Methods for Non-Destructive Analysis of Fiber Dispersion in Fiber Reinforced Cementitious Composites

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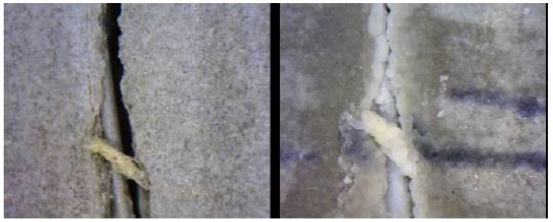
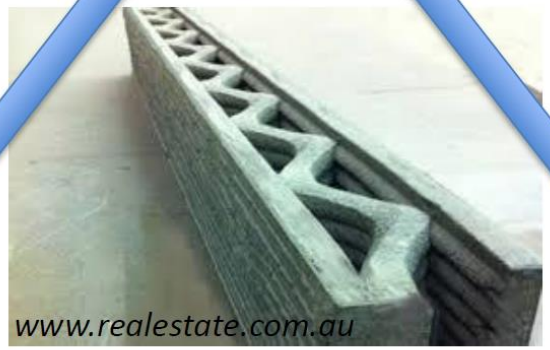
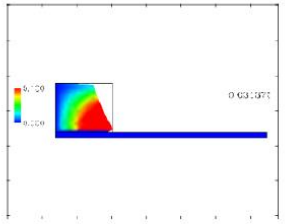
A holistic approach to the design of FRC structures



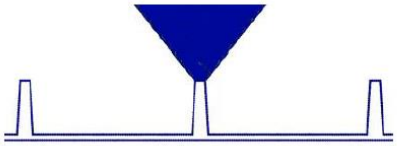
Understanding the performance

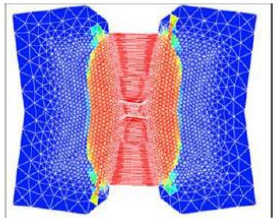


«Tailoring» the performance



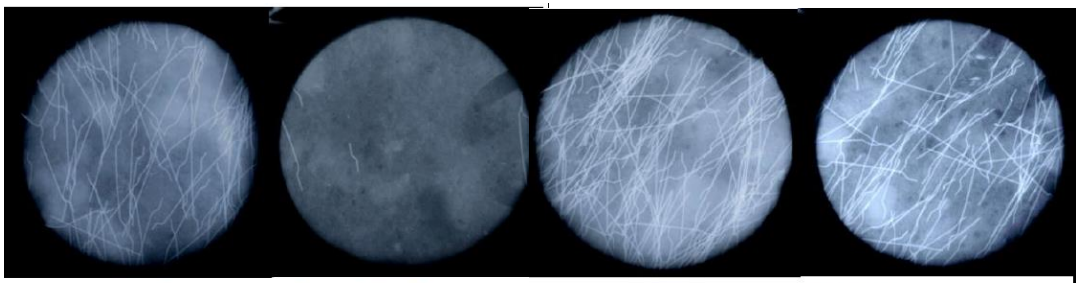
Modelling the performance





Progresses in concrete rheology «fostering» the study of fibre orientation issues

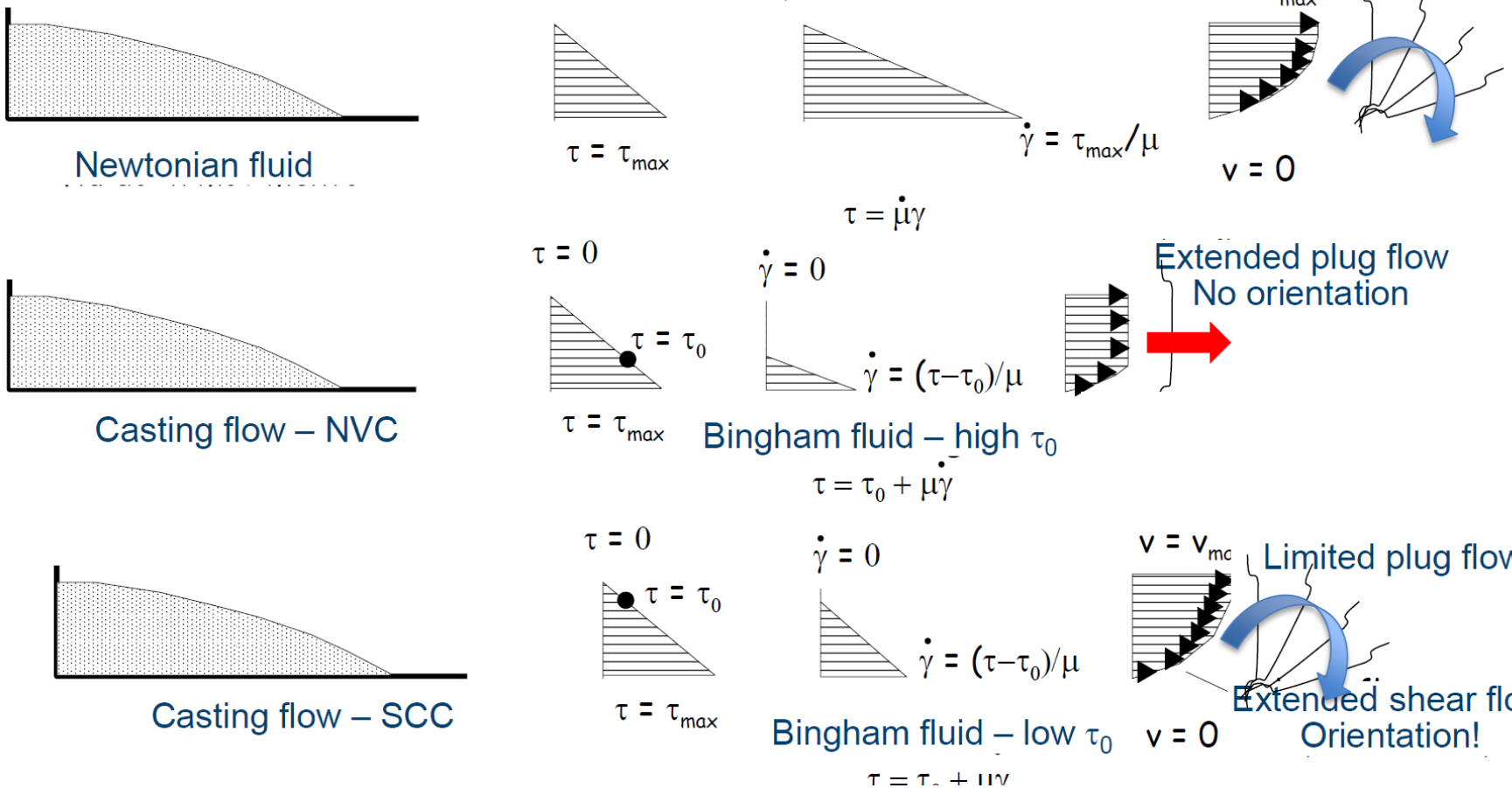
Controlling the rheology!



