Additive Manufacturing in Construction
2nd funding period: The Opportunity for Large Impact

AMC TRR 277

C01

Bridging Scales – From Geometric Part Details to Construction Elements

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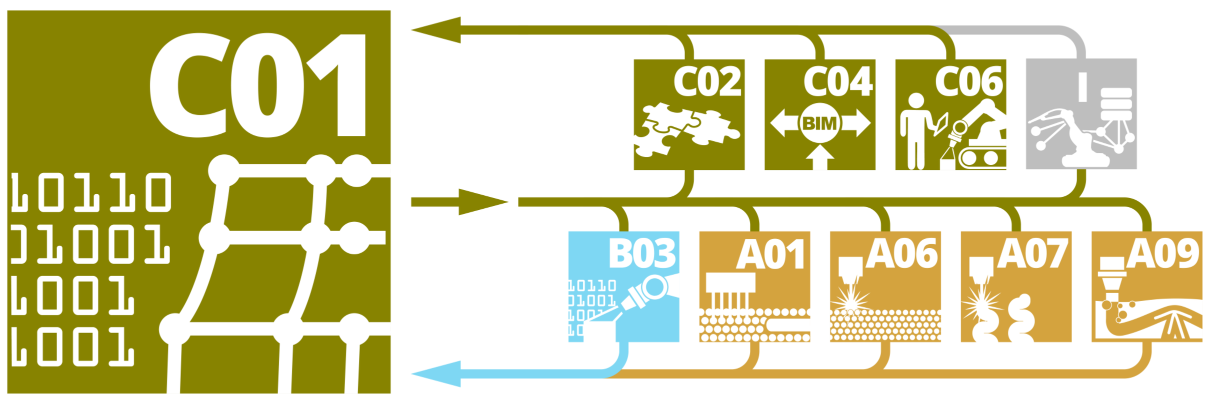
Project aims of 2nd funding period

Digital qualification for parts produced by AM
- Metal based (fatigue)
- Mineral based (elastic and limit load analysis)
- From CT scan and images obtained during the manufacturing process

Effect of defect
- As-designed versus as-built (nonlinear analysis)
- Global-local-global analysis (respecting mutual influences of scales)

As-designed versus as-built
- True operating conditions
- Comparison to as-predicted

Key collaborations in 2nd funding period



- A01: Digital product qualification for mineral based components
- A06: Digital product qualification for steel
- A09 & B03: Concerning parts produced by injection 3D printing
- C02: Concerning the design of the global structure
- C06: Concerning as-built structures

Work programme

WP 1
Digital Product Qualification for steel
- **WP 1.1** High cycle fatigue
- **WP 1.2** Influence of pores
- **WP 1.3** Virtual CT-scan

↕ A06

WP 2
Digital Product Qualification for concrete
- **WP 2.1** Material model
- **WP 2.2** Local part defects

