Structural Behaviour of UHP(FR)C Compression Struts Subjected to Transverse Tension and Cracking

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Overview

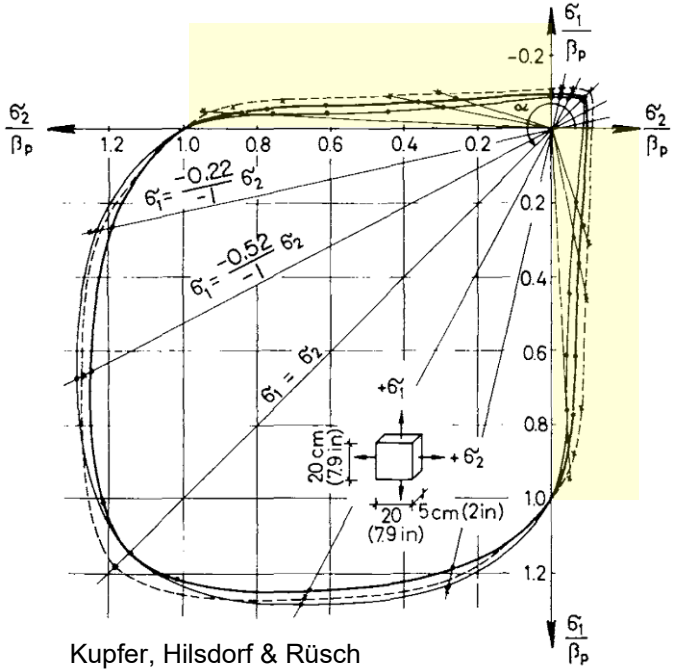
- Introduction:
  Why Performing Biaxial Tests?
  The History of Panel Tests at University of Kassel

- Biaxial Tests on UHP(FR)C Panels:
  Experimental Investigations at University of Kassel (2005-2006)
  Recent Evaluation of Test Data (2019)

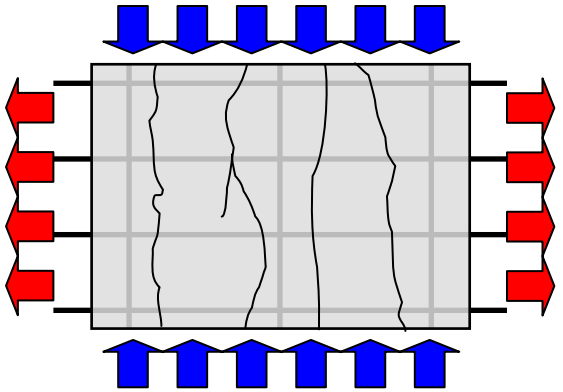
- Summary and Conclusions

Why Performing Biaxial Tests?

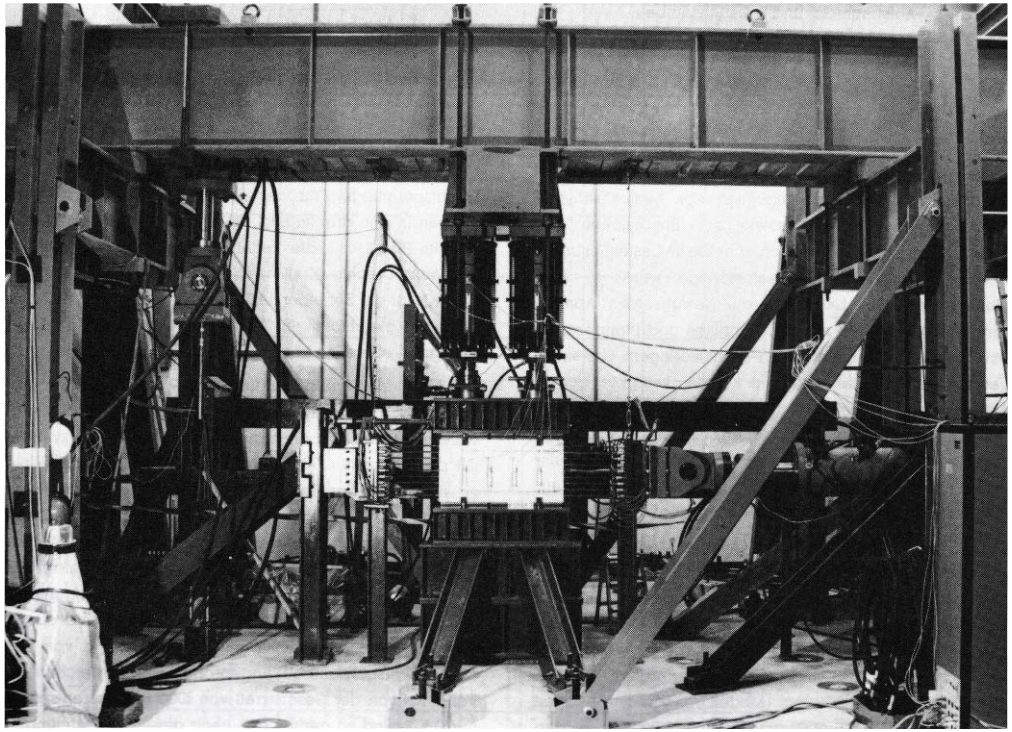
- Biaxial tension-compression stress reduces both compressive and tensile strength of concrete.
- RC: tensile failure of concrete is not relevant, …
- … however: multiple cracking "separates" individual compression struts.
- Compressive strength of biaxial loaded structural member is affected by …
  … the presence of reinforcement,
  … the tensile strain state,
  … the shape of compression struts.



Kupfer, Hilsdorf & Rüsch



The History of Panel Tests at University of Kassel



1984-1987
Kollegger & Mehlhorn
47 RC-panels (NSC)

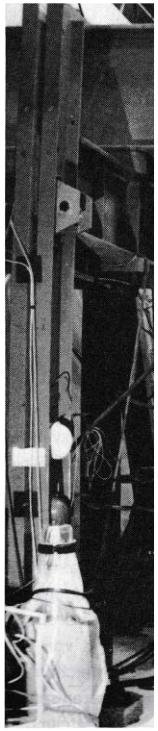
The History of Panel Tests at University of Kassel

2005-2006
Fehling, Leutbecher, Röder & Stürwald
46 UHP(FR)C-panels

2003-2004
Fehling, Leutbecher & Röder
39 (F)RC-panels (NSC)

