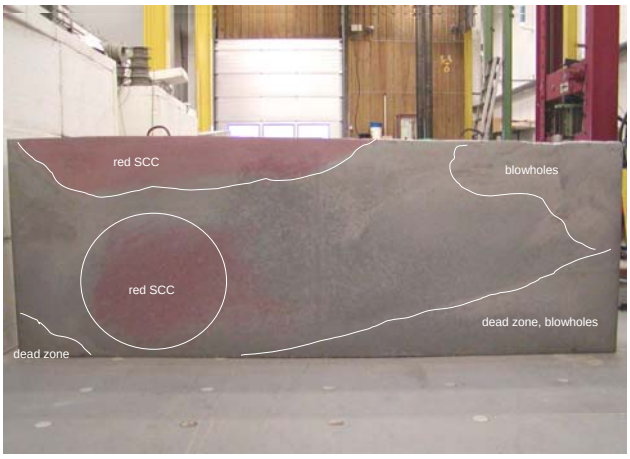
DANISH TECHNOLOGICAL INSTITUTE

Results: Flow Patterns, Experimental, Side of inlet

Nordic Concrete Day
2005

DANISH TECHNOLOGICAL INSTITUTE

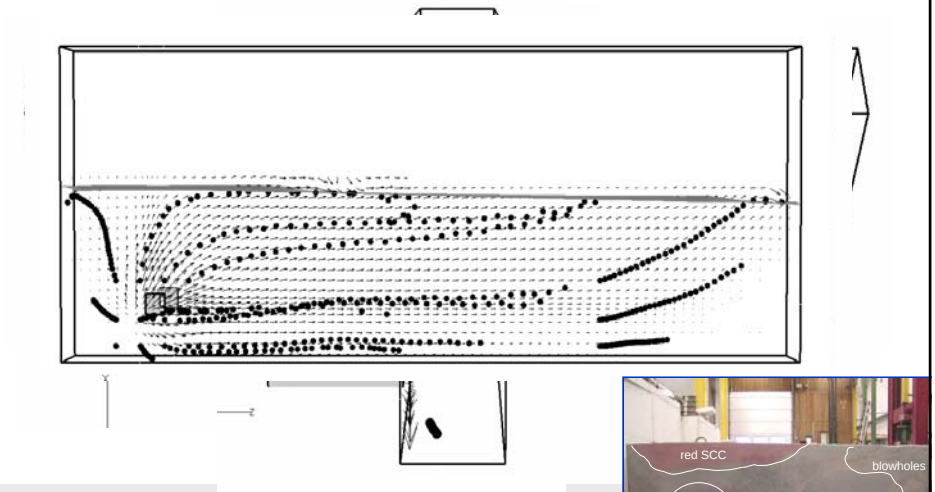
Results: Flow Patterns, Experimental, Transparent Side



Nordic Concrete Day
2005

DANISH TECHNOLOGICAL INSTITUTE

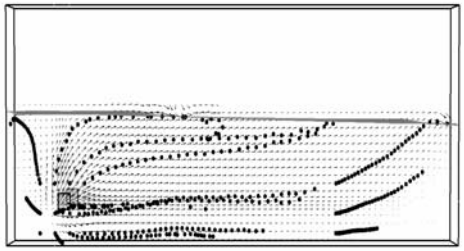
RESULTS: Flow Patterns, Simulation, Transparent Side



Nordic Concrete Day
2005

DANISH TECHNOLOGICAL INSTITUTE

RESULTS: Flow Patterns



DANISH TECHNOLOGICAL INSTITUTE

Conclusions – Part 2

- Single fluid simulation of a Bingham fluid seem to capture the observations of the free surface and flow patterns observed in the form filling experiment.
- The flow patterns affect the dynamic segregation resistance
- The surface quality seems dependent on the shearing history at the formwork.