Vibrated SFRC SCSFRC

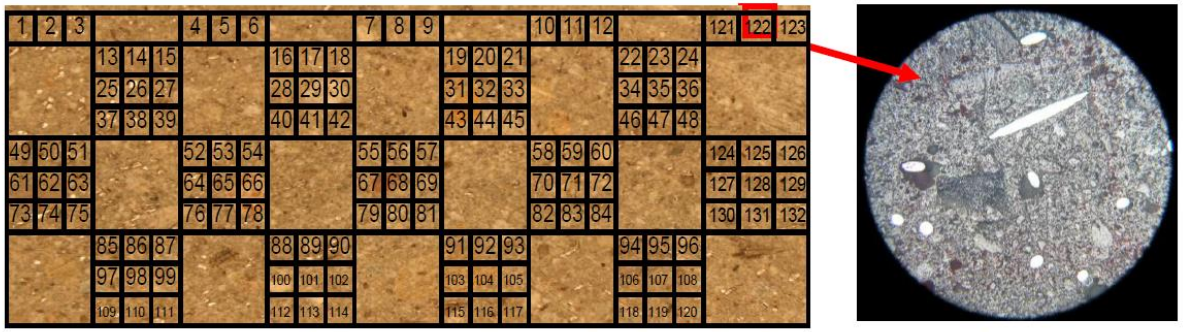
Ferrara and Meda, Materials and Structures 2006

Progresses in concrete rheology «fostering» the study of fibre orientation issues



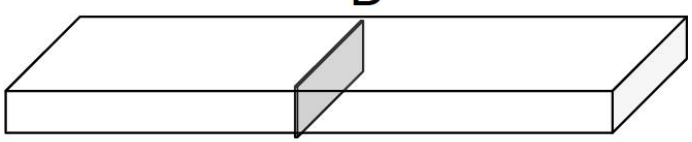
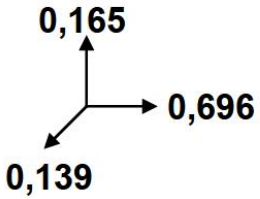
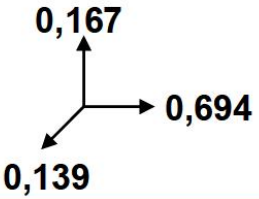
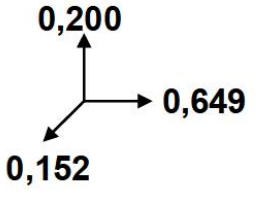
Progresses in concrete rheology «fostering» the study of fibre orientation issues

Tailored casting



Micrograph analysis of mid-span section

Orientation number: projected length of fiber available along each direction

	Vp: 0,55	Vp: 0,60	Vp: 0,65
			

Ferrara et al., Materials and Structures, 2011

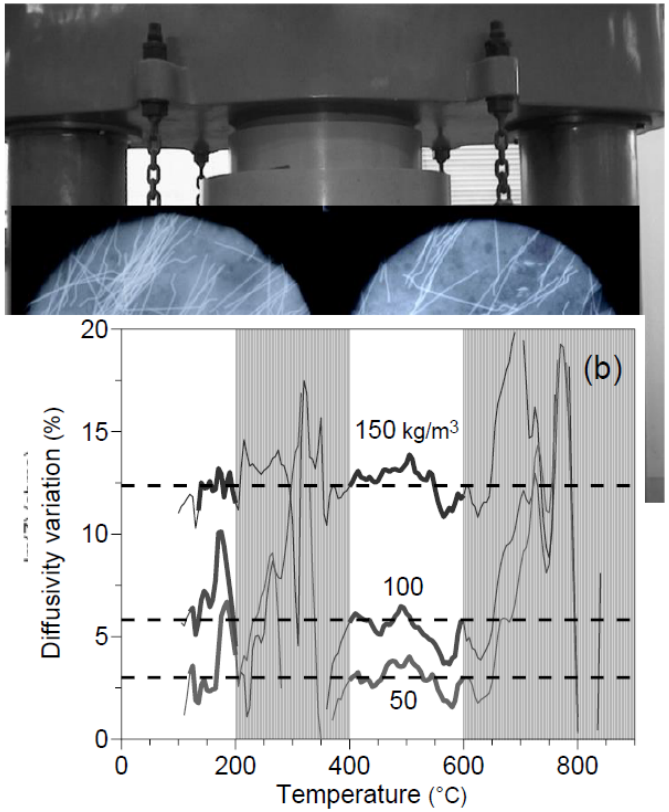
Monitoring the «in structure» fibre dispersion

Control in the fresh state

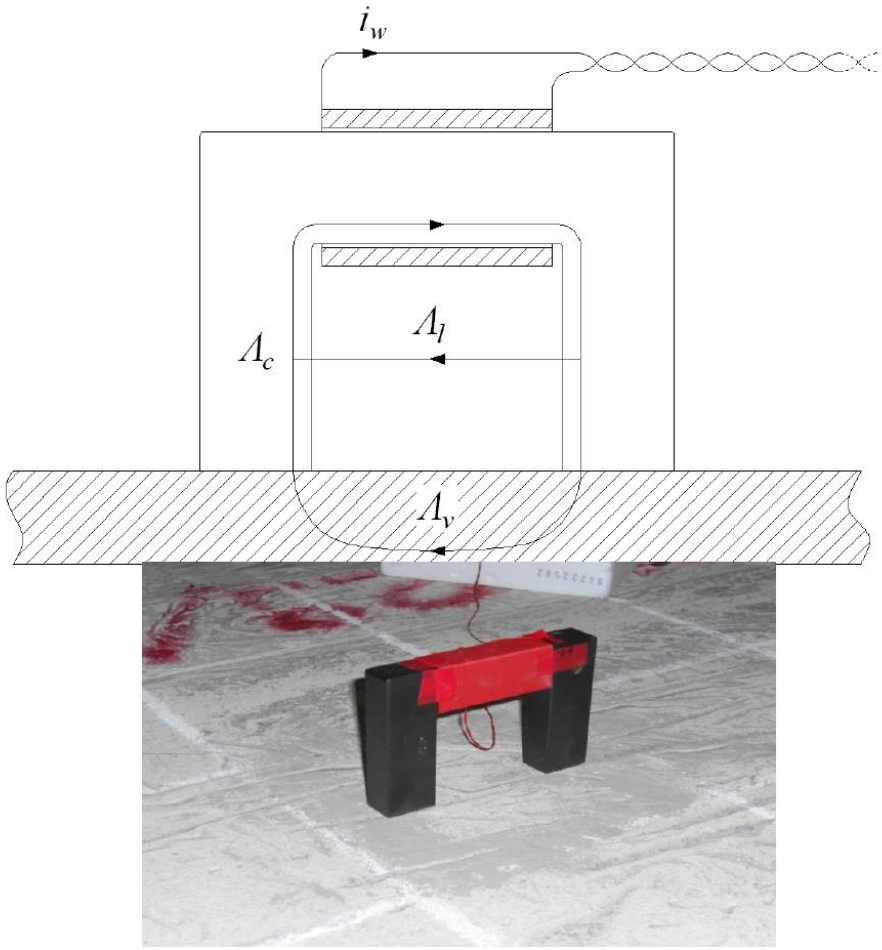
"wash" and sieve the fibers

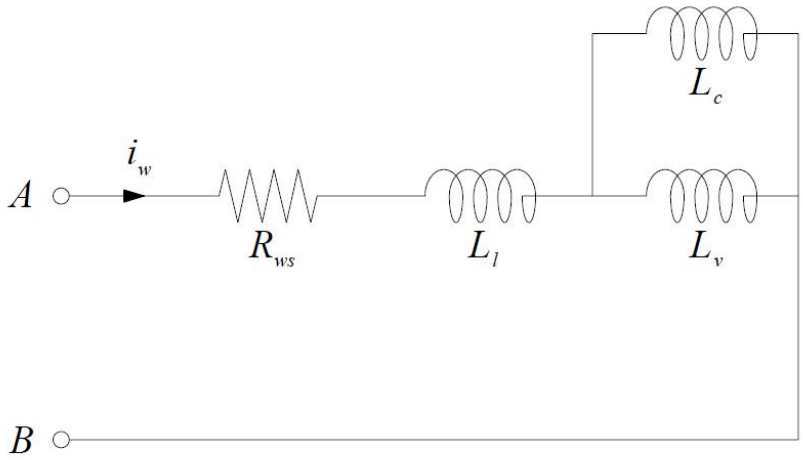
Control in the hardened state

- Destructive methods
  e.g.: drill cores, crush and weigh fibers
- Non-destructive methods
  - X-rays
  - Electrical-resistivity/impedance method Wansom et al., Lataste et al., Franchois
  - Thermal methods (Felicetti and Ferrara
  - Magnetic inductance methods



Monitoring the «in structure» fibre dispersion: a magnetic inductance based method