2003
Fehling & Bullo
17 (F)RC-panels (NSC)

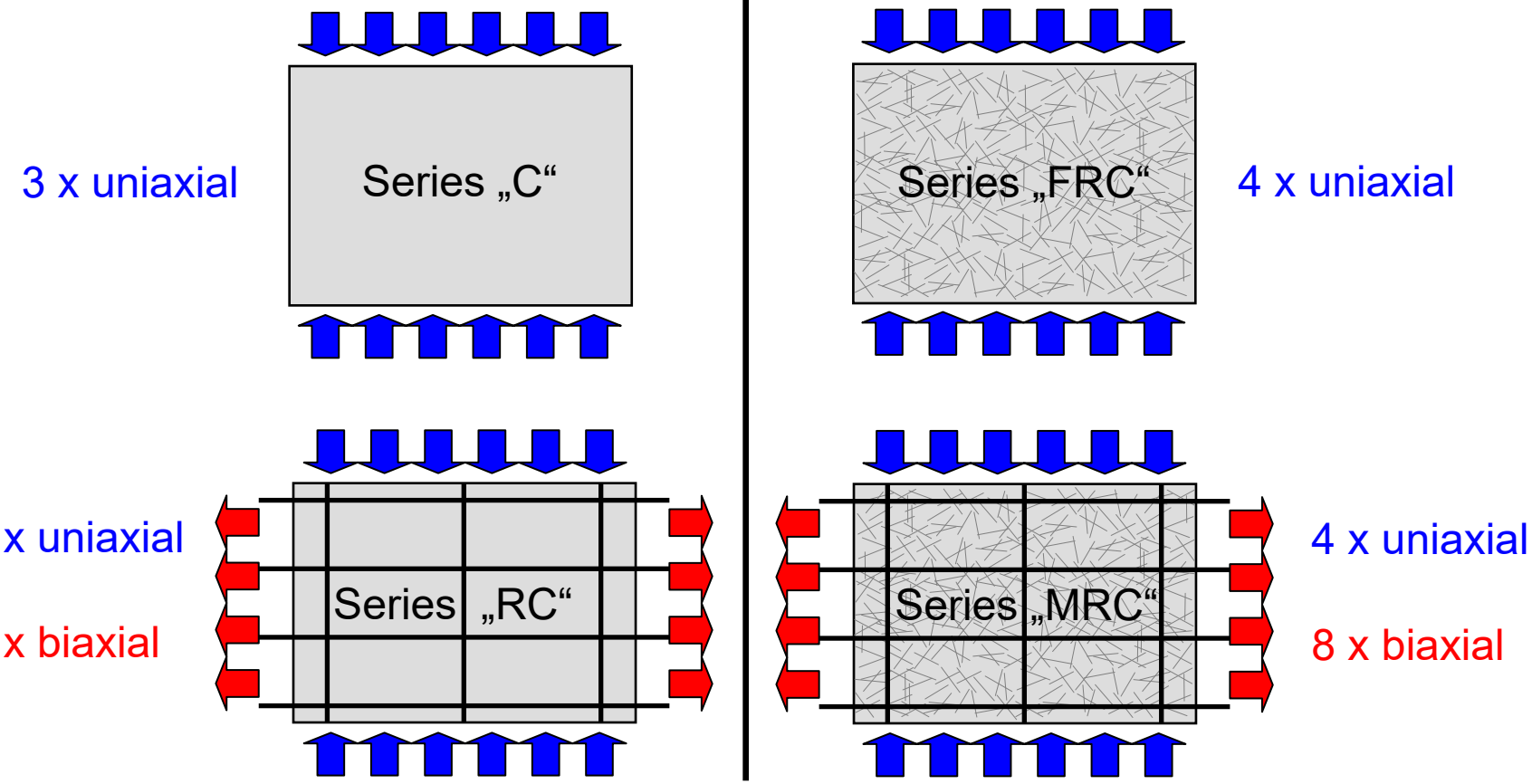
1984-1987
Kollegger & Mehlhorn
47 RC-panels (NSC)



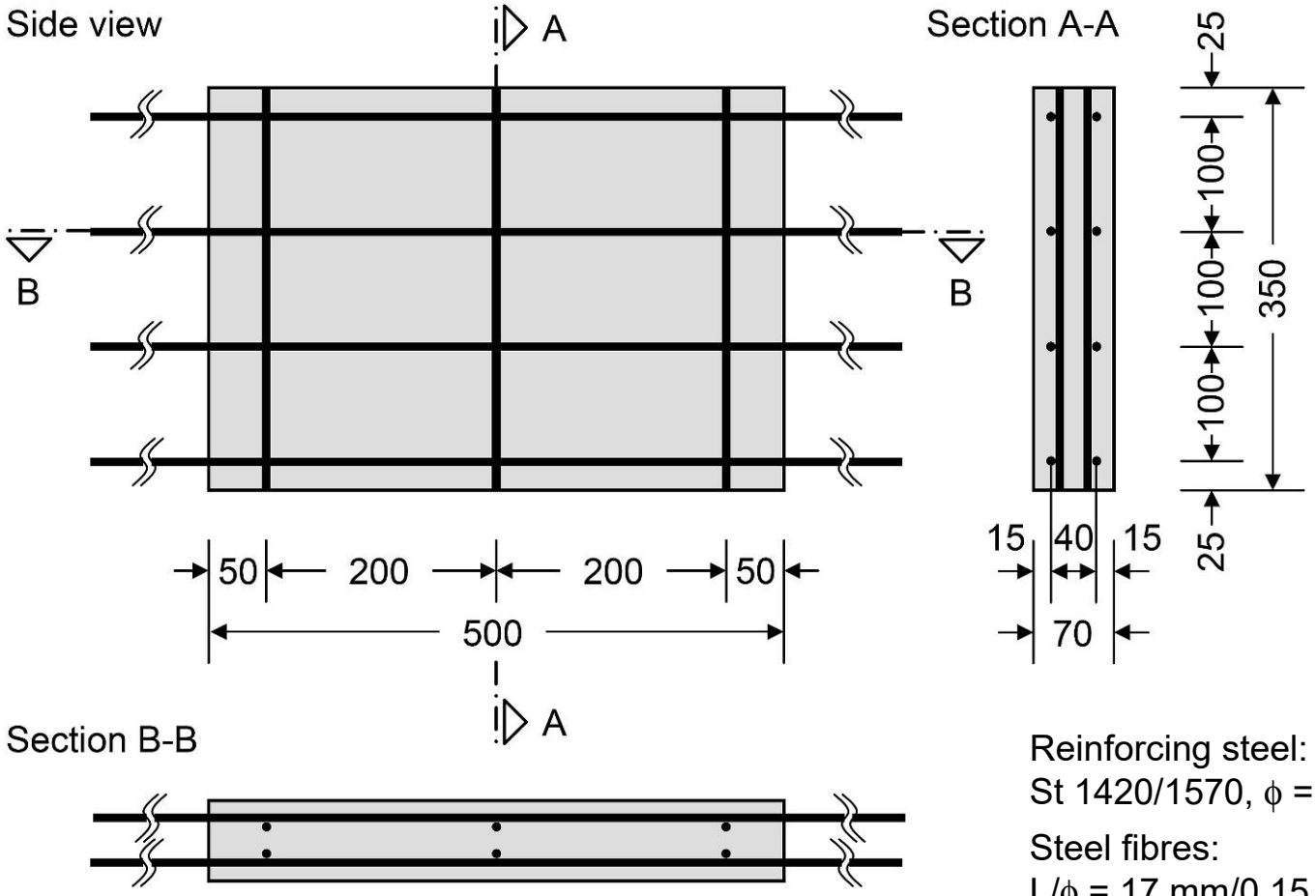
Biaxial Tests on UHP(FR)C-Panels (2005-2006): Test Programme

Fine-grained UHPC ($f_{cm,cyl} \approx 130$ MPa)

Fine-grained UHPFRC ($f_{cm,cyl} \approx 170$ MPa)



