Scale-bridging Modeling of Microstructural Changes in Concrete and Damage Analysis of Concrete Structure for the Identification of Coda Signals

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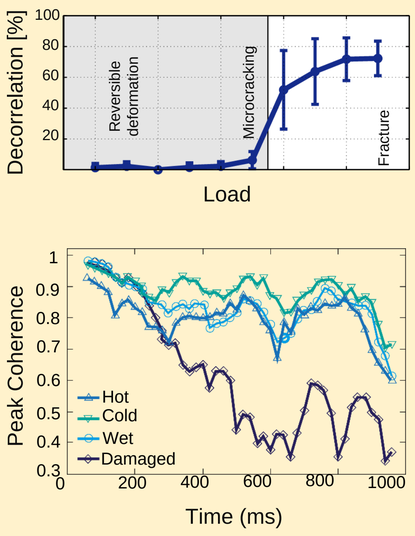
CONCRETE DAMAGE ASSESSMENT BY CODA WAVES

RUB1

Motivation

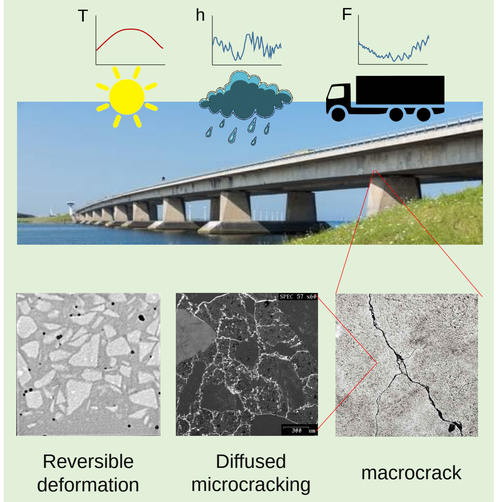
Coda features



- Can **characteristics of the Coda signal** be assigned to certain **stress-specific structural changes or damage**?
- Is it possible to determine a reliable **precursor** characteristic for the **transition from diffuse to localized damage** in concrete and reinforced concrete structures?

Relationship between coda wave and material and structural changes

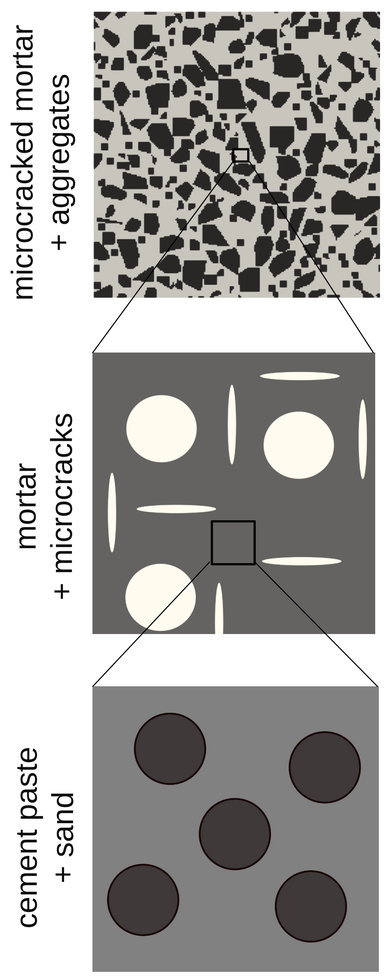
Load Induced Material and Structural Damage



Methodology

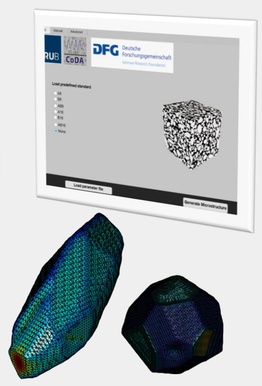
Scale-bridging modelling of microcracking in concrete

Multiscale Model



Microstructure generation → FFT solver → Model reduction

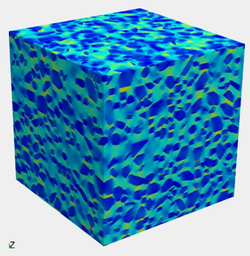
- App **Virtual Concrete Lab**
- 6 concrete standards (DIN ISO 3310)
- Aggregates as concave polyhedrons



- Lippmann-Schwinger equation in Fourier space

$$\varepsilon^{k+1}(\mathbf{x}) = \mathbf{E} - \Gamma^0 * \boldsymbol{\sigma}^k(\mathbf{x})$$