Magnetic inductance associated to the flux

$L_V = L_{V0} + \Delta L_{fibers}$

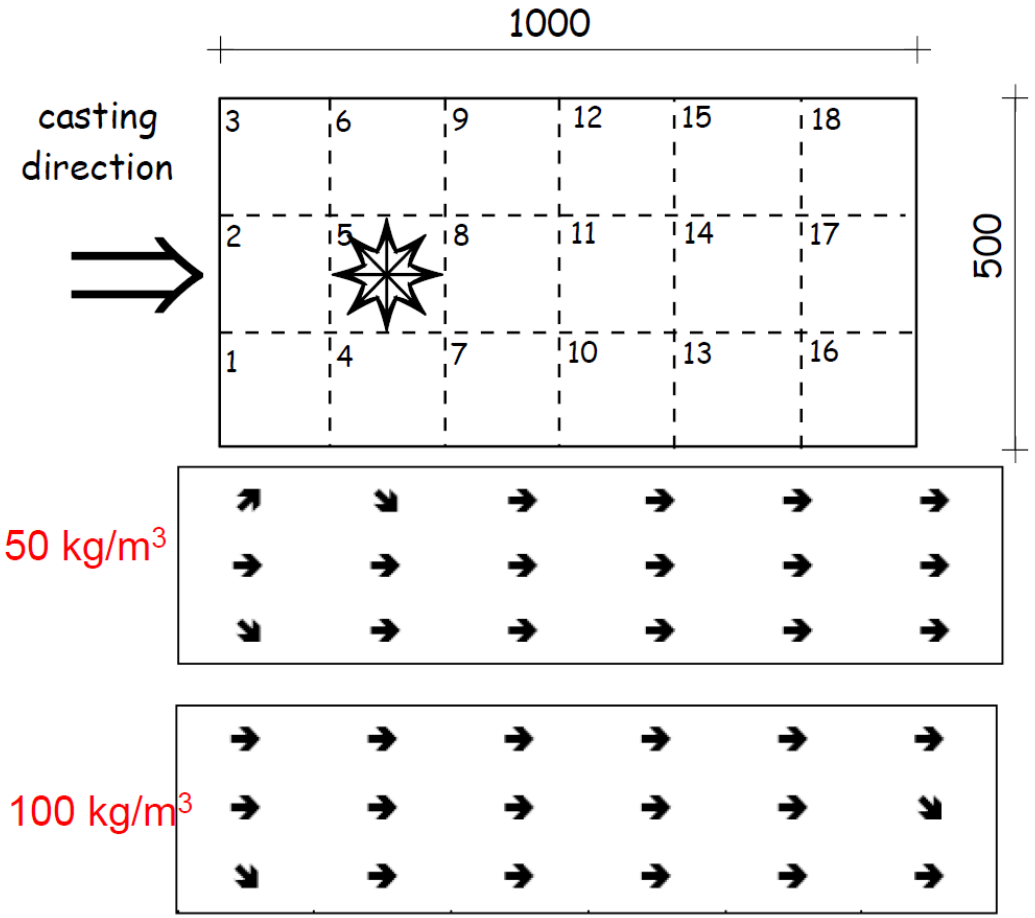
Matrix contribution L_{V0}

Fiber contribution ΔL_{fibers}

Assess local concentration and orientation of fibers

Ferrara et al., Materials and Structures, 2012

Monitoring the «in structure» fibre dispersion: a magnetic inductance based method



Per each cell:

Measures along 4 directions

3 measures along each direction

Hypothesis confirmed:

Tailored rheology =

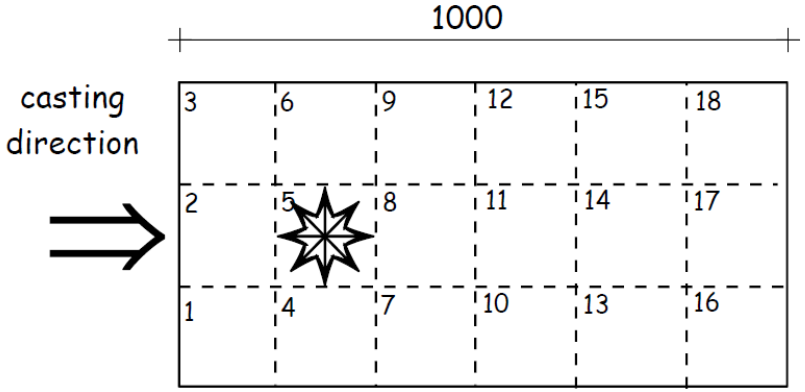
flow induced fiber orientation

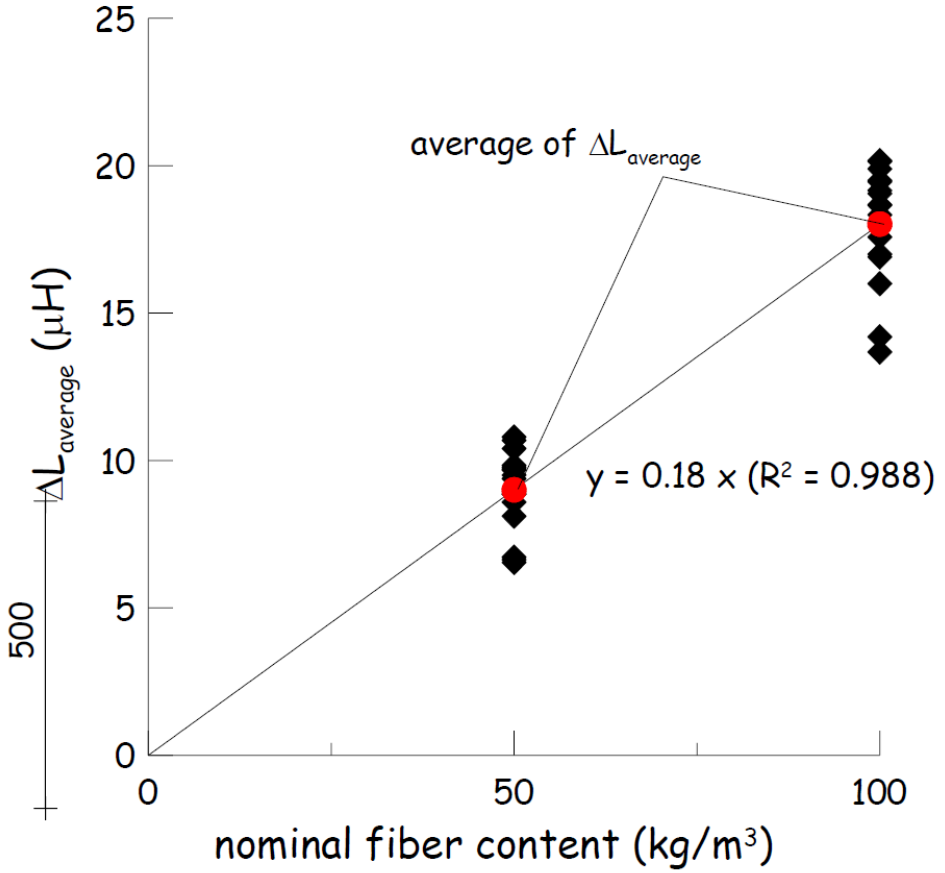
Ferrara et al., Materials and Structures, 2012

Monitoring the «in structure» fibre dispersion: a magnetic inductance based method

Calibration

Quantitative assessment of local unhomogeneities in fiber dispersion



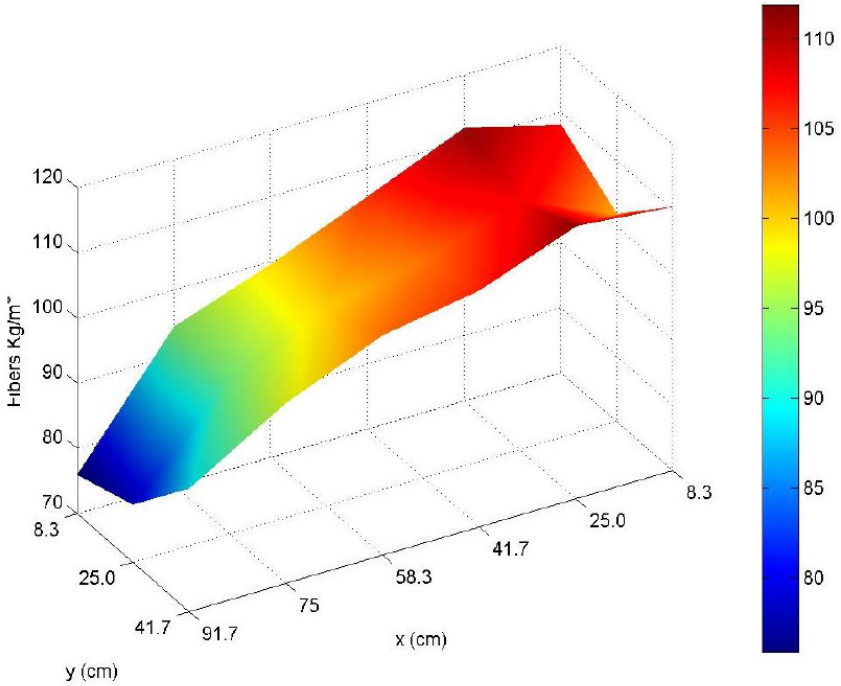


Ferrara et al., Materials and Structures, 2012

Monitoring the «in structure» fibre dispersion: a magnetic inductance based method