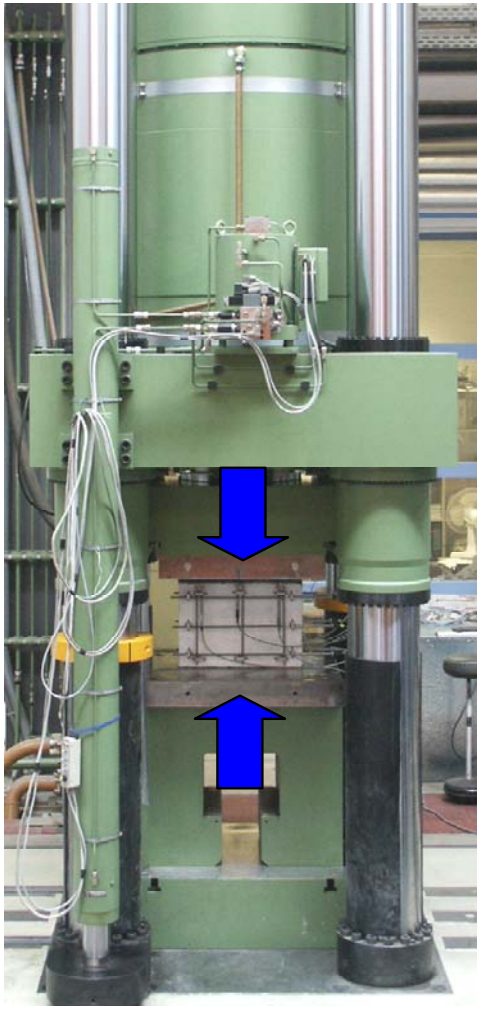
Reinforcement Configuration



Reinforcing steel:
St 1420/1570, ϕ = 8 mm

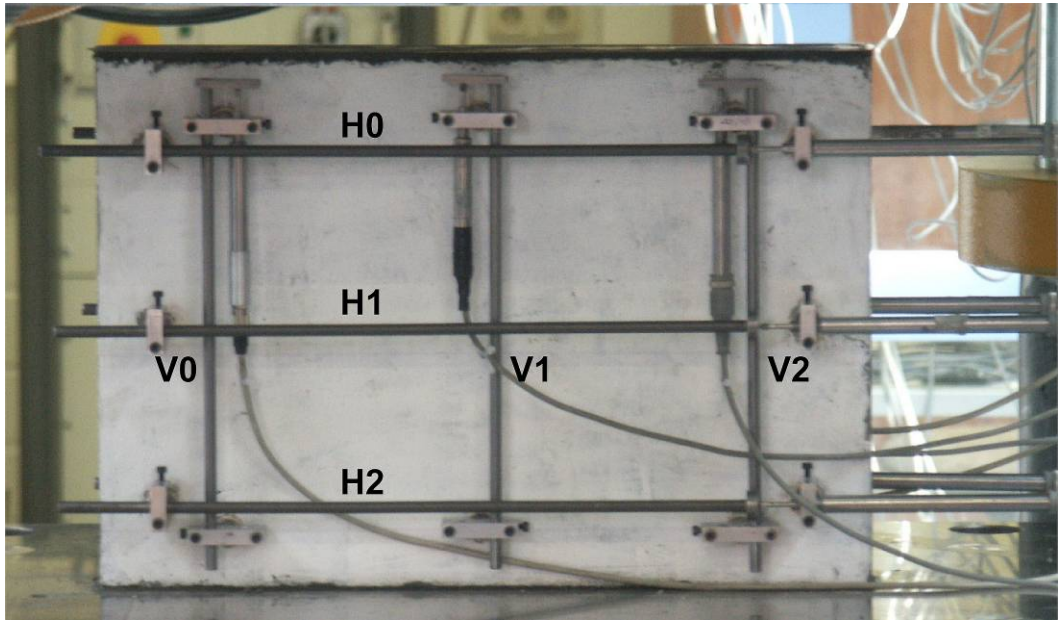
Steel fibres:
L/ϕ = 17 mm/0.15 mm, 1.0 % by vol.

Uniaxial Tests: Test Setup



6.3 MN servo-hydraulic testing machine

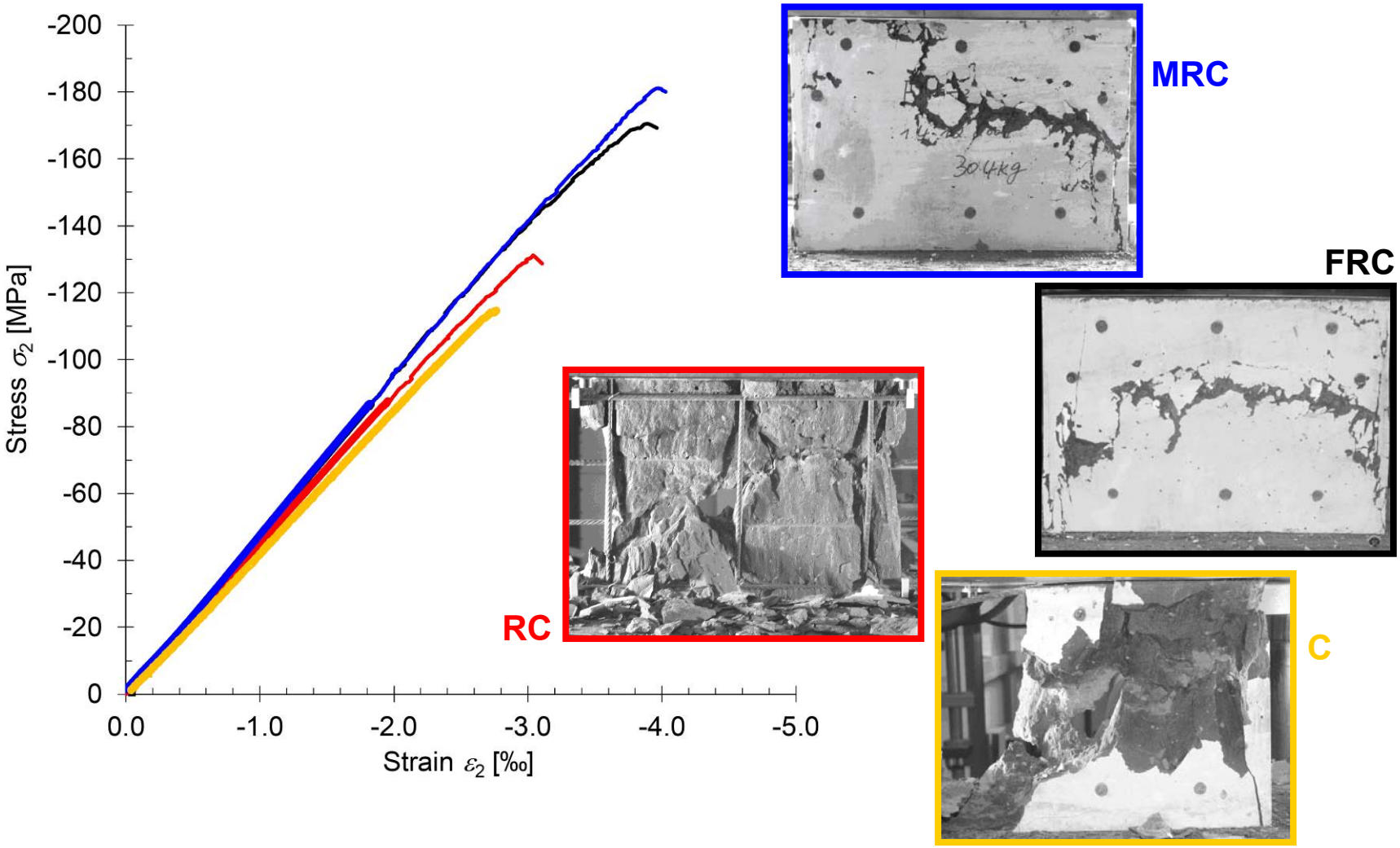
Instrumentation:



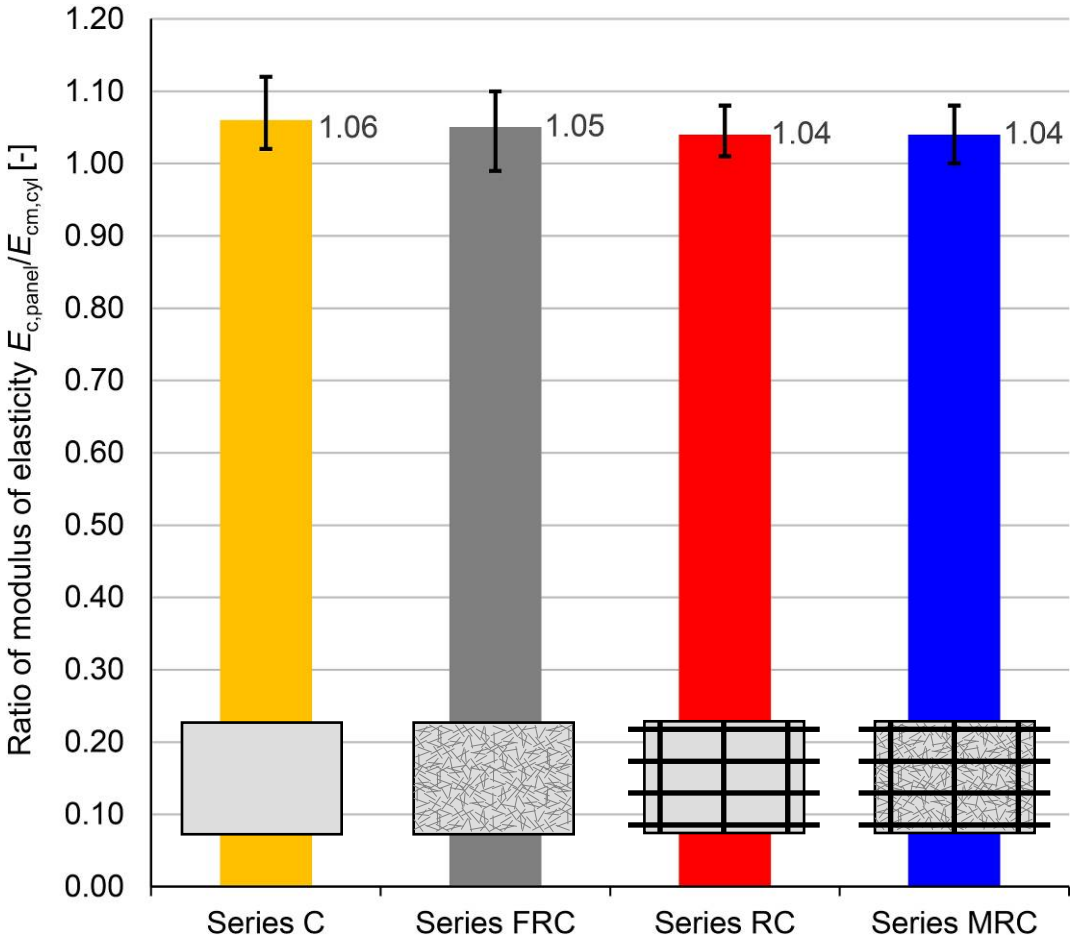
3 x LVDT in horizontal direction
3 x LVDT in vertical direction

at front and back

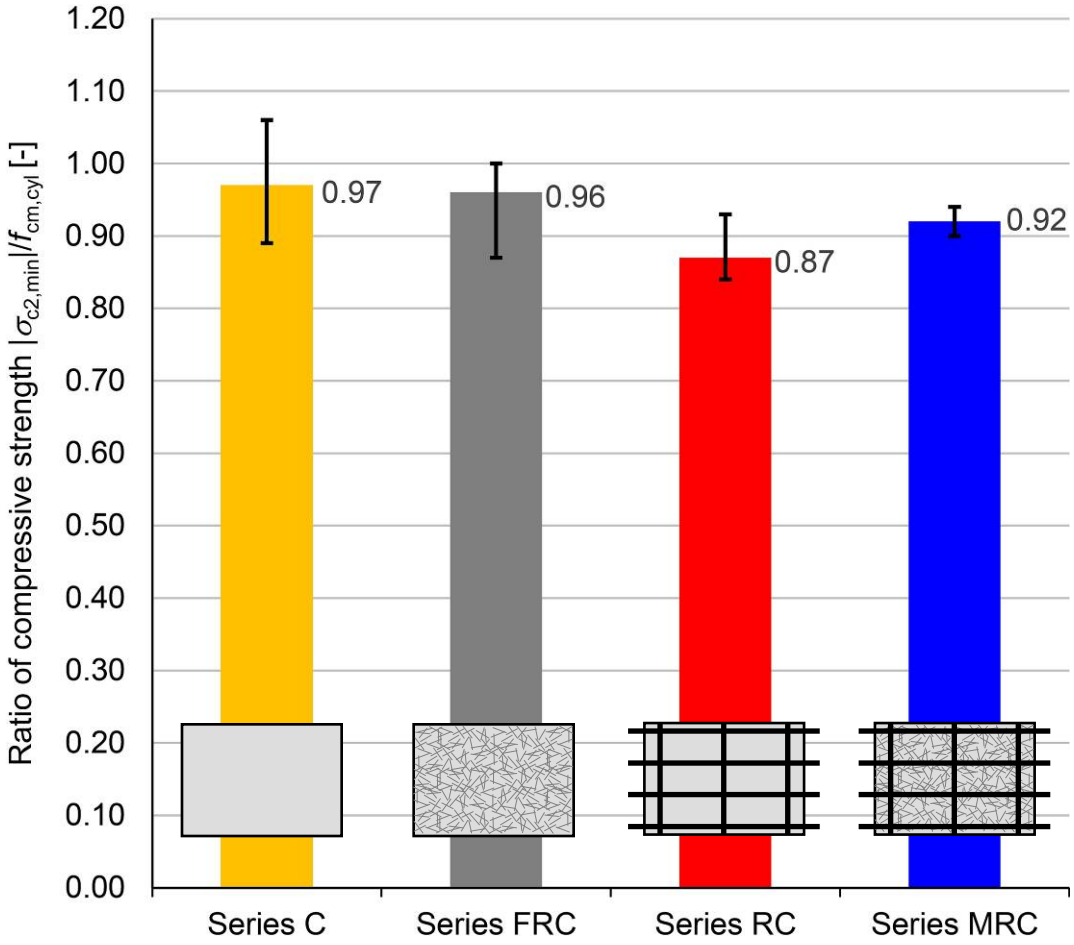
Uniaxial Tests: Stress-Strain-Curves and Failure Pattern