↔ A01

WP3
Limit-load analysis

↕ A01

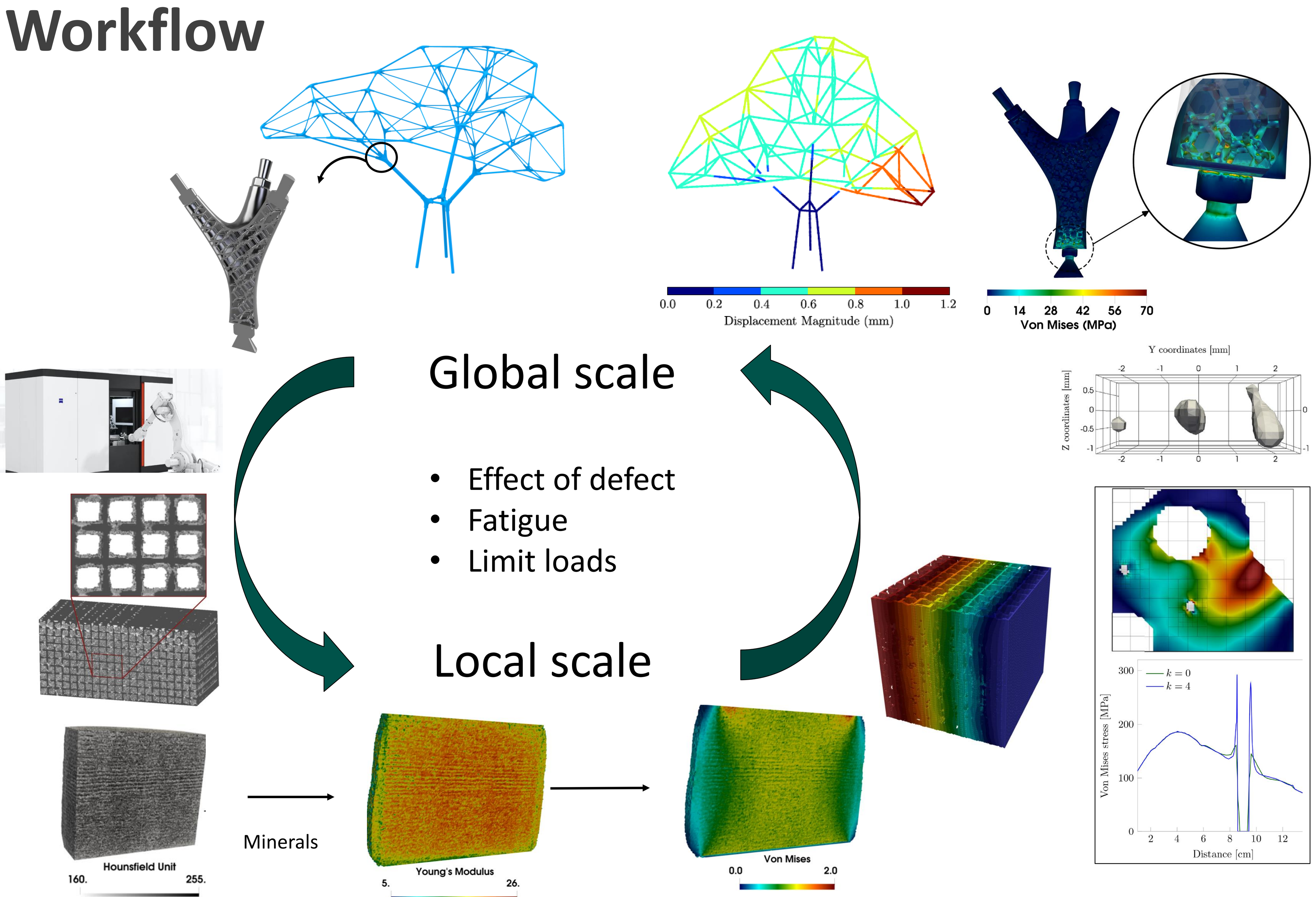
WP4
Effect of Defect - I3DCP

↕ A09, B03, C06

WP5
Global-local analysis on as built structures

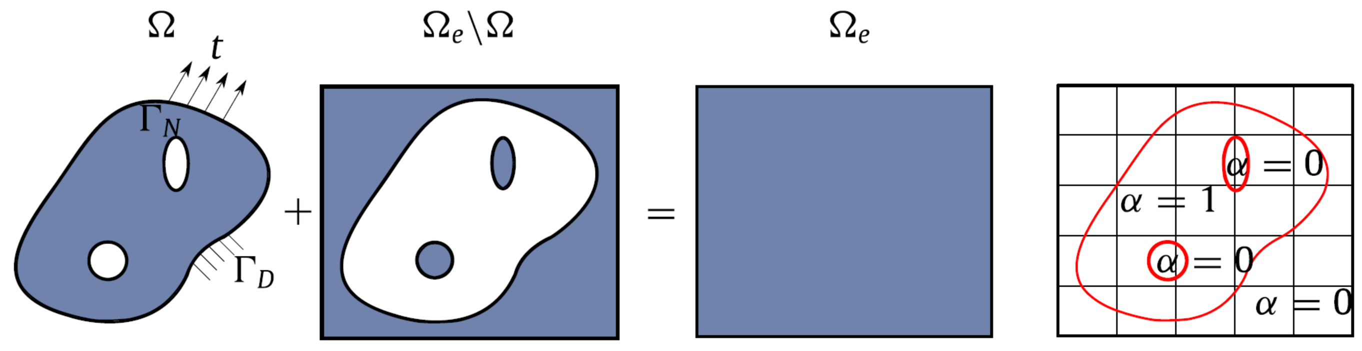
A06, A09 ↔ C02, C04 ← C06

Workflow



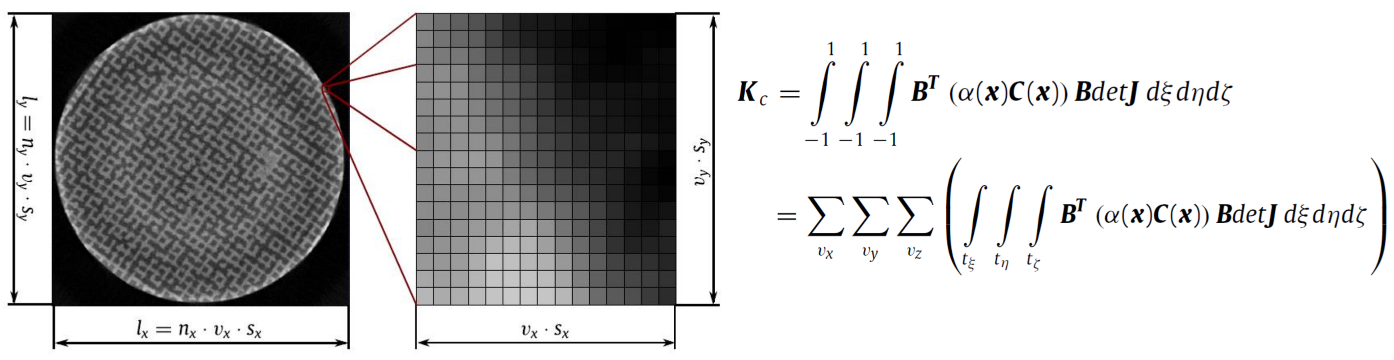
Methods

Image based analysis & Finite Cell Method



$$\mathcal{B}_e^{\alpha}(\boldsymbol{v},\boldsymbol{u}) = \int_{\Omega_e} \boldsymbol{\varepsilon}(\boldsymbol{v}) : \alpha(\boldsymbol{x})\mathbf{C}(\boldsymbol{x}) : \boldsymbol{\varepsilon}(\boldsymbol{u})\, d\Omega_e \quad \text{where} \quad \alpha(\boldsymbol{x}) = \begin{cases} 1.0 & \forall \boldsymbol{x} \in \Omega \\ \approx 0.0 & \forall \boldsymbol{x} \in \Omega_e \setminus \Omega \end{cases}$$

and the finite cells are defined as a union of voxels:



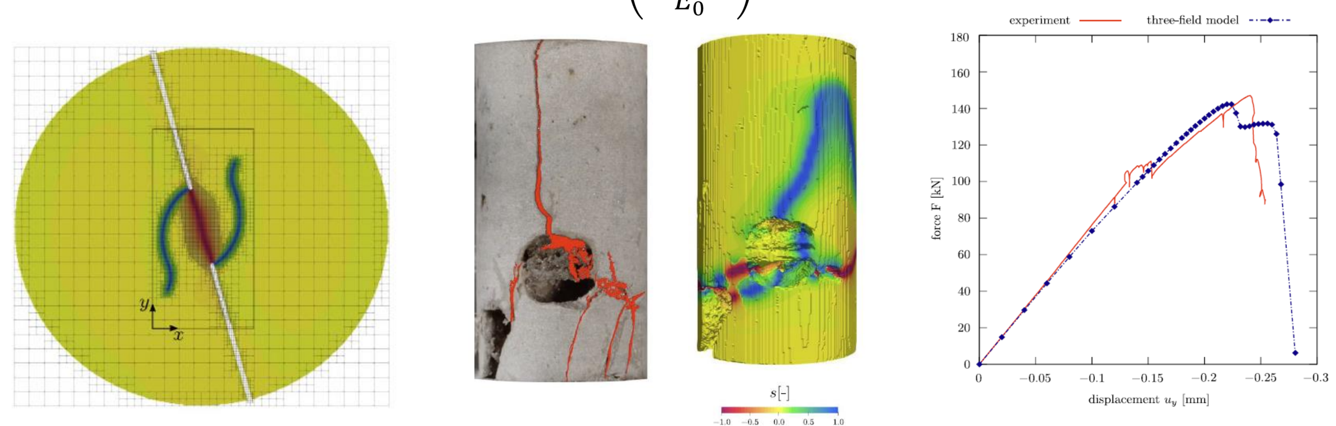
$$\boldsymbol{K}_c = \int_{-1}^{1}\int_{-1}^{1}\int_{-1}^{1} \boldsymbol{B}^T\, (\alpha(\boldsymbol{x})\mathbf{C}(\boldsymbol{x}))\, \boldsymbol{B}\det\boldsymbol{J}\; d\xi\, d\eta\, d\zeta = \sum_{v_x}\sum_{v_y}\sum_{v_z}\left(\int_{t_\xi}\int_{t_\eta}\int_{t_\zeta} \boldsymbol{B}^T\, (\alpha(\boldsymbol{x})\mathbf{C}(\boldsymbol{x}))\, \boldsymbol{B}\det\boldsymbol{J}\; d\xi\, d\eta\, d\zeta \right)$$

Phase field method

$$\mathrm{div}(\boldsymbol{\sigma}) + \rho\, \boldsymbol{b} = \rho\, \ddot{u} \qquad -4\, l_0^2\, \Delta s + \frac{1}{2}\, w'(s) = -\frac{c_w}{2}\, \frac{l_0}{G_c}\, g'(s)\, \mathcal{H}$$

wherein the fracture toughness is determined from HU as

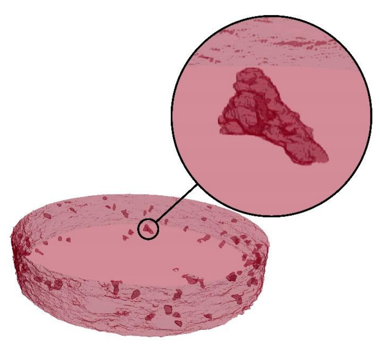
$$G_{c_I}(HU) = G_{c_0} \left(\frac{E(HU)}{E_0}\right)^{\beta}$$



Virtual shear disk experiment — CT scan to limit load for a core sample of rock

Fatigue analysis

- High-cycle fatigue based on homogenized models (e.g. Crossland criteria)
- Influence of pores (hot spot analysis)
- Prediction on virtual CT scans



Outlook 3rd funding period

- Structural reinforcement
- Plasticity and low-cycle fatigue
- Non-linear local-global analysis

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