Application of the fluid dynamics model to the field of fiber reinforced self-compacting concrete

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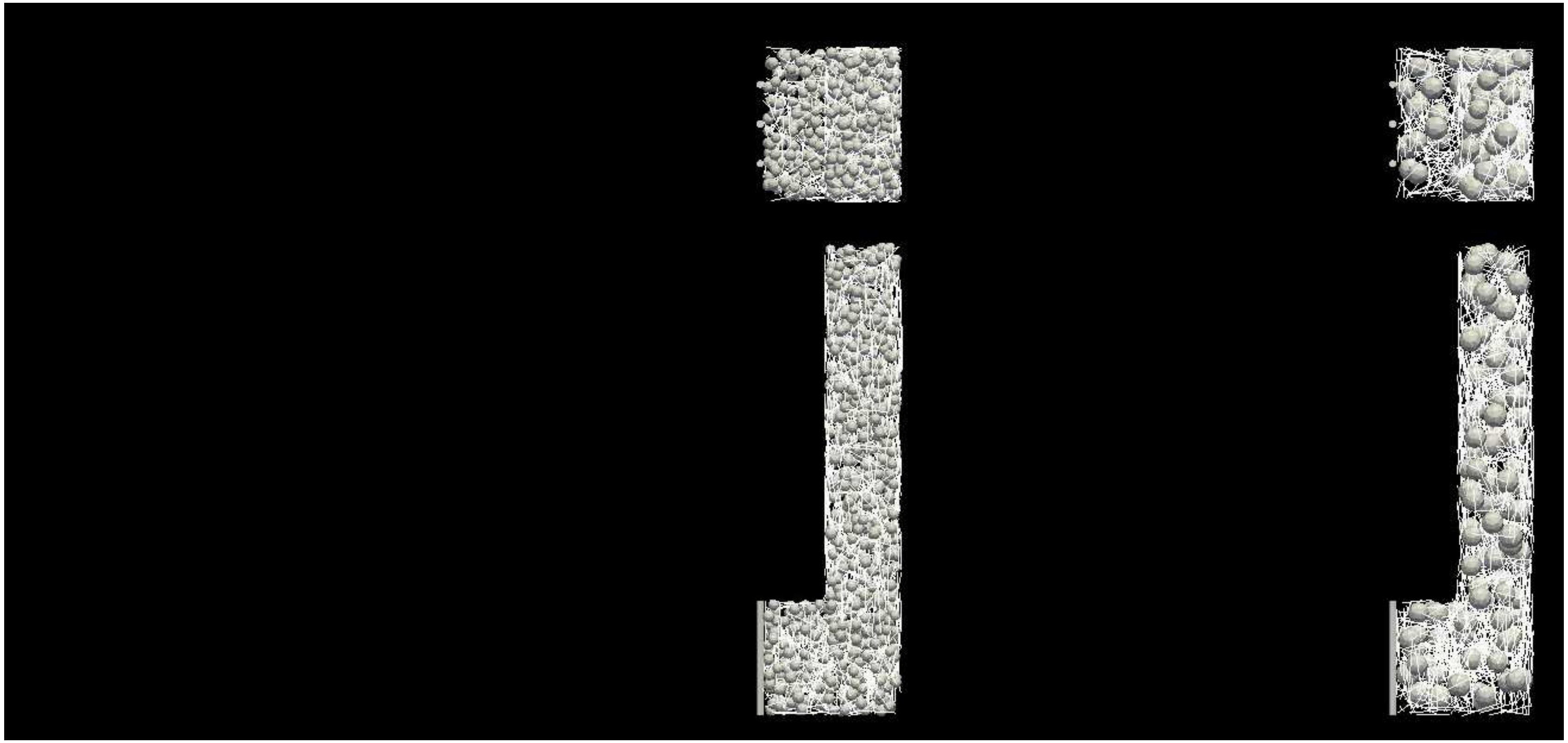
What do we do?

- Part of a larger project
  - Innovation consortium "Sustainable Concrete Structures using Steel Fiber Reinforced Concrete" (fund: Danish Strategic Research Council)
  - Main task: to provide tools for better and wider usage of SFRC-SCC



How do we do it?