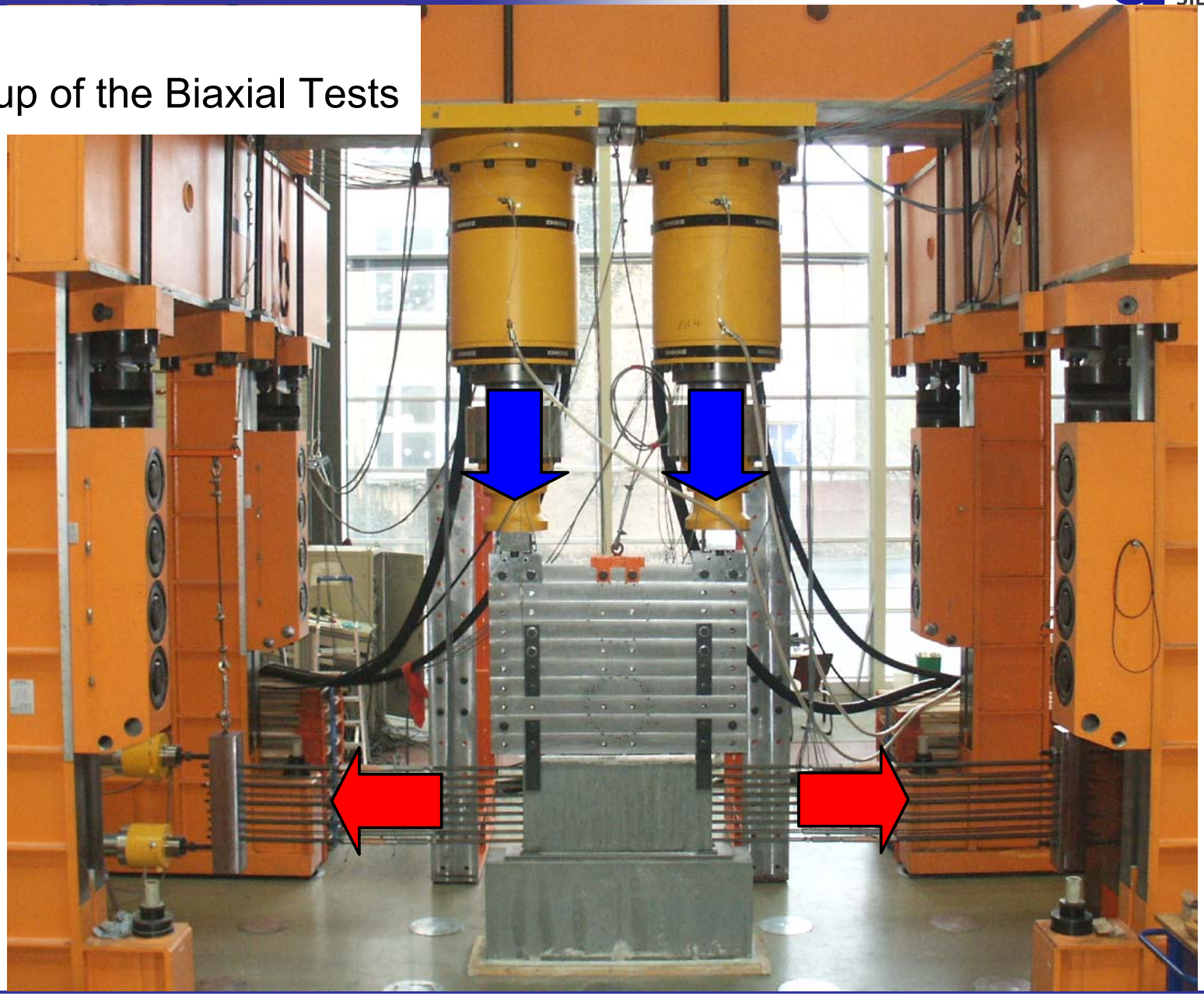
Uniaxial Tests: Ratio of Modulus of Elasticity