Calibration

Quantitative assessment of local unhomogeneities in fiber dispersion: check with destructive assessment

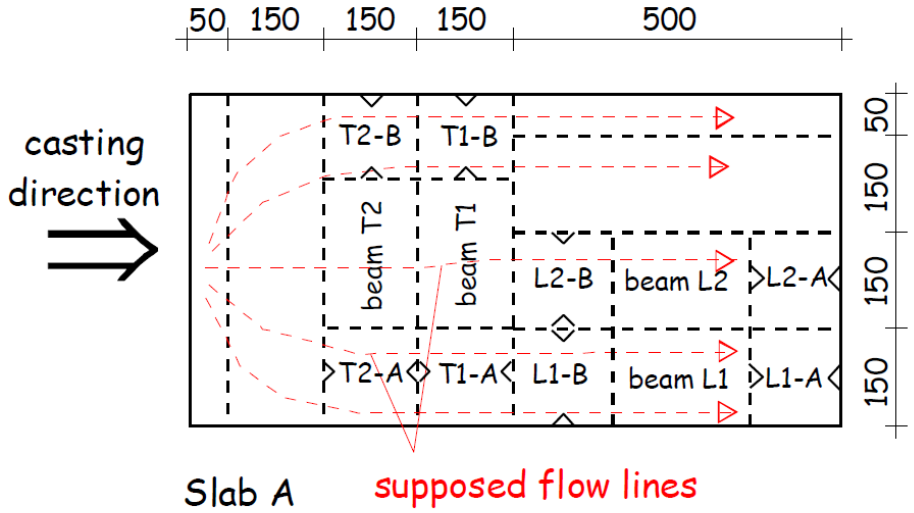


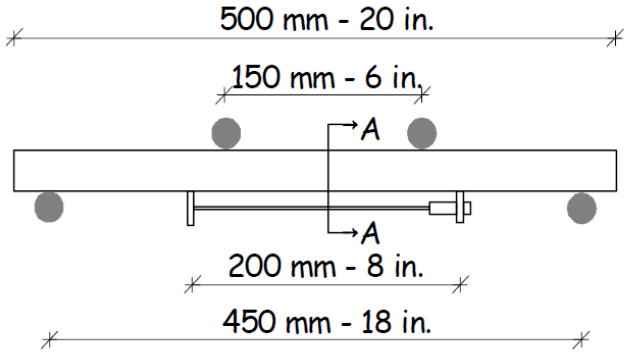
100 kg/m^3

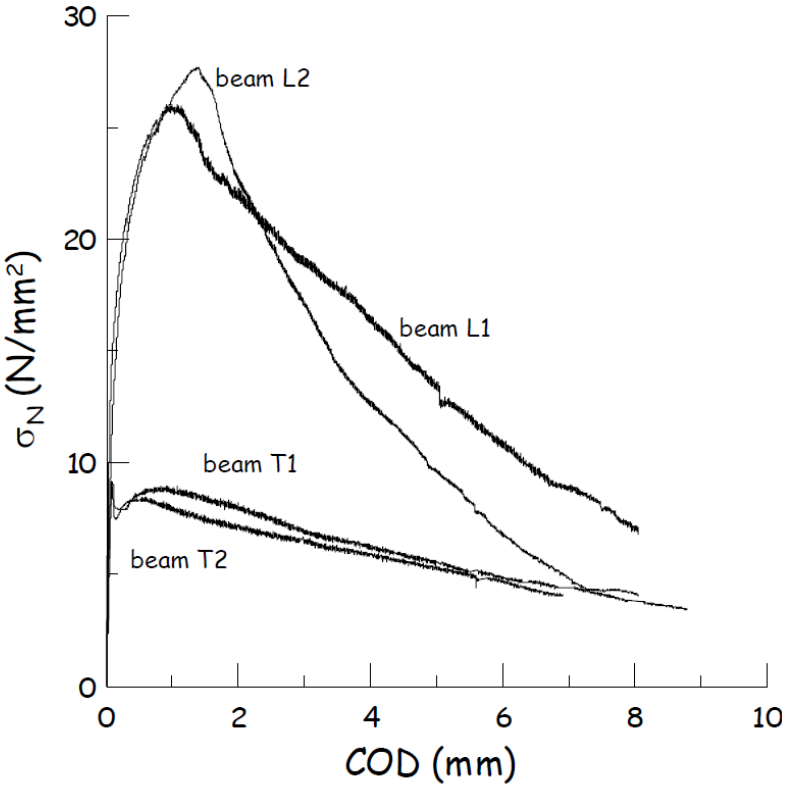
3 ND = 110.5	6 ND = 110.5	9 ND = 106.6 D = 109.9	12 ND = 103.6 D = 106.7	15 ND = 97.5	18 ND = 88.7
2 ND = 101.8 D = 119.1	5 ND = 108.7 D = 109.5	8 ND = 103.5 D = 107.8	11 ND = 100 D = 101.9	14 ND = 93.7 D = 98.2	17 ND = 79.4 D = 85
1 ND = 100.8	4 ND = 111.7	7 ND = 105.7 D = 105.6	10 ND = 99.5 D = 99.4	13 ND = 94.2	16 ND = 75.9