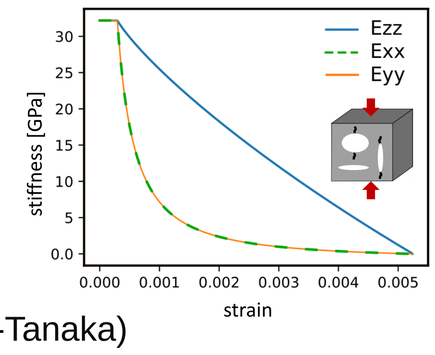
Strain-field obtained from FFT solver

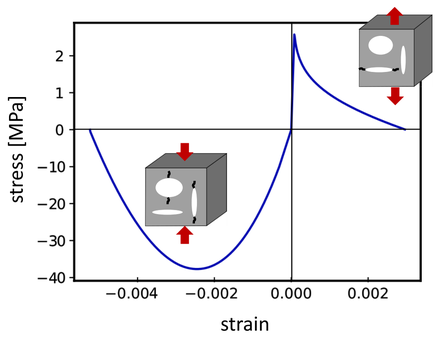


- Model order reduction using k-means clustering

Micromechanical modelling of microcracking in mortar

- 3 pre-existing orthogonal crack families
- LEFM criterion for microcrack propagation
- Analytical homogenization scheme (Mori-Tanaka)





Material properties of mortar

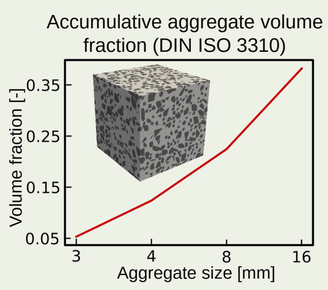
- 3-step analytical homogenization scheme (Mori-Tanaka)
- Step 1: low density and high density C-S-H phases
- Step 2: C-S-H matrix + clinker phases, CH crystal and porosity
- Step 3: Cement paste + sand and small size aggregates

Results

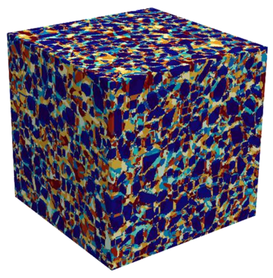
Stiffness upscaling

Material parameters of individual constituents

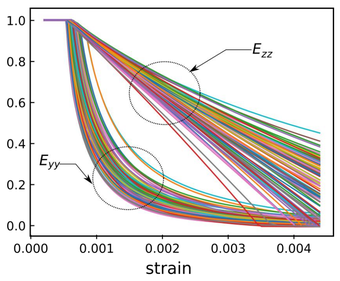
E_{matrix}	24.114 GPa
υ_{matrix}	0.1377
E_{Quartz}	84.6 GPa
υ_{Quartz}	0.12
vf_{Quartz}	0.382
number of aggregates	4794



INPUT



Clustered microstructure



Stiffness reduction in different clusters

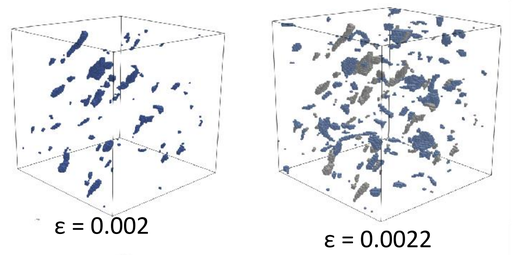
OUTPUT

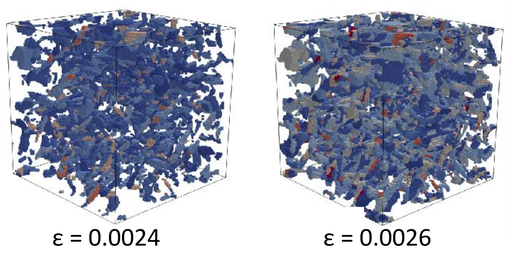
Upscaled material properties of concrete

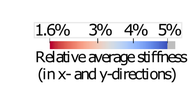
Bulk modulus (GPa)	Young's modulus (GPa)	Shear Modulus (GPa)	Poisson's ratio
17.636	38.331	16.845	0.13776

Upscaled Young's modulus deviates from experimentally measured value by 3.2%

Damage evolution at mesoscale

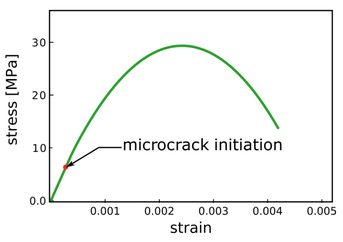




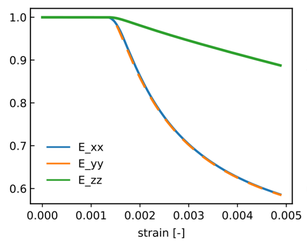


Microcrack development under uniaxial compression

Concrete behavior at macroscale



Homogenized concrete behaviour in uniaxial compression



Concrete stiffness reduction in uniaxial compression