Uniaxial Tests: Ratio of Compressive Strength

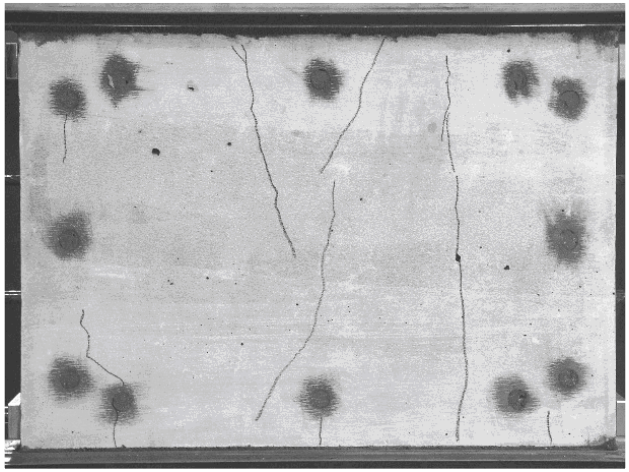


Setup of the Biaxial Tests

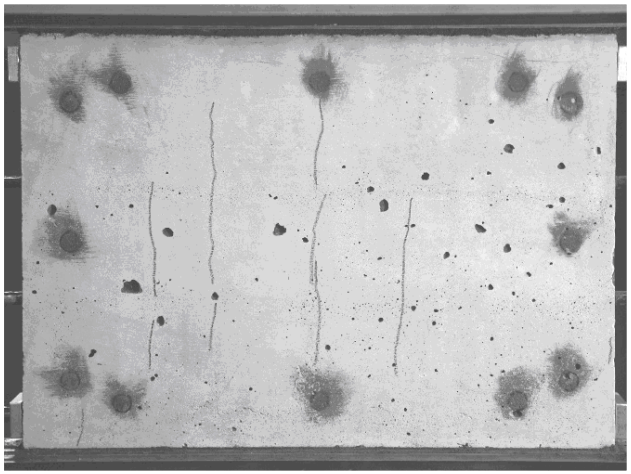


Biaxial Tests: Crack Pattern after Applying the Tensile Load

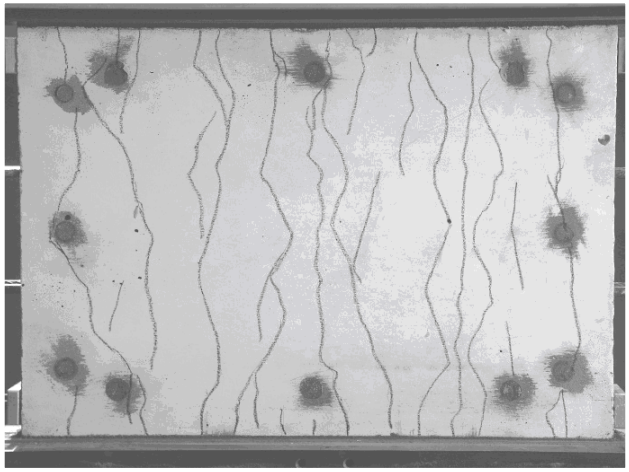
RC with $\varepsilon_{1,max}$ = 0.64 ‰



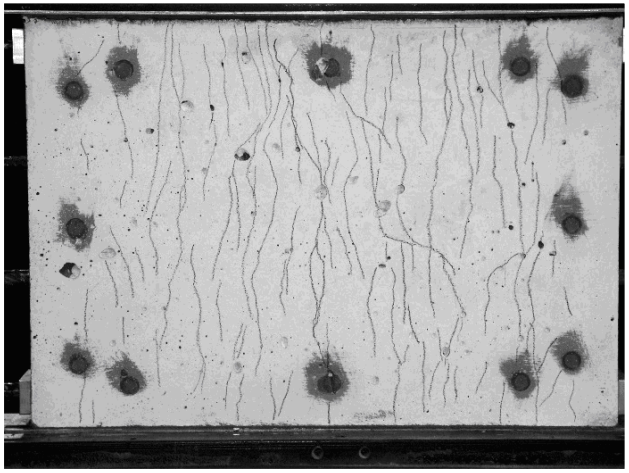
MRC with $\varepsilon_{1,max}$ = 0.70 ‰