Ferrara et al., Materials and Structures, 2012

Monitoring the «in structure» fibre dispersion: mechanical verification

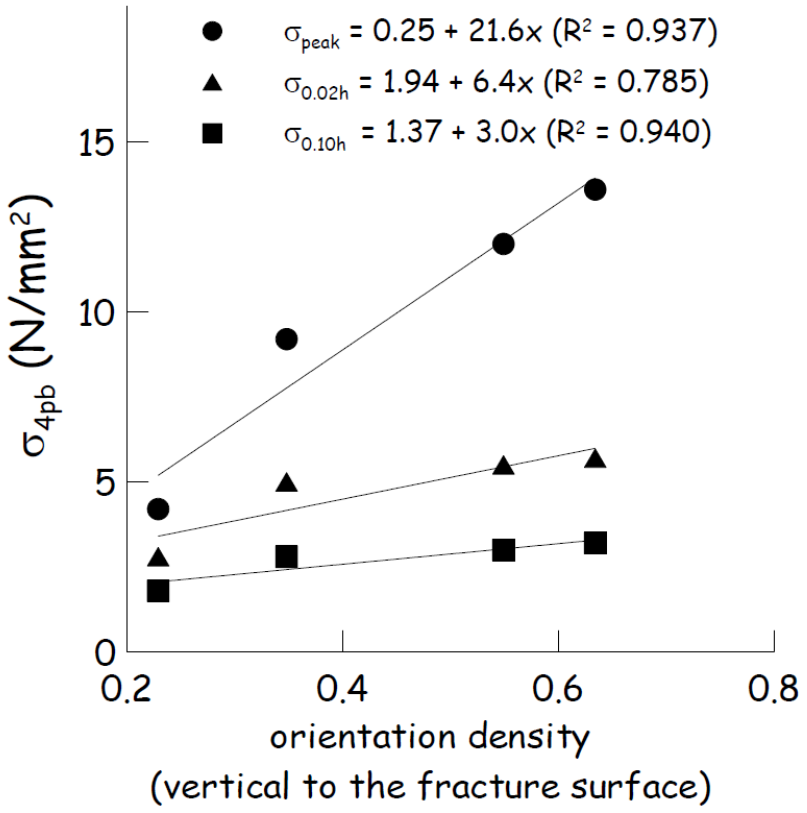


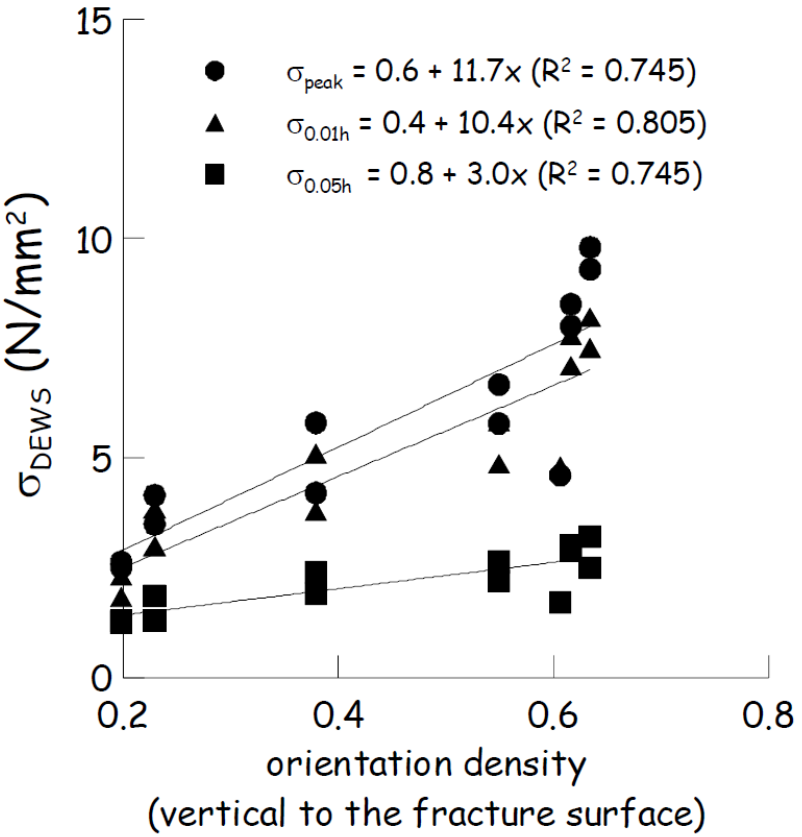




Ferrara et al., Materials and Structures, 2011

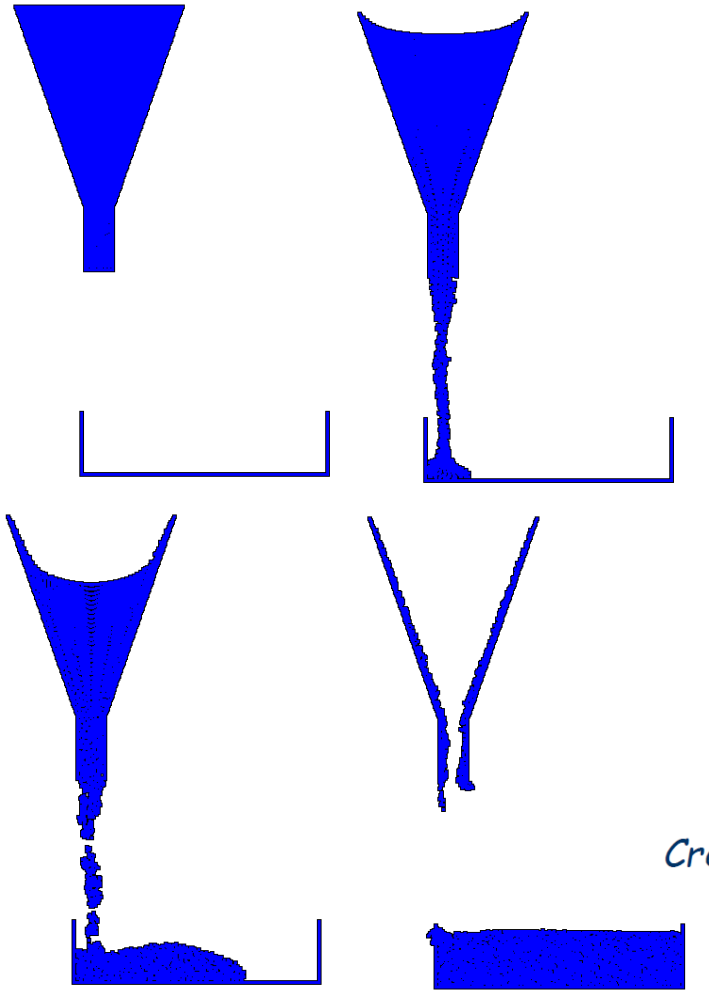
Monitoring the «in structure» fibre dispersion: mechanical verification

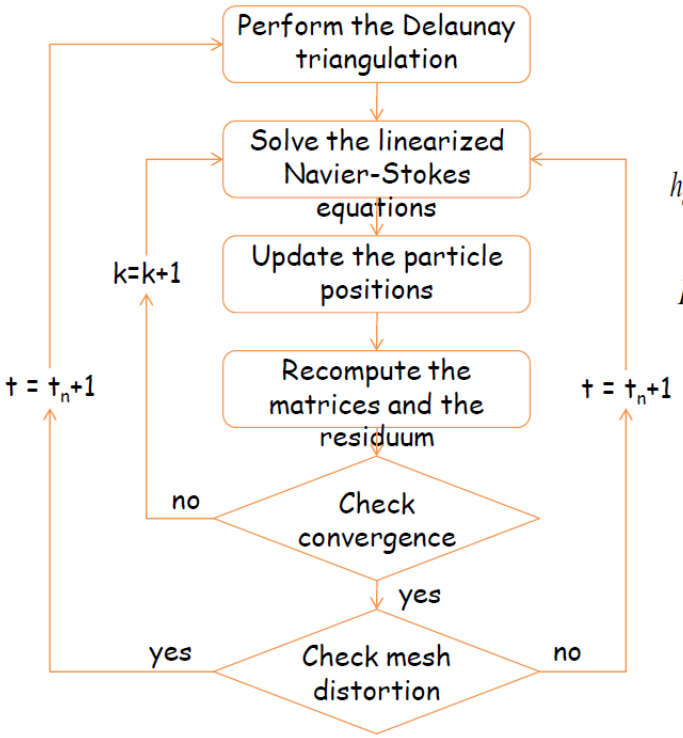




di Prisco et al., Materials and Structures, 2013

Predicting the «in structure» fiber dispersion: a particle finite element approach





Index of mesh distortion

for every element:

$$q_e = \sqrt{3}\alpha_e = \sqrt{3}\frac{R_e}{h_e} \gg 1$$

h_e the minimal distance between two nodes in the element

R_e the radius of the circumcircle

The quality of the entire mesh is then evaluated by an arithmetic mean:

$$Q = \frac{1}{N_{el}} \sum_{e=1}^{N_{el}} q_e$$

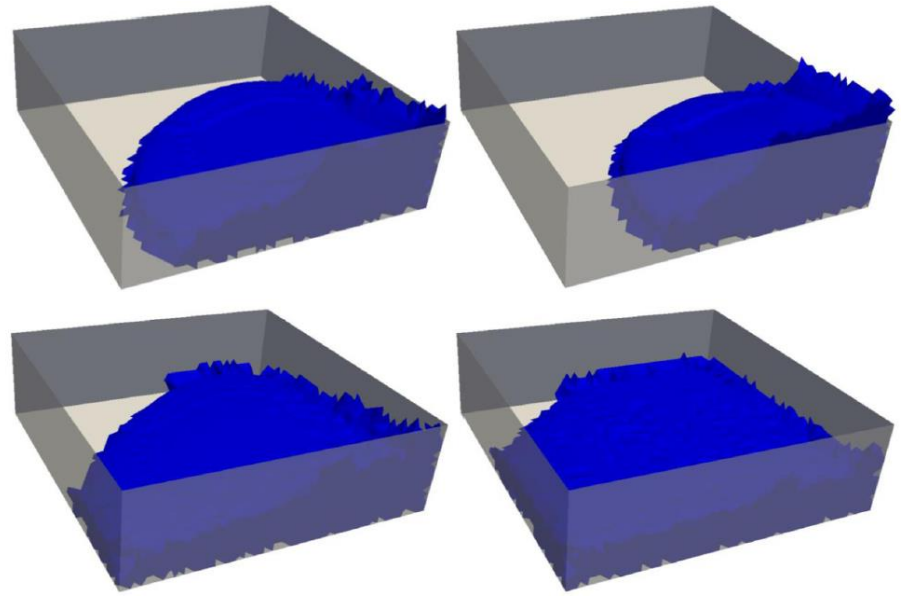
The mesh is regenerated only if:

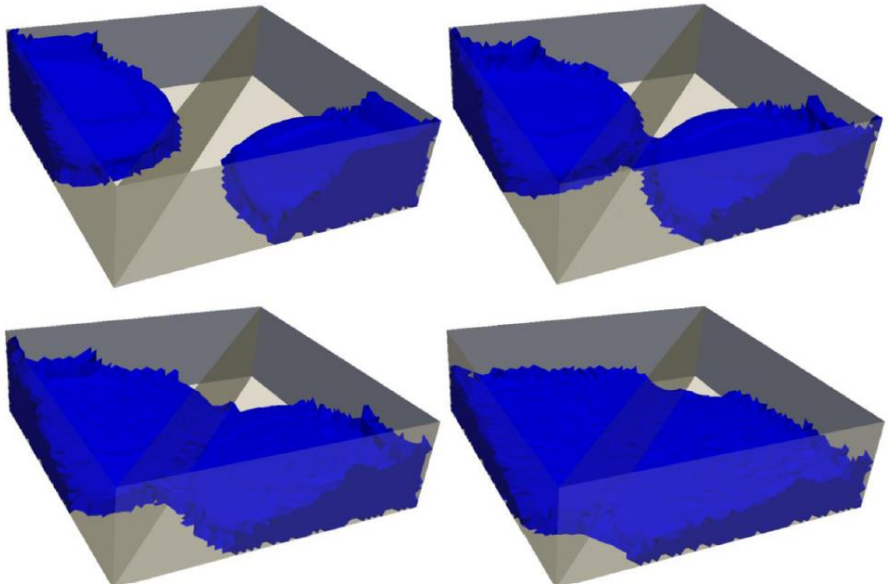
$$Q > \beta$$

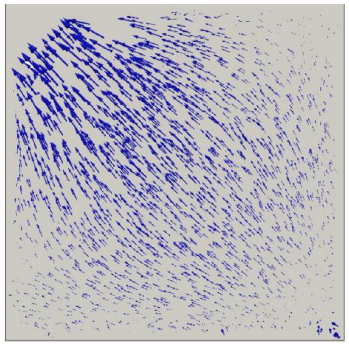
Cremonesi et al. Journal for Numerical Methods in Engineering, 2010

Ferrara et al., Cement and Concrete Research,2012

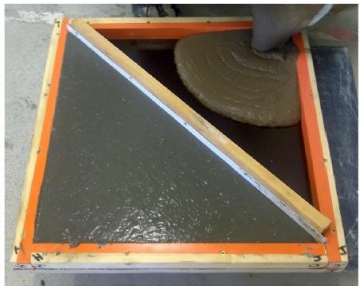
Predicting the «in structure» fiber dispersion: a particle finite element approach

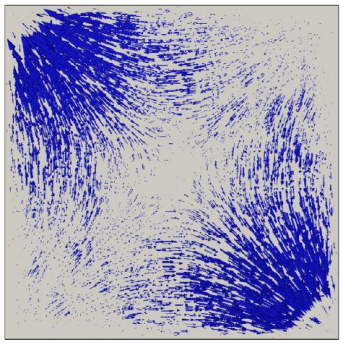




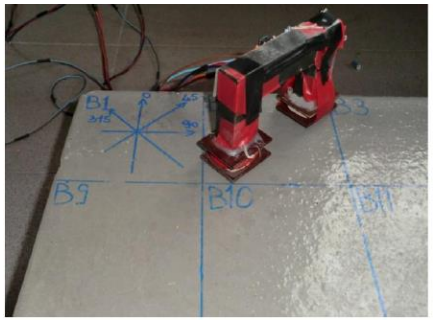


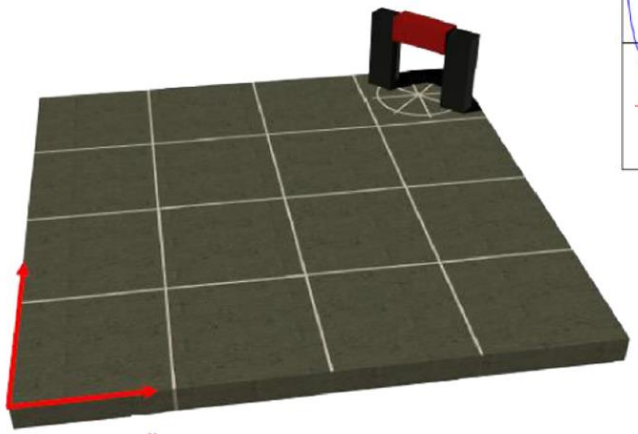
Sorelli et al., CBM, 2016
Ferrara et al., Engineering Structures 2017

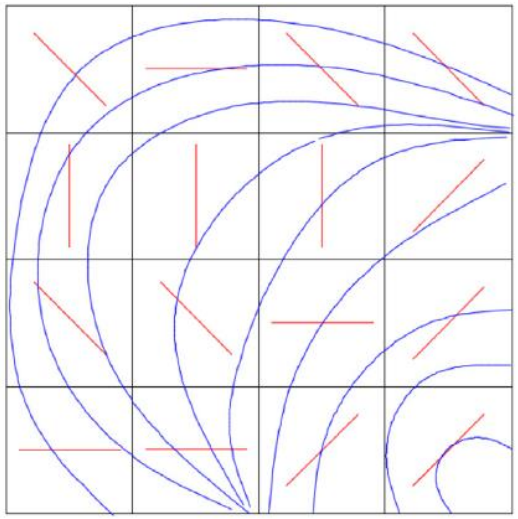




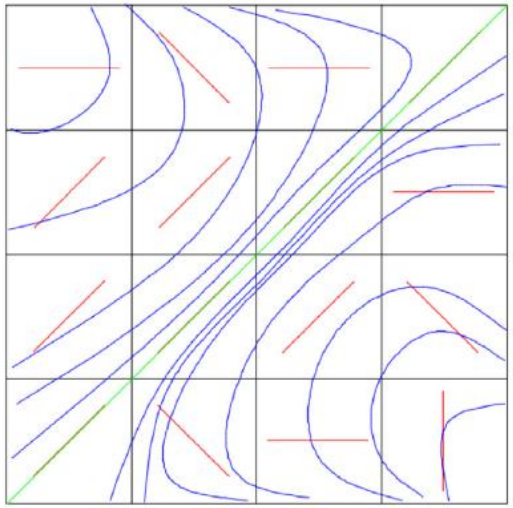
Predicting the «in structure» fiber dispersion
A particle finite element approach: verification







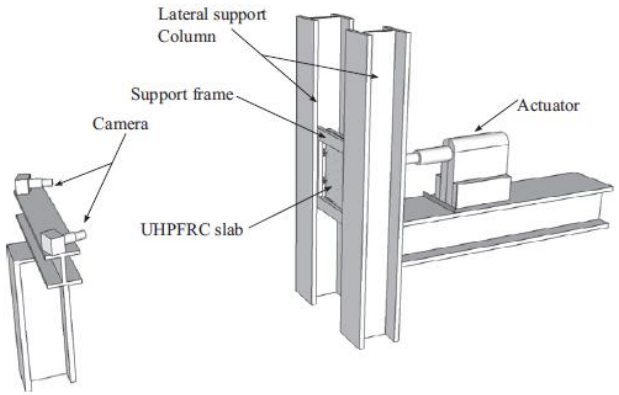
Reference slab (1)