We have developed model capable of:

- Fluid Dynamics solver
    - Non-Newtonian, Free Surface
    - Boundary Conditions (walls, inlets, re-bars…)
- Solid particle model
    - Fibers, Aggregates (spheres, ellipsoids…)
    - Collisions and other interactions
- Parallelized (running on 25 cores and more)

(Further information in our papers)

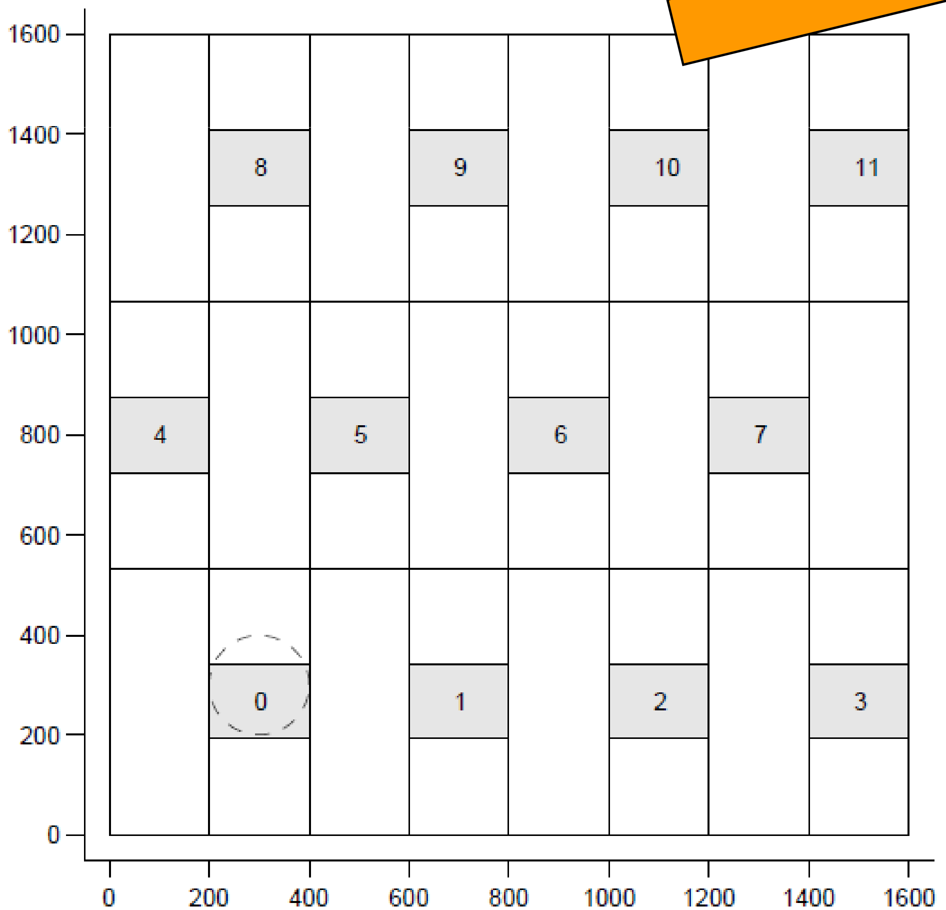
Number of			
Files	Lines	Characters	Eq. Pages
340	34 000	1 450 000	800

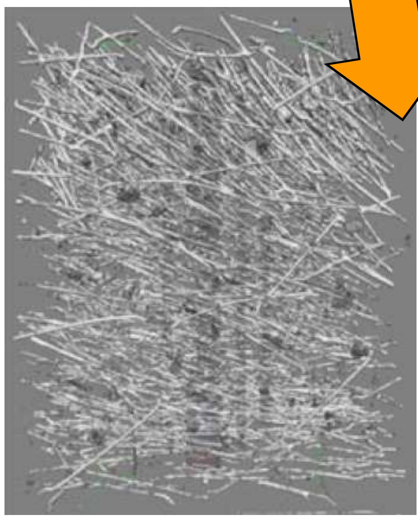
Code, code, code, code …

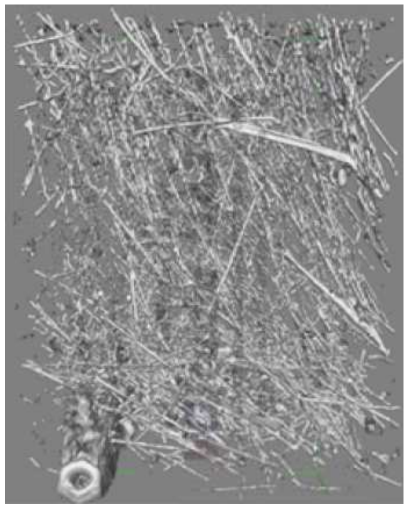
```
let collide (phase, f, rho, u, tau, g: triple) =
  let fEq = lt.Consts.getfEqA (rho, u)
  let fNeq = f |> Array.mapi (fun i f-> f - fEq.[i])
  let devStressInv, shearRate =
    deviatoricStressTensorInvariantAndShearRate (fNeq,
  let tauN =
    match phase with
      | Interface _ -> tau
      | _ -> getNewTau (2. * sqrt (shearRate * shearRa
  lt.Consts.collide (f, fNeq, tauN, getForce (shearRate

let stream (xyz, f: float []) =
  let add xyz dMass =
    if lt.MassExchange.ContainsKey xyz then
      lt.MassExchange.[xyz] <- lt.MassExchange.[xyz] +
    else lt.MassExchange.Add (xyz, dMass)

  let bounceBack xyz i id interfaceMO =
      match bcP.Objects.[id].Purpose with
        | BcBounceBackI (vel, slip) ->
          let fMod, xs, is = bcP.getFmodXsIs (id, (xyz
          let fop = lt.Par.RhoA.[xyz].Value * fMod + f
          match lt.Par.getPhase xs, lt.Par.getfA xs wi
            | Fluid, Some fxs ->
              interfaceMO |> Option.iter (fun _ ->
                add xyz (fxs.[is] * slip)
                if lt.Par.PA.exists xs = false then ad
              fxs.[is] * slip + fop * (1. - slip)
            | Interface m1, Some fxs ->
              match interfaceMO with
                | Some m0 ->
```