RC with $\varepsilon_{1,max}$ = 4.57 ‰



MRC with $\varepsilon_{1,max}$ = 4.34 ‰



Biaxial Tests: Stress-Strain-Curves and Compression Failure

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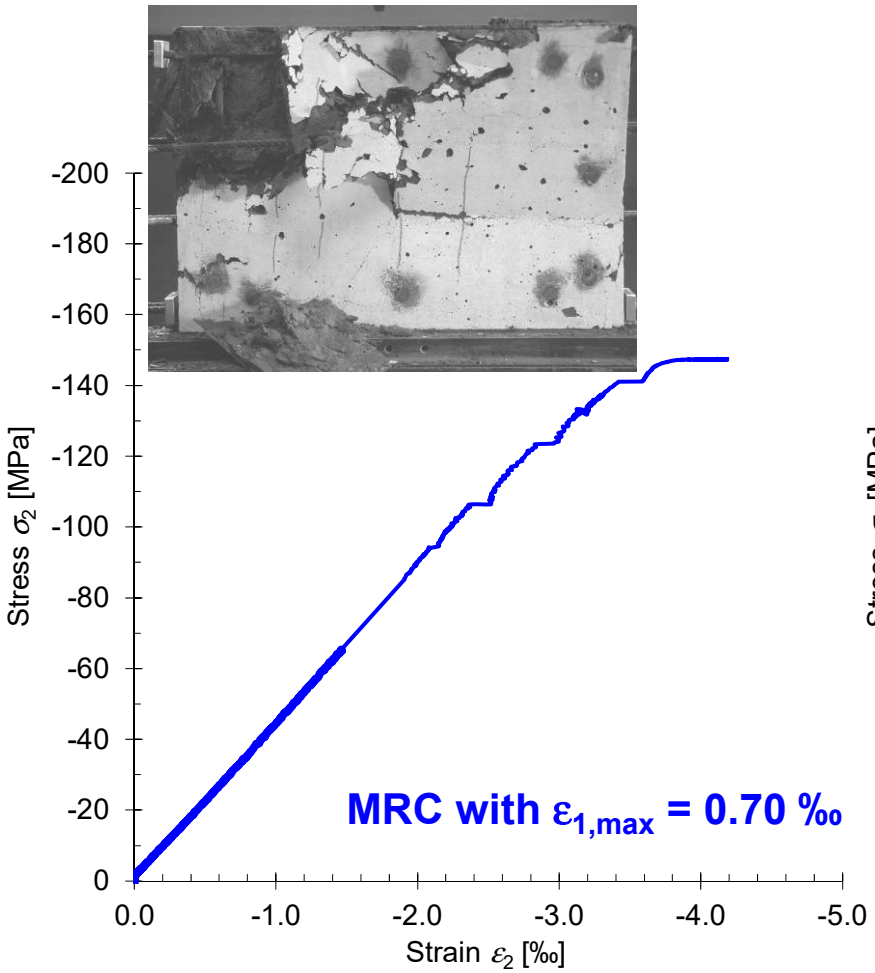
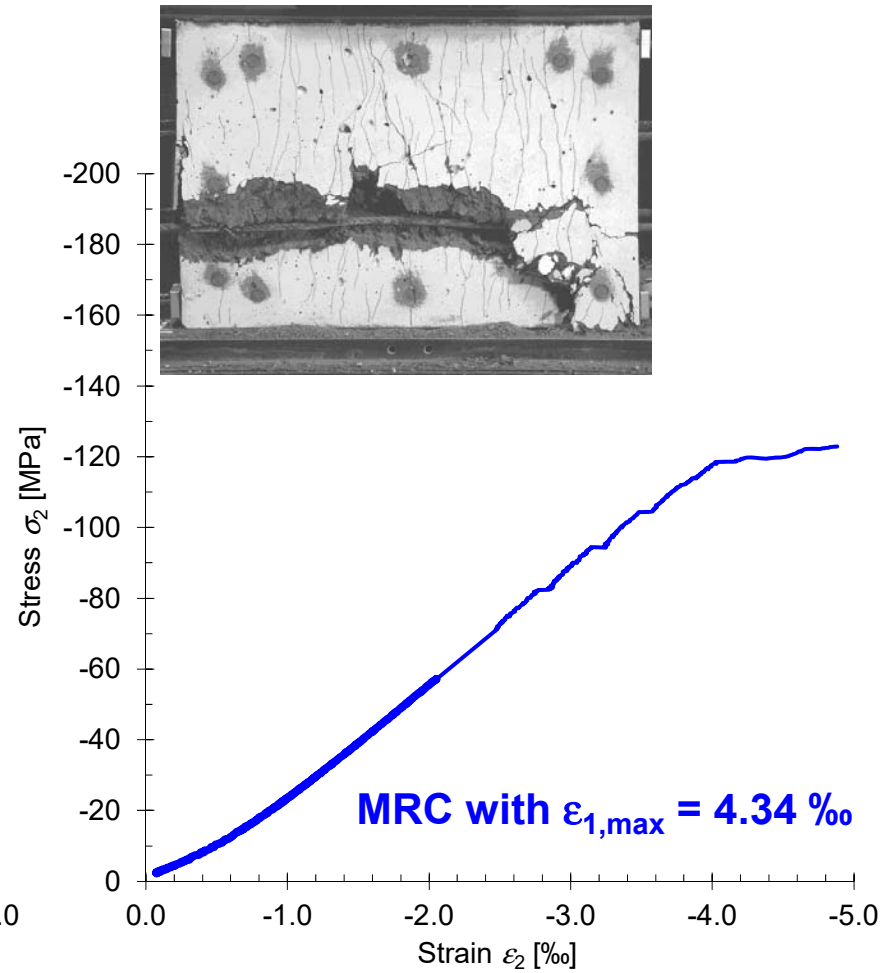
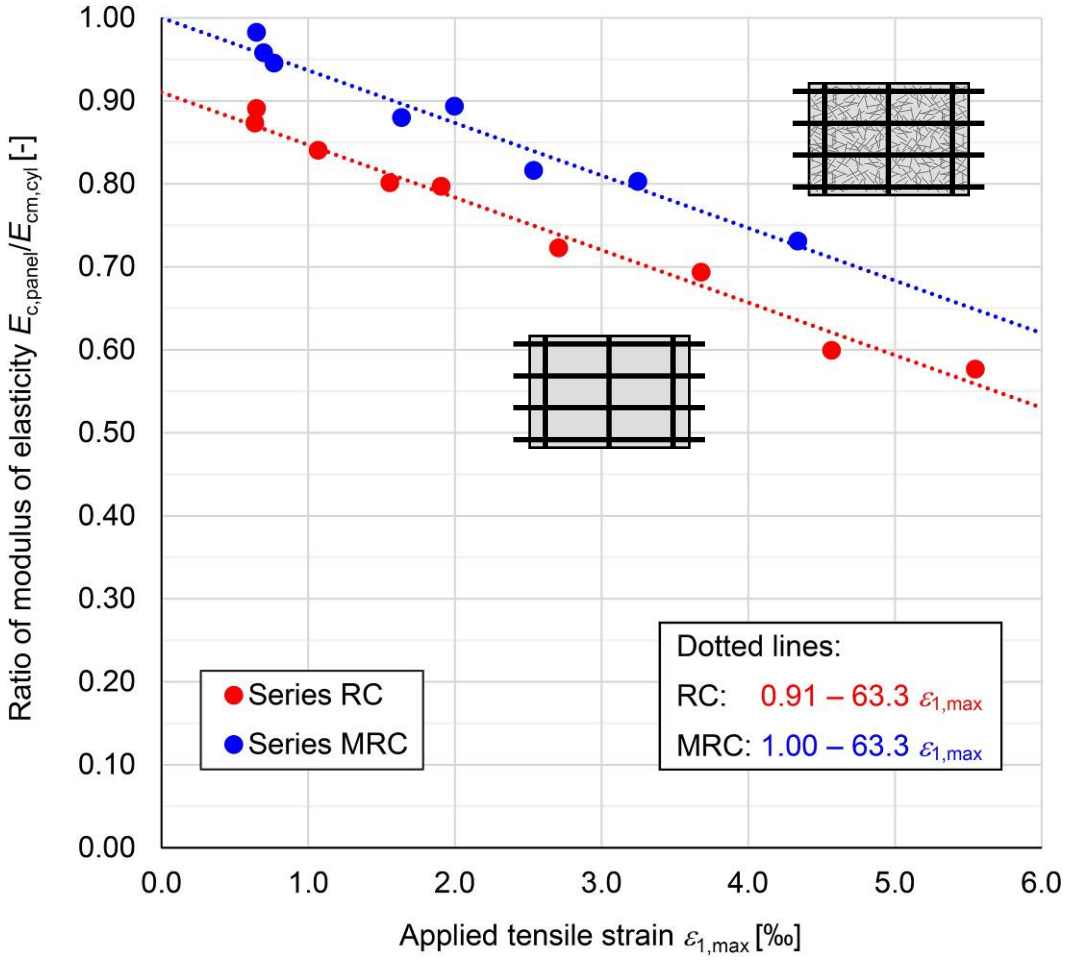
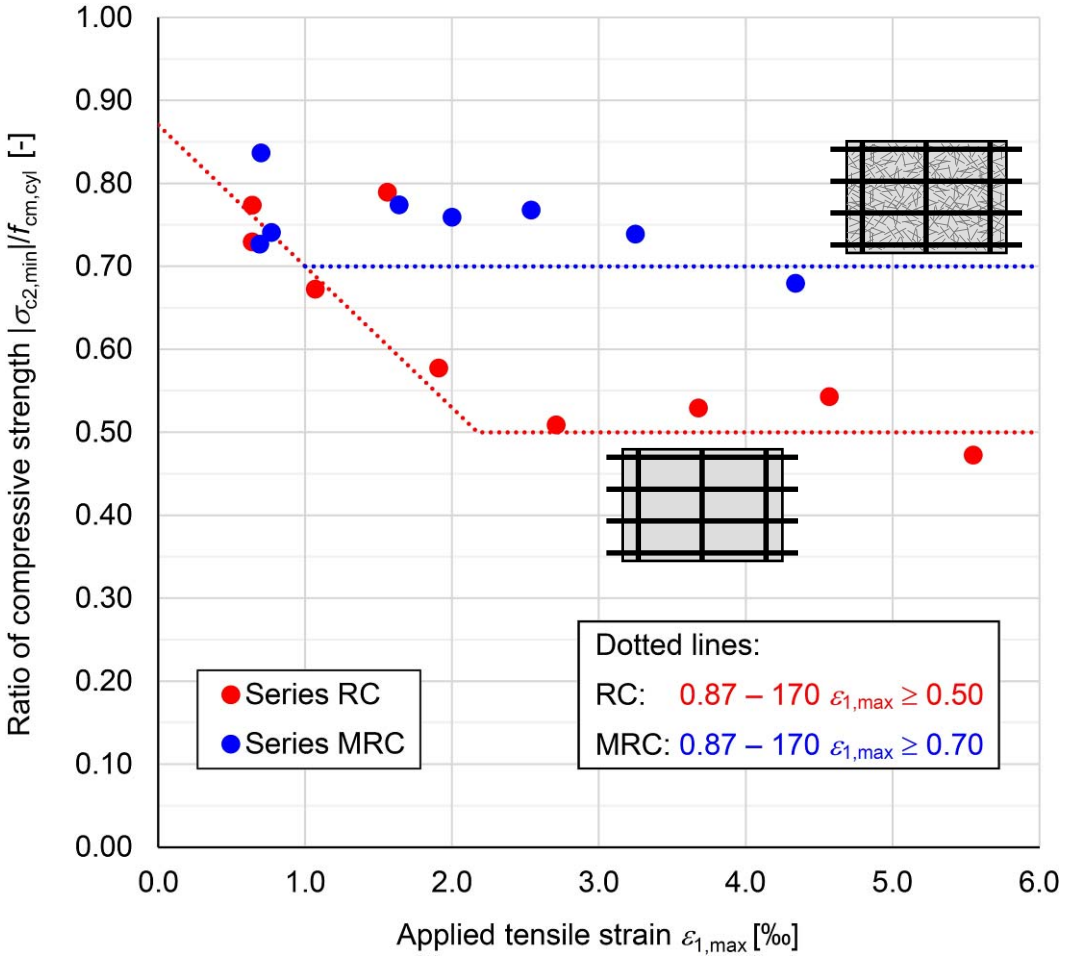