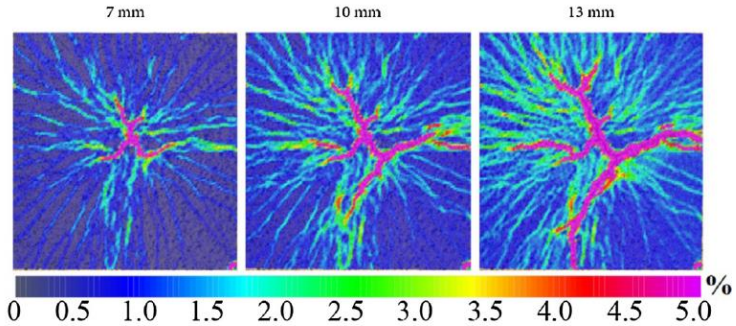


Diagonal defective cast slab (4)

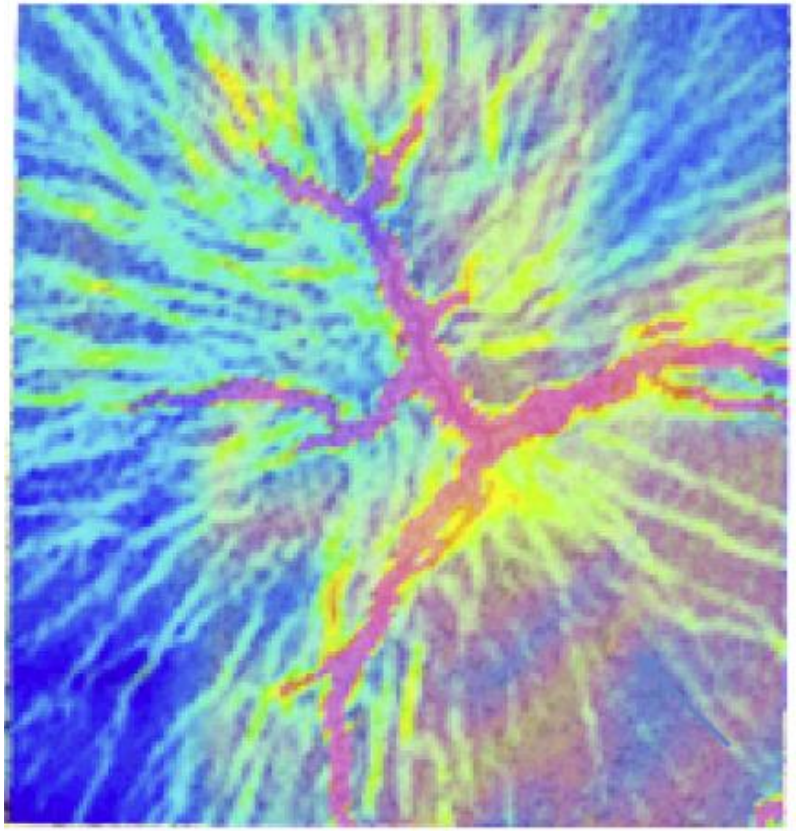
Sorelli et al., CBM, 2016
Ferrara et al., Engineering Structures 2017

Monitoring and predicting the «in structure» fiber dispersion: a structural check



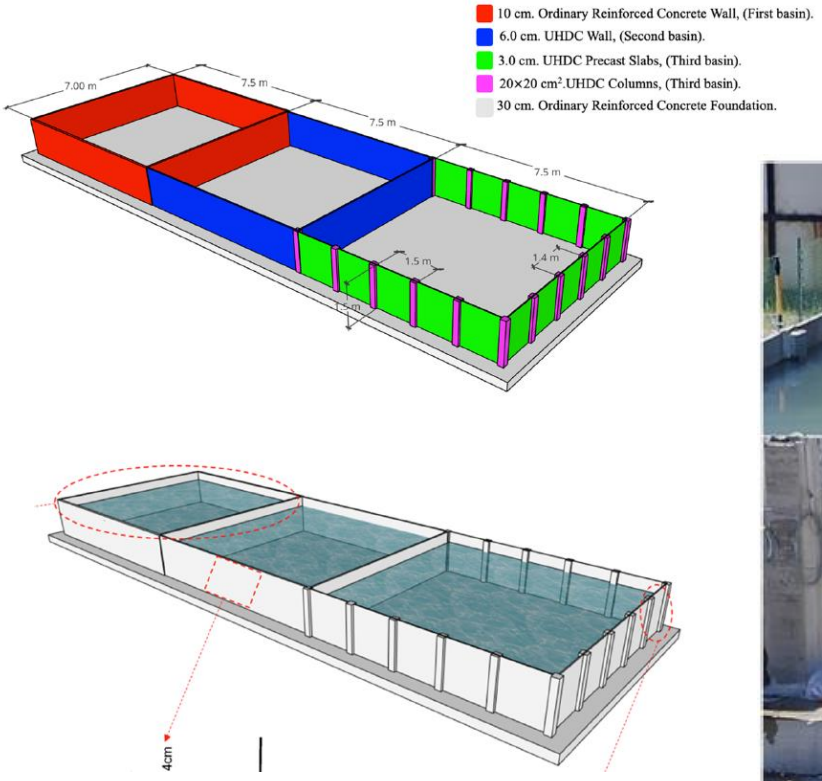


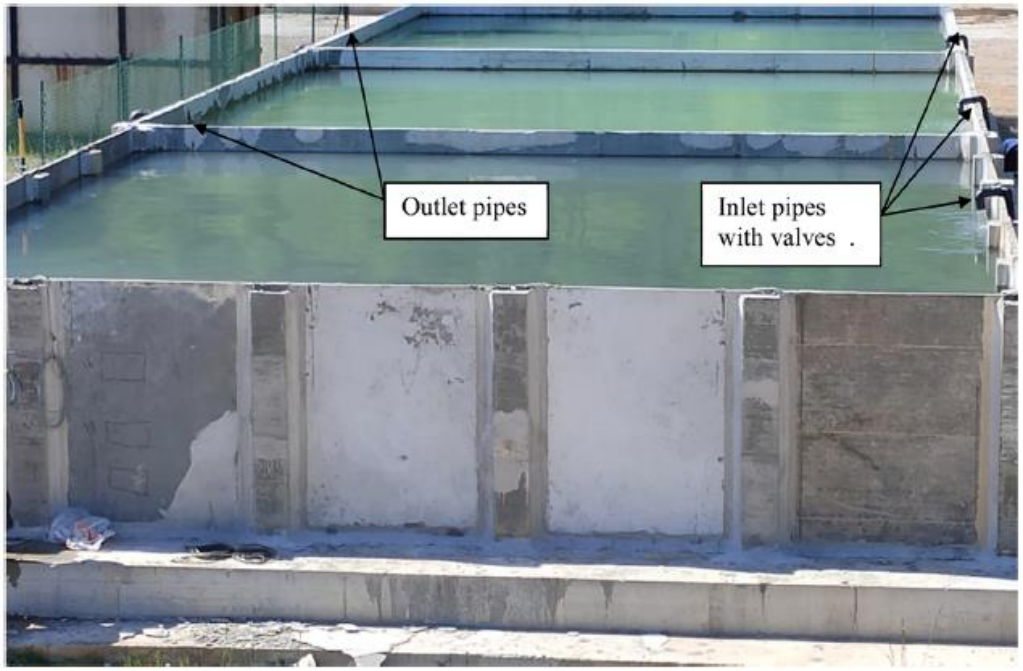
(a) - Reference slab (1) - homogeneous cast from one corner.