SLAB CASTING

Computed Tomography

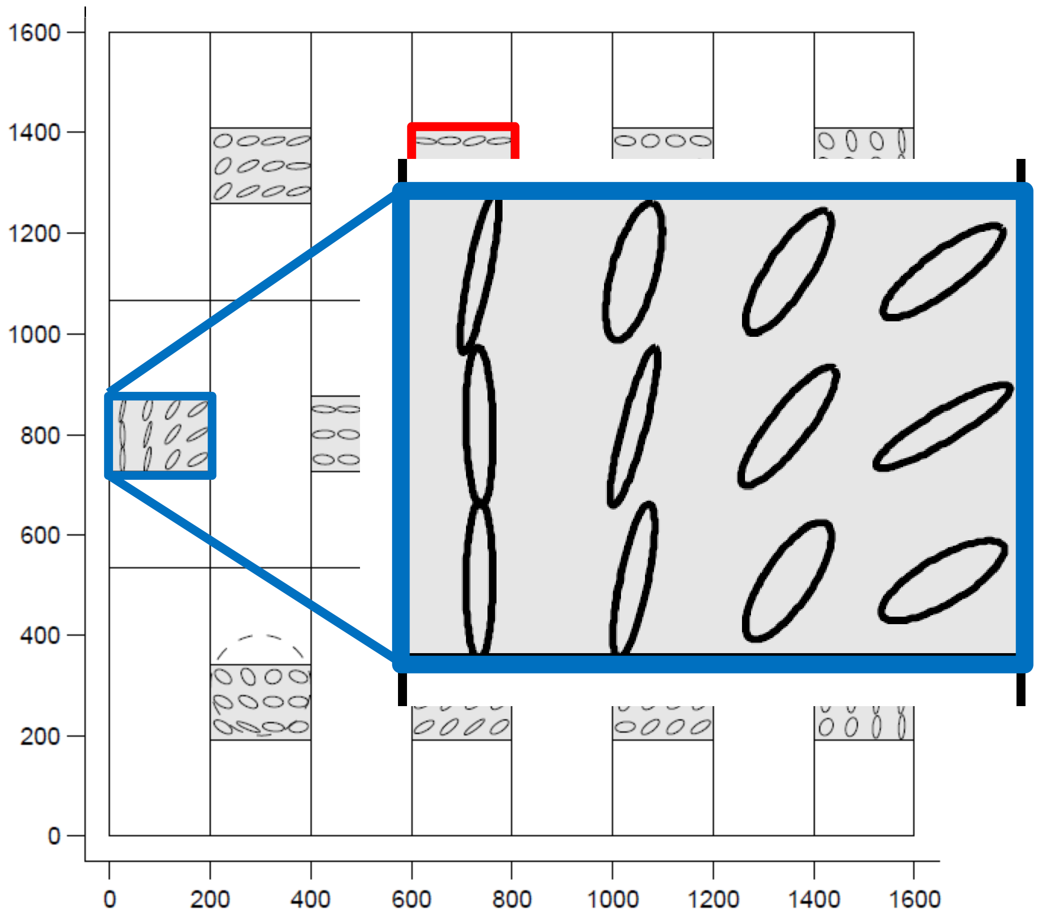




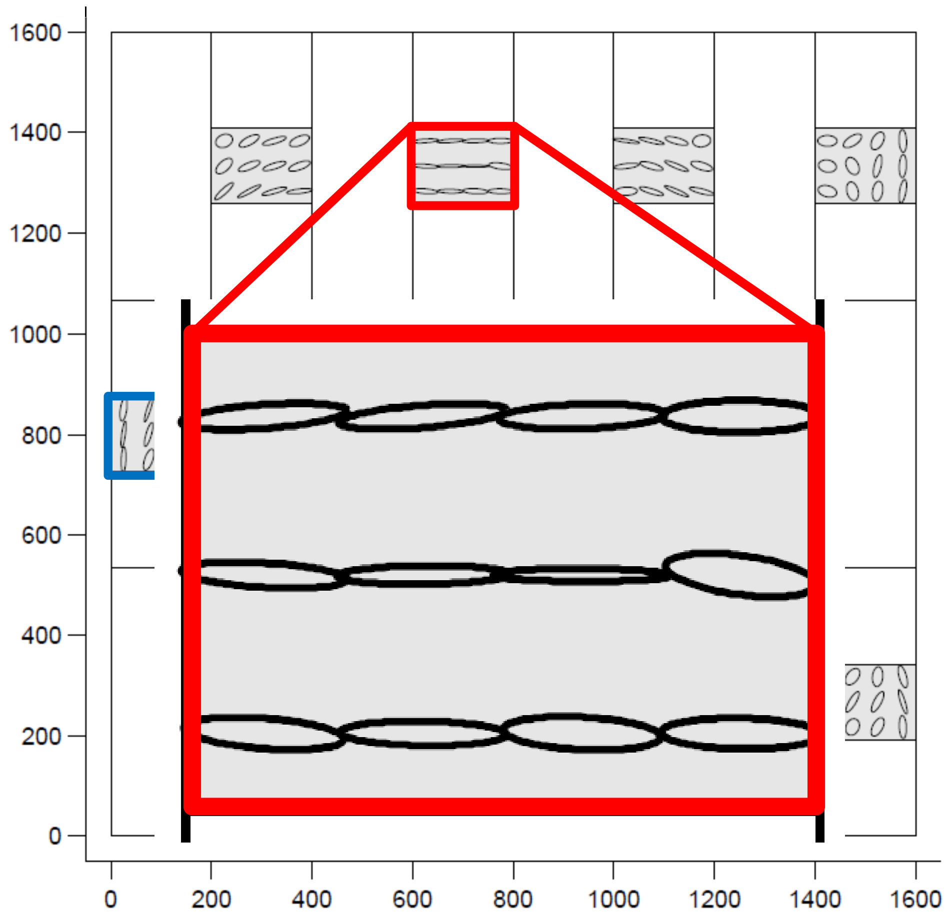


Computed tomography results

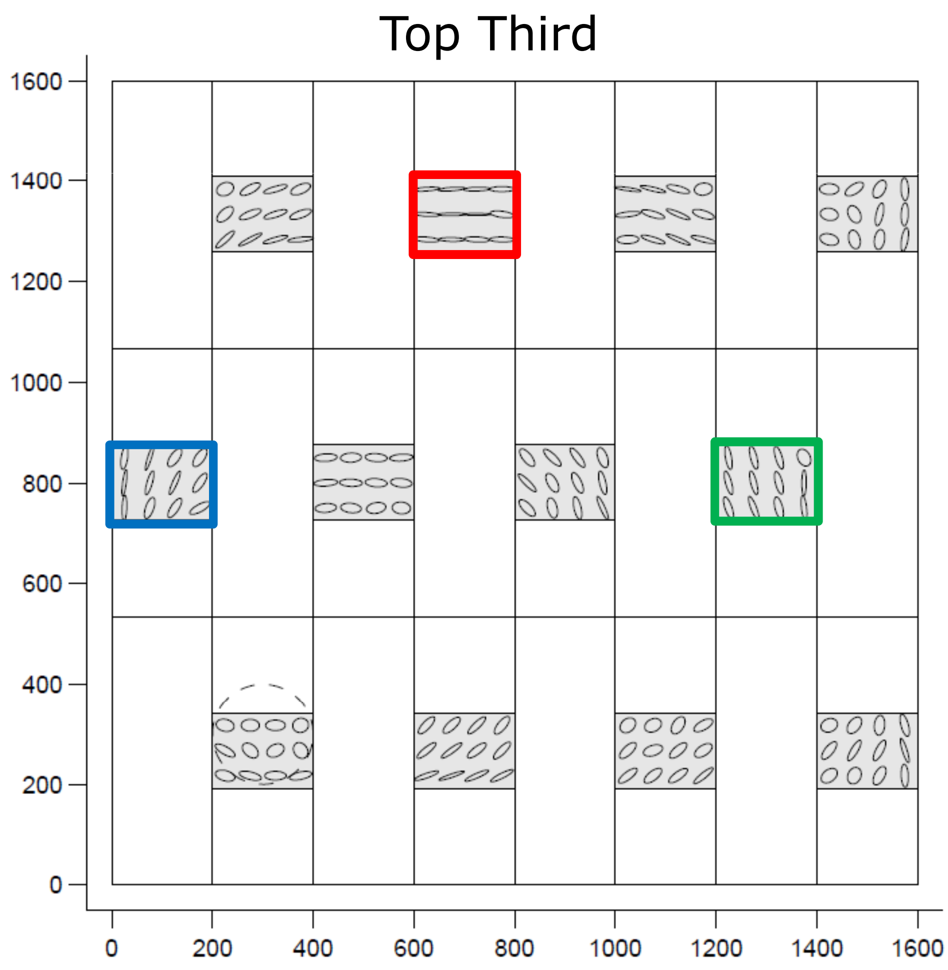
Bottom Third

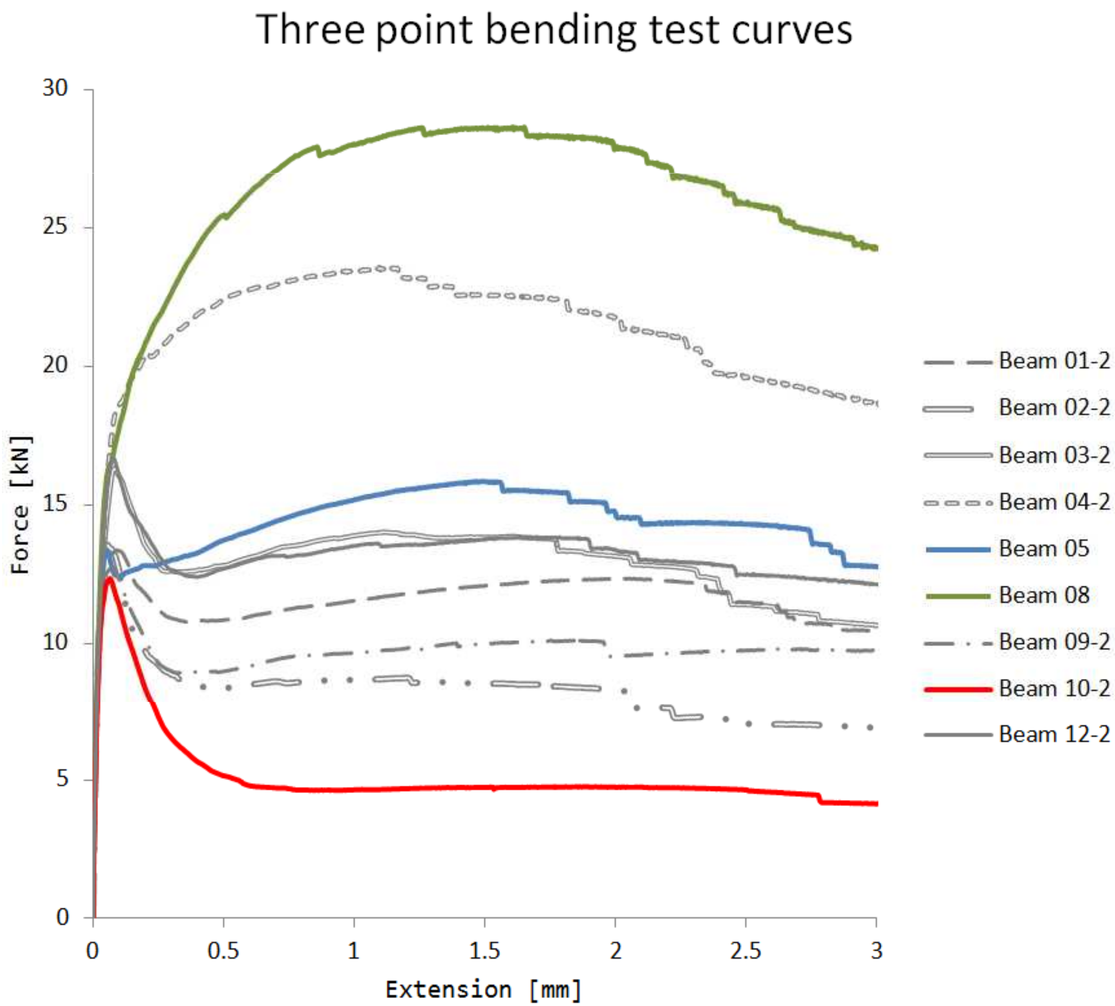


Top Third

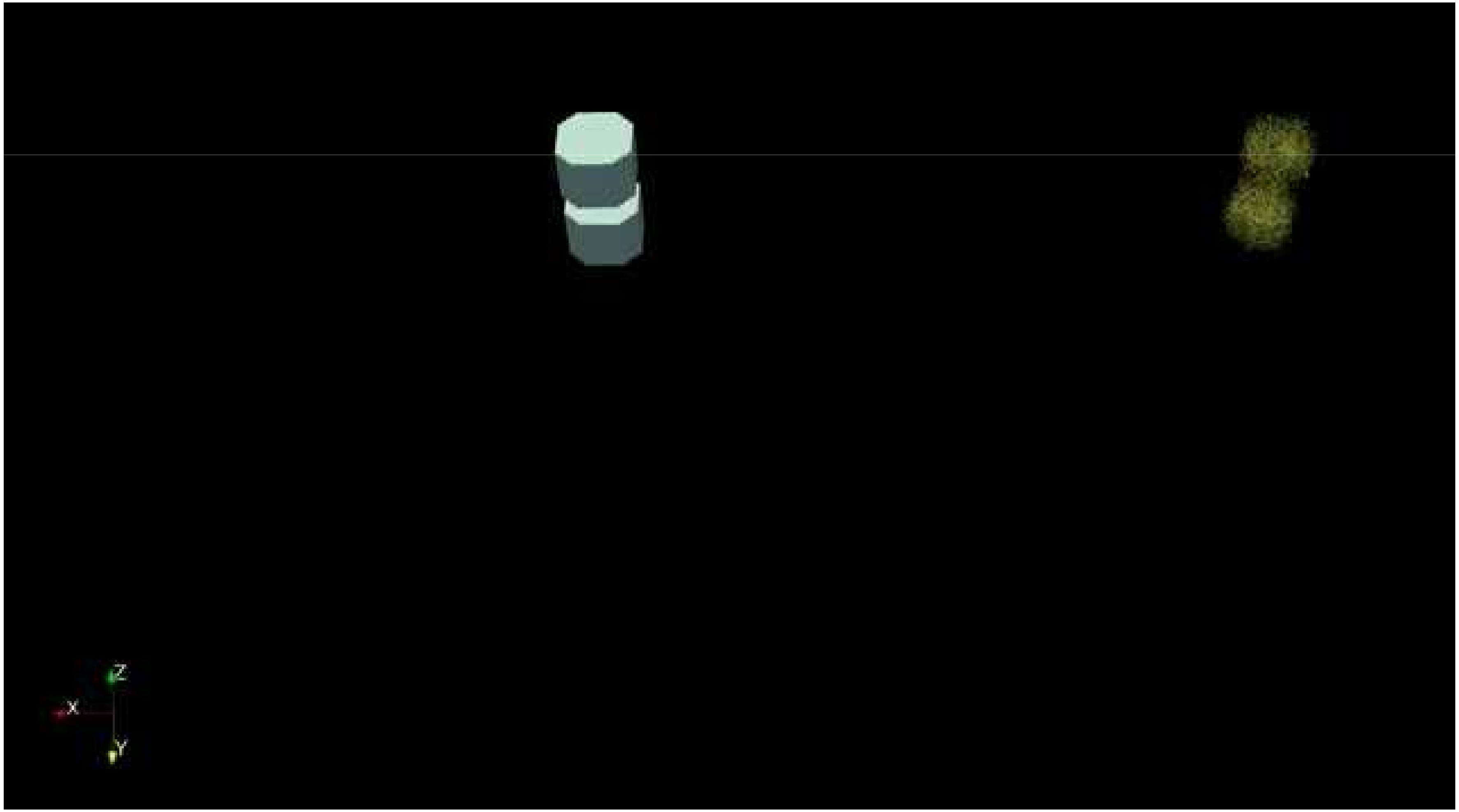