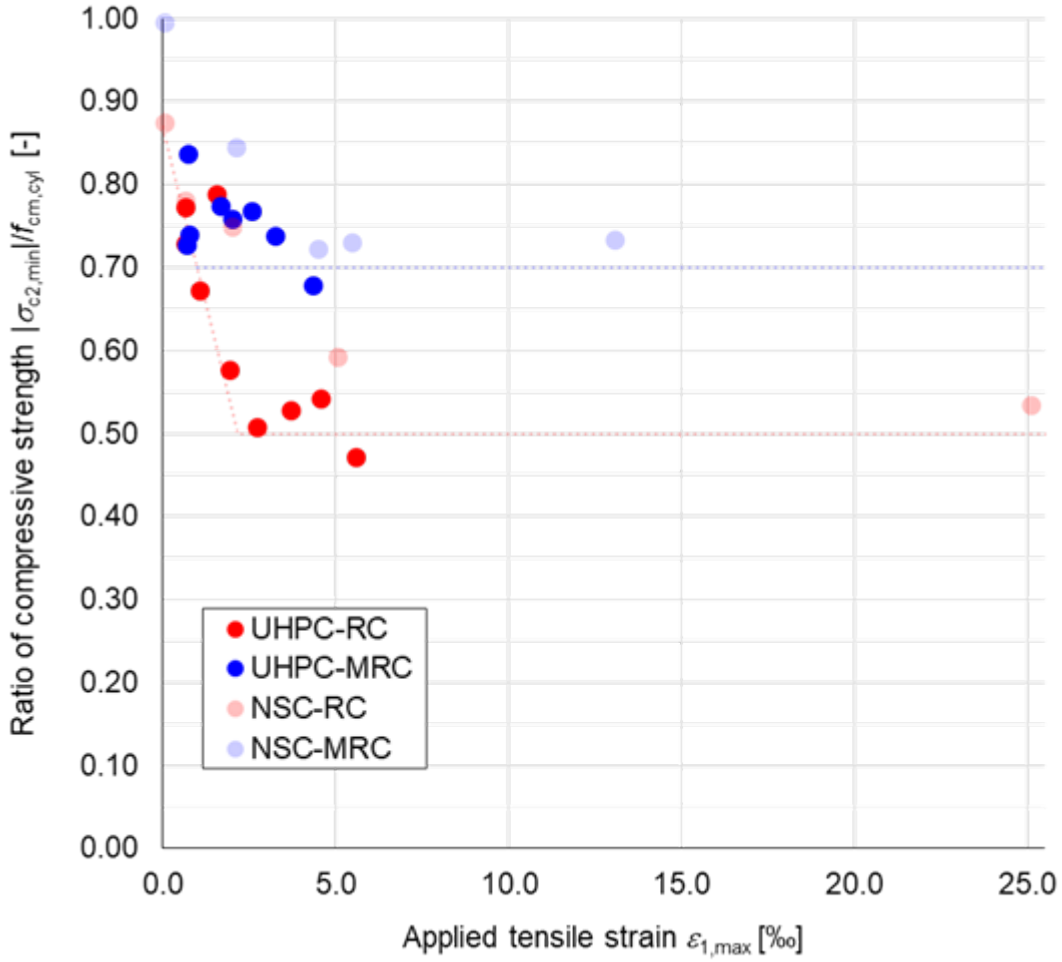
Biaxial Tests: Ratio of Modulus of Elasticity



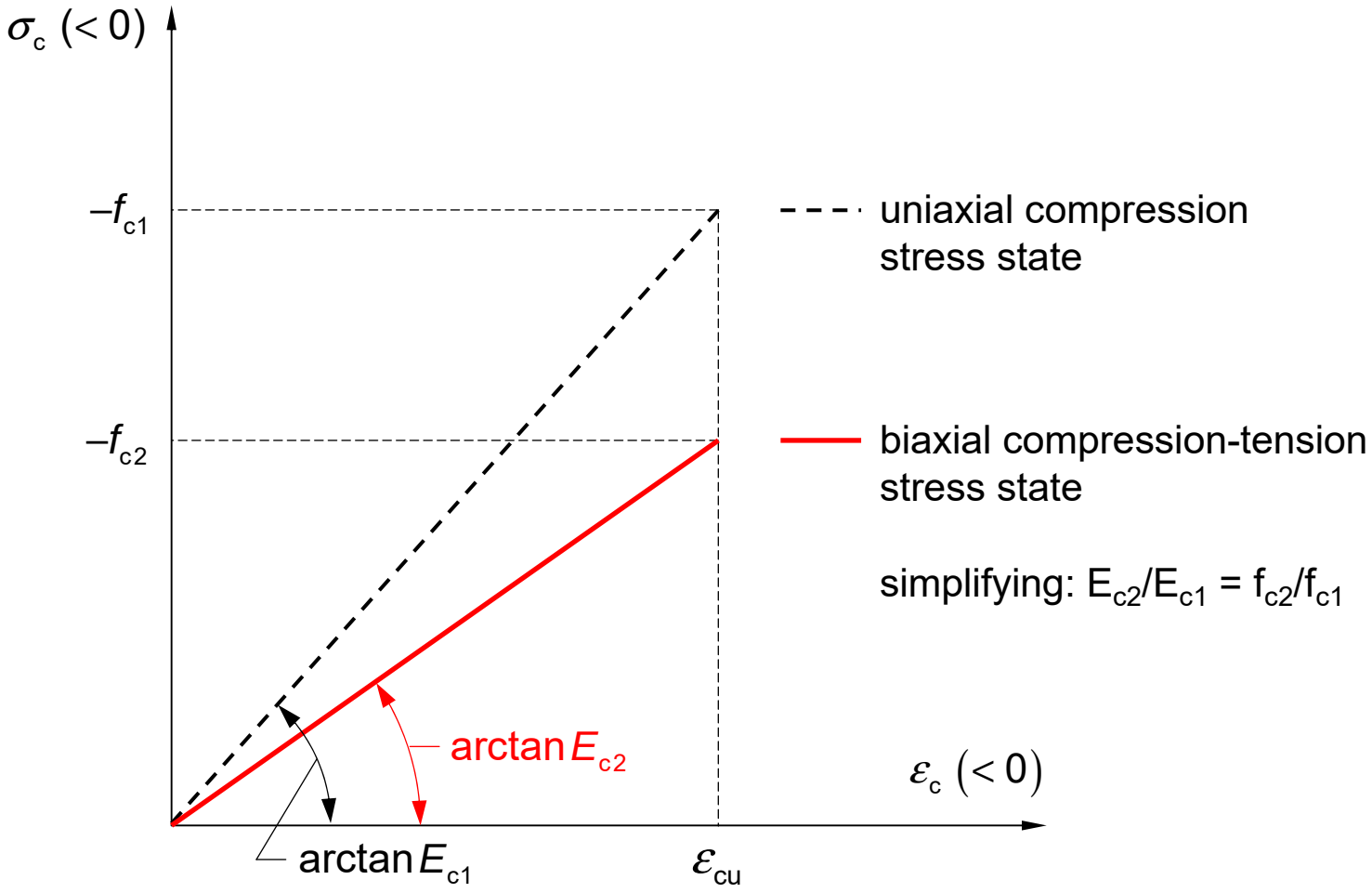
Biaxial Tests: Ratio of Compressive Strength



Ratio of Compressive Strength: UHPC vs. NSC (2003-2004)



Stress-Strain Model for UHP(FR)C Structural Members in Compression



Summary and Conclusions

- Strength reduction of 10 to 15 % even in uniaxial stress state due to reinforcement perpendicular to compressive direction.
- Biaxial loading reduces compressive strength of UHP(FR)C significantly:
  - up to 53 % for UHPC-panels,
  - up to 32 % for UHPFRC-panels.
- Strength reduction is comparable to NS(FR)C (tested 2003-2004).
- Also reduction of compressive stiffness due to irregular geometry of the struts.
- Strength reduction is larger than stiffness reduction because local weak points have more impact on compressive strength.
- Addition of fibres has favourable effect on strength and stiffness:
  - fibres reduce effects of local stress concentrations,
  - fibres facilitate interaction of neighbouring struts.
- Linear stress-strain model is appropriate in uniaxial and biaxial stress state.


Thank You Very Much for Your Attention!