Sorelli et al., CBM, 2016
Ferrara et al., Engineering Structures 2017

Monitoring the «in structure» fiber dispersion: a real case study application





Al Obaidi et al., Case Studies in Construction Materials, 2023

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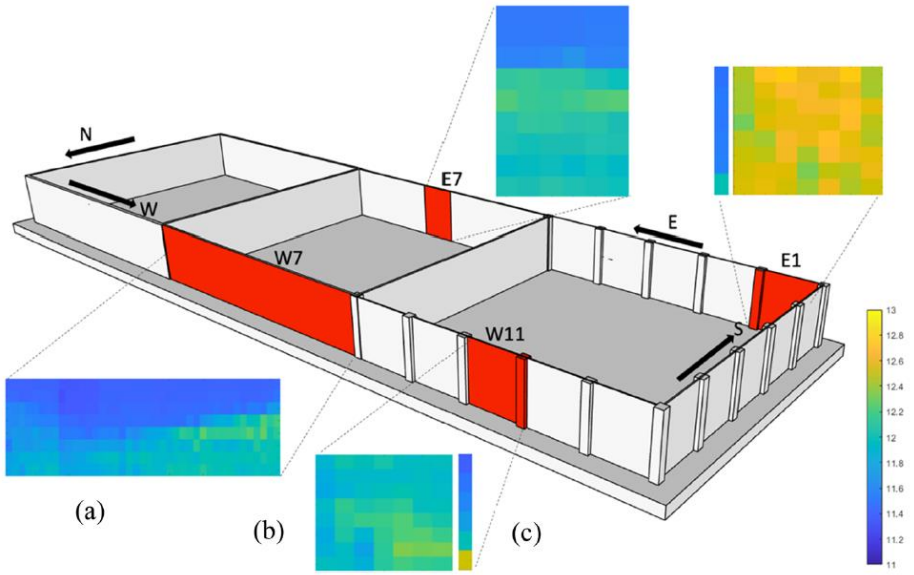

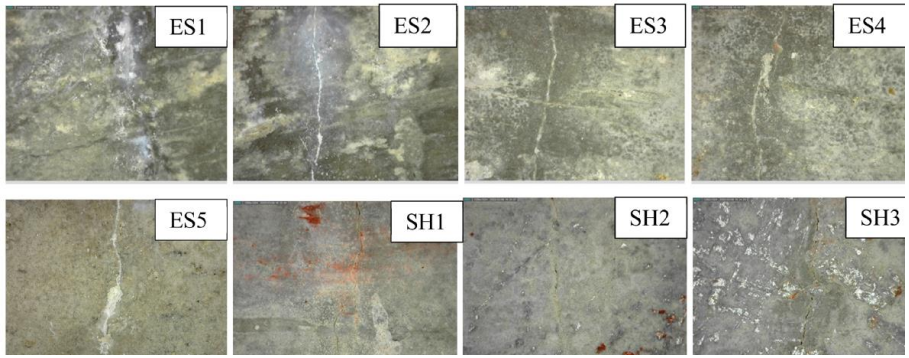

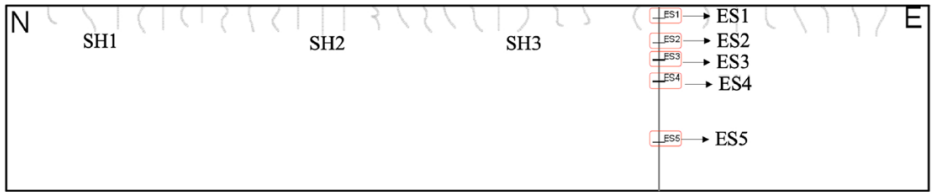

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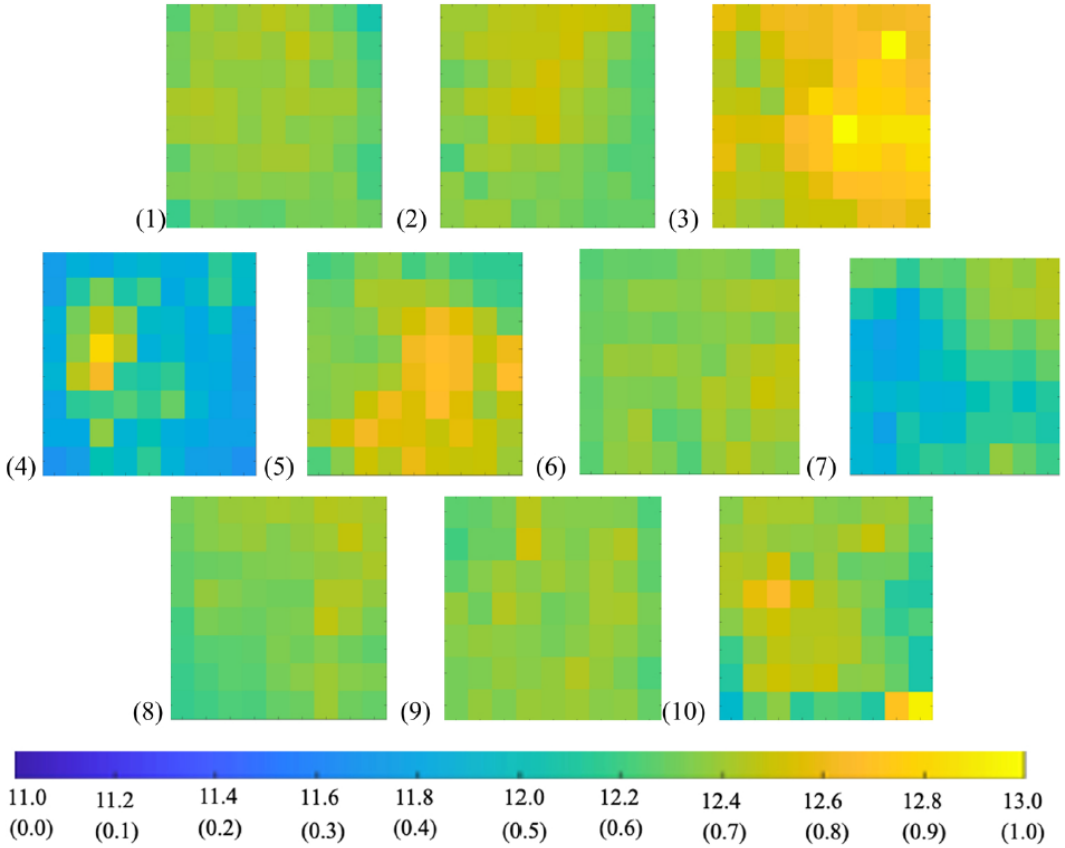

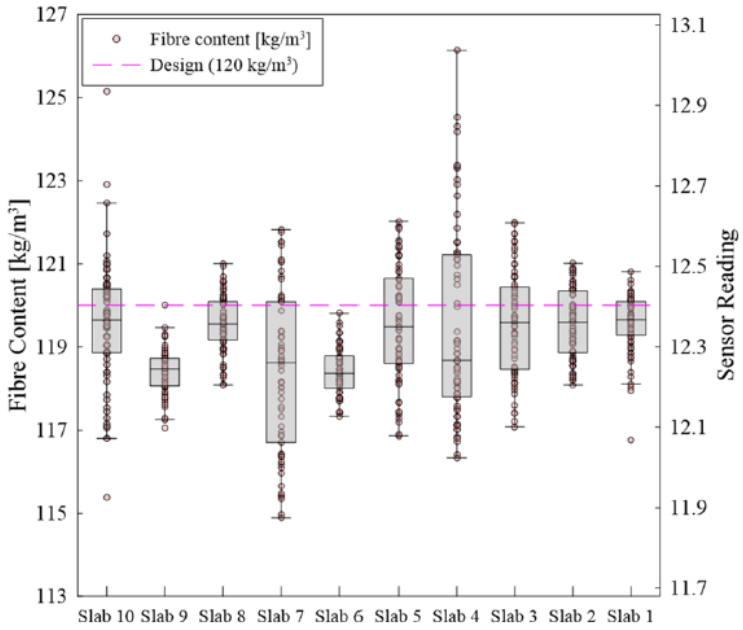

Al Obaidi et al., Case Studies in Construction Materials, 2023

Concluding remarks

Non destructive method based on magnetic inductance for fibre dispersion and orientation monitoring

Validation at the lab scale

Correlation with predictions from CFD tool and with mechanical material and structural performance

On site application to a real case study

Thank you for your attention

This project has been funded by the European Union – NextGenerationEU, under the National Recovery and Resilience Plan (NRRP) Mission 4 Component 2 Investment Line 1.5: Strenghtening of research structures and creation of R&D "innovation ecosystems", set up of "territorial leaders in R&D"

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement Nº 760824