Fiber orientation vs. fracture response



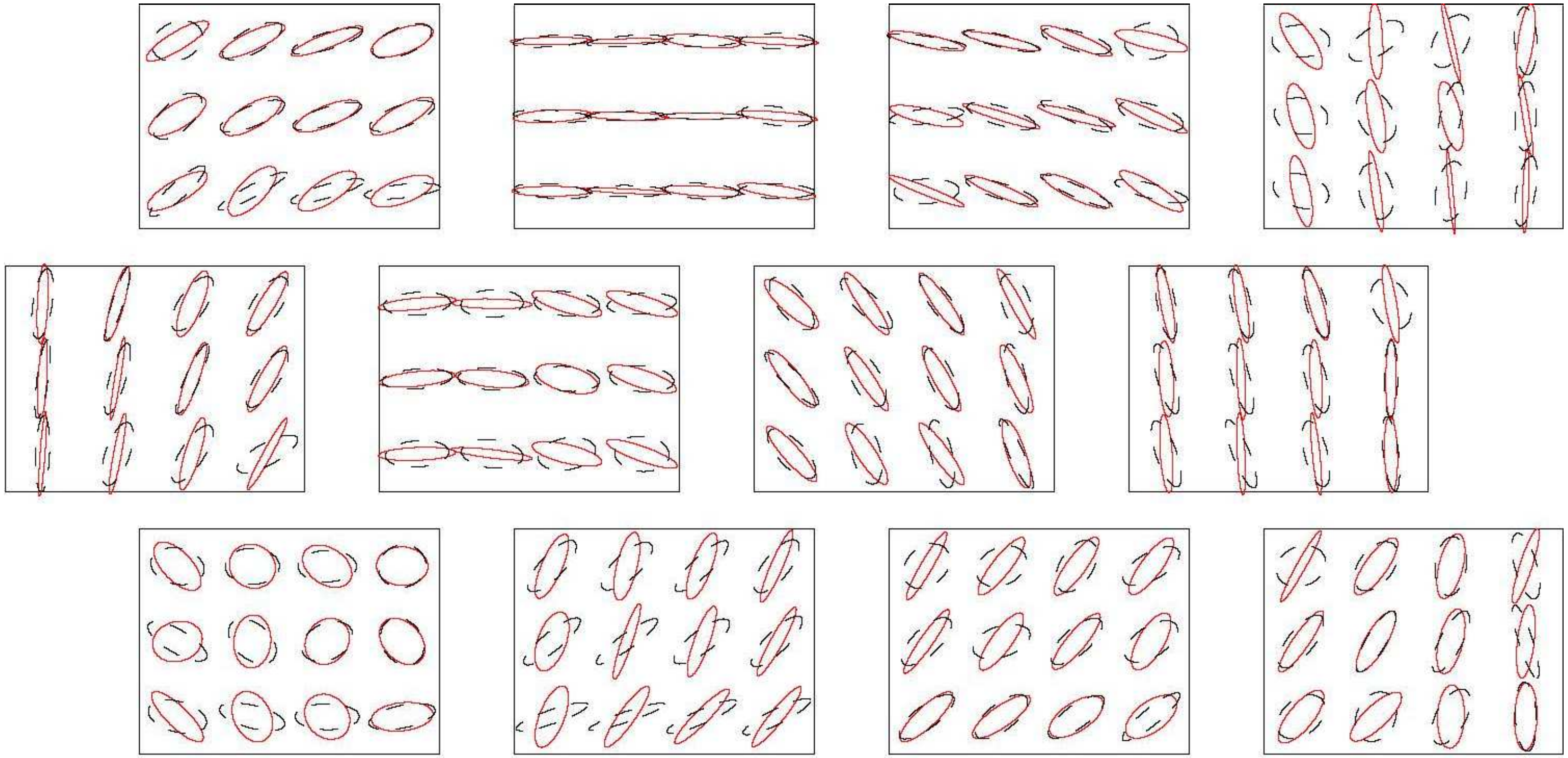


Simulation



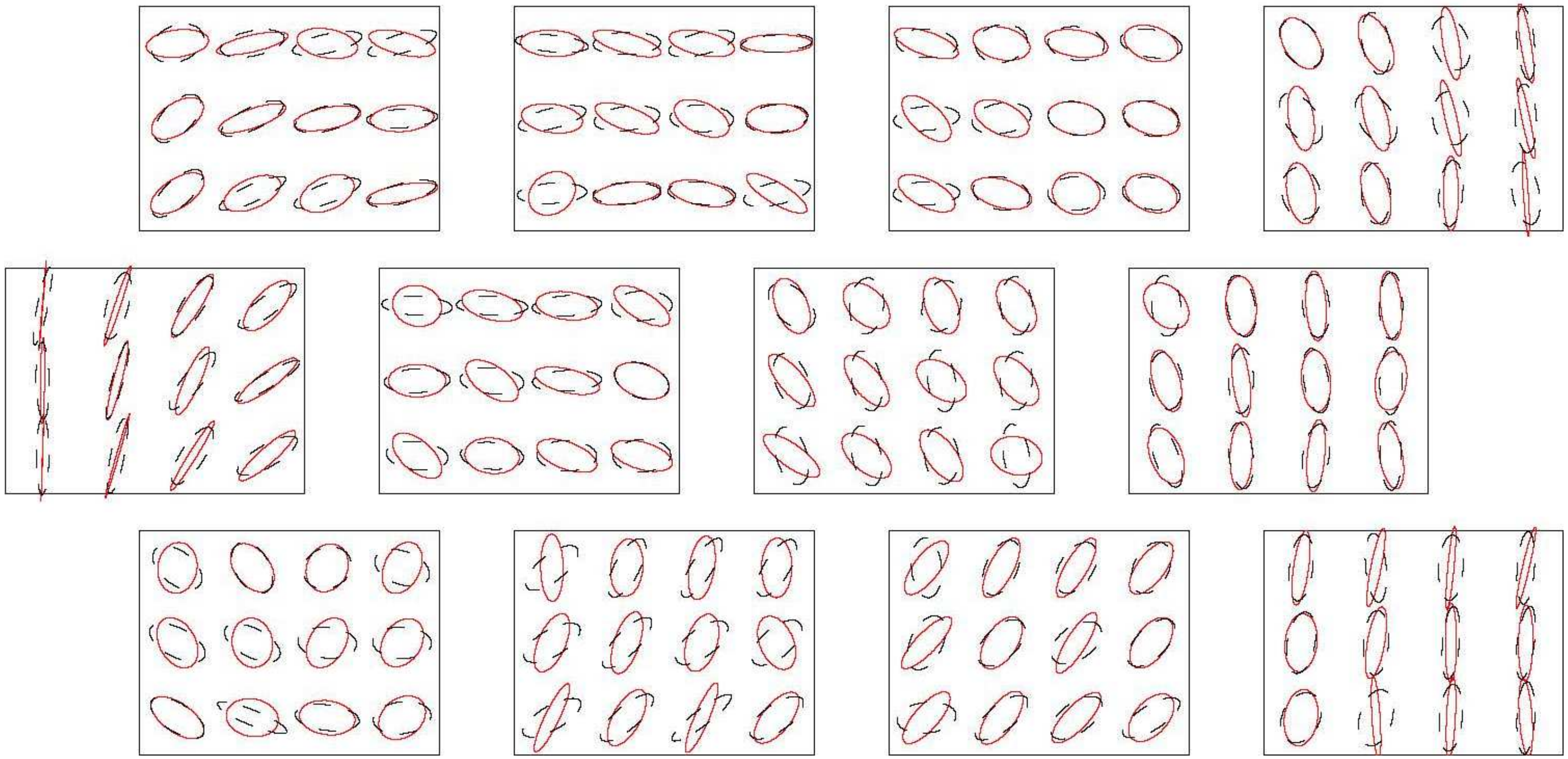
CT vs. Simulation

Upper third of the slab



CT vs. Simulation

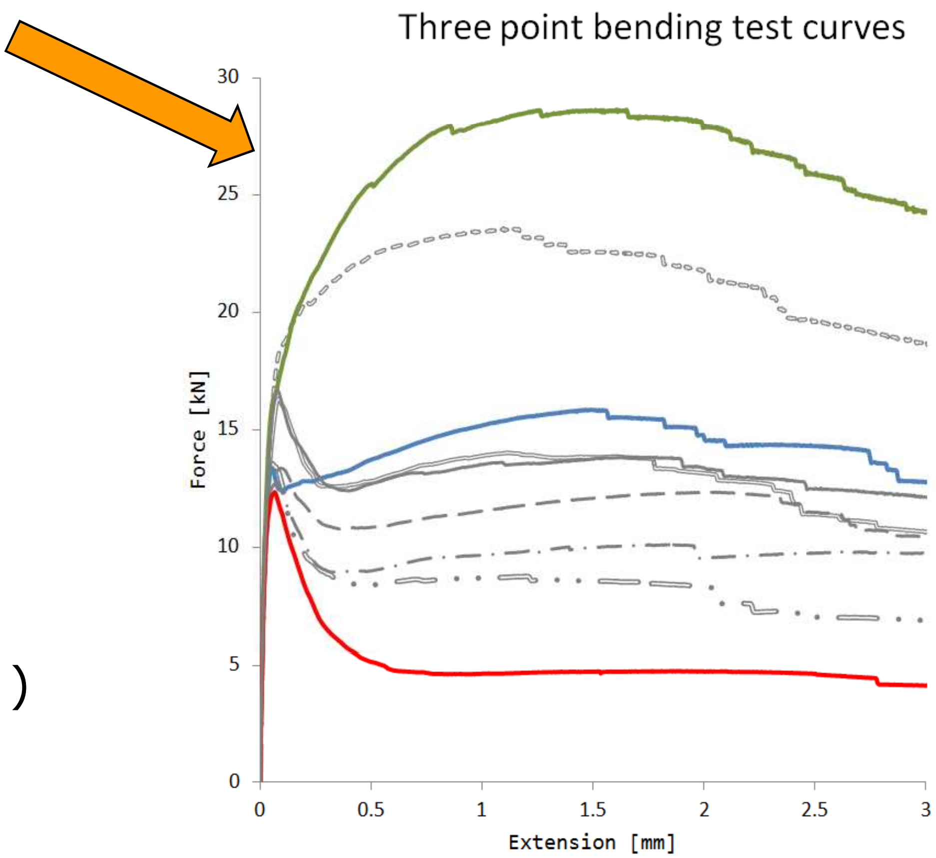
Lower third of the slab



Conclusions

- **Fibers orient due to the flow of the SCC**
  - Knowledge of the casting process is required (rheology, type of filling, surface of the formwork …)
- **We are able to predict the final orientation and distribution of fibers**

- **<u>Future work:</u>**
  - Relation between
    - Fiber orientation (i.e. fiber counts at the fracture plane …)
    - Final mechanical properties of the elements



Thank you for your attention

Conference papers

- **CMM 2011**: Fully coupled Lattice Boltzmann simulation of fiber reinforced self compacting concrete flow
- **ICCC 2011**: Flow simulation of fiber reinforced self compacting concrete using Lattice Boltzmann method
- **ICCC 2011**: Modeling of flow of flow of particles in non-Newtonian fluid using lattice Boltzmann method
- **BEFIB 2012**: Fibre reinforced self-compacting concrete flow simulations in comparison with L-Box experiments using Carbopol
- **SSCS 2012**: Application of the fluid dynamics model to the field of fibre reinforced self-compacting concrete

Journal papers

- **To be published**: Free surface flow of a suspension of rigid particles in a non-Newtonian fluid: a Lattice Boltzmann approach, Journal of Non-Newtonian Fluid Mechanics

Other

- **Nordic symposium 2011**: Prediction of flow induced inhomogeneities in self compacting concrete