DTU Civil Engineering
Department of Civil Engineering

DANISH TECHNOLOGICAL INSTITUTE

CONCRETE EXPERTCENTRE

Service life modelling of reinforced concrete structures subjected to corrosion

Prepared by:
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Prepared for:
Concrete Expert Centre Reference Group Meeting, March 28, 2012

Outline

- Basic concept of service life model
- Examples
  - Un-cracked
  - Cracked concrete
- Impact of cracks
  - Transport of matter
  - Corrosion
- Further needs
  - Improved transport and chemical models
  - Improved mechanical models

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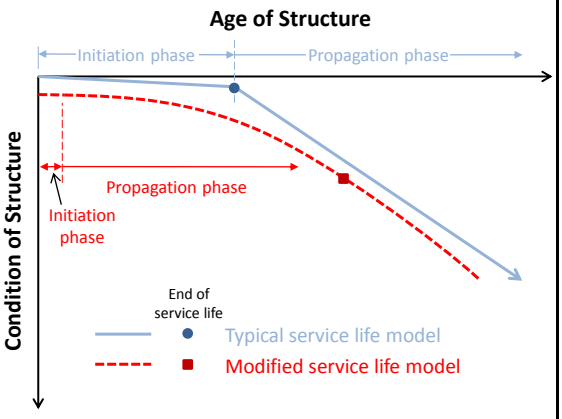
Basic concept of service life model

Underlying hypothesis:

A service life model, which is able to take into account the conditions of real structures, i.e. the presence of cracks, defects, varying reinforcement surface conditions and more, has to deal with the **propagation phase** as well as the initiation phase and it has to be rest on a probabilistic foundation



(Pease et al., 2012)

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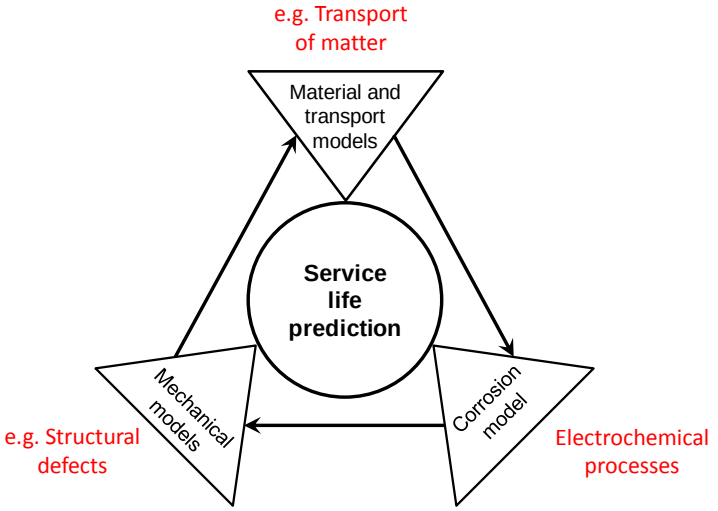
Basic concept of service life model



(Michel et al., 2010)

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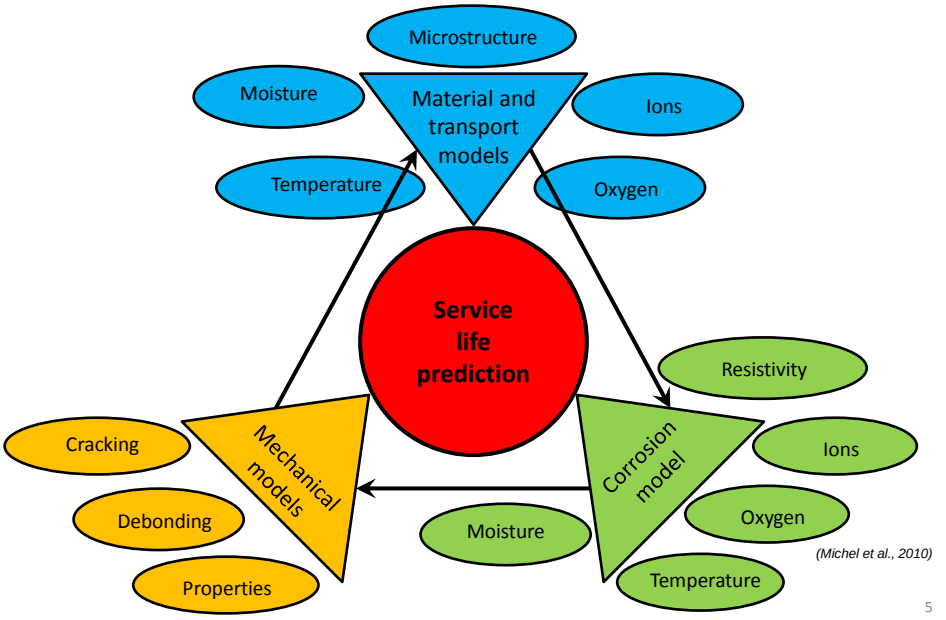
Basic concept of service life model



(Michel et al., 2010)

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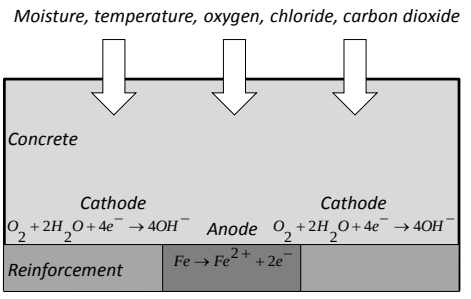
Examples - un-cracked / cracked concrete

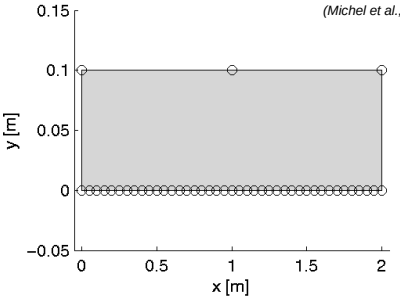
Two-phase model:

- Homogeneous defect-free steel and concrete
- Transport processes
- Material properties
- Anodic and cathodic sites form "randomly"

- Electrochemical processes (preselected)



(Michel et al., 2009)



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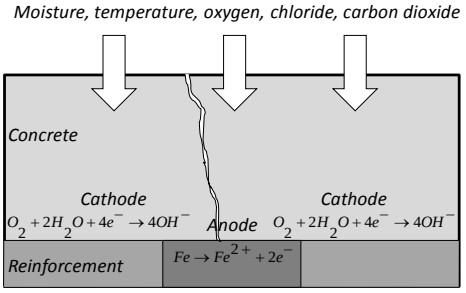
Examples - un-cracked / cracked concrete

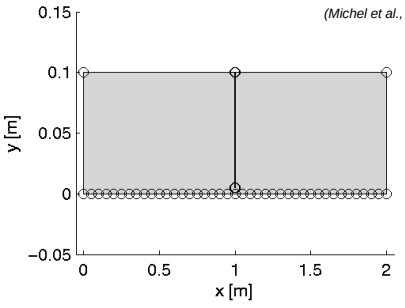
Multi-phase model:

- Varying material properties and defects, cracks
- Transport processes
- Material properties
- Anodic and cathodic sites form “randomly”

- Electrochemical processes (preselected)



(Michel et al., 2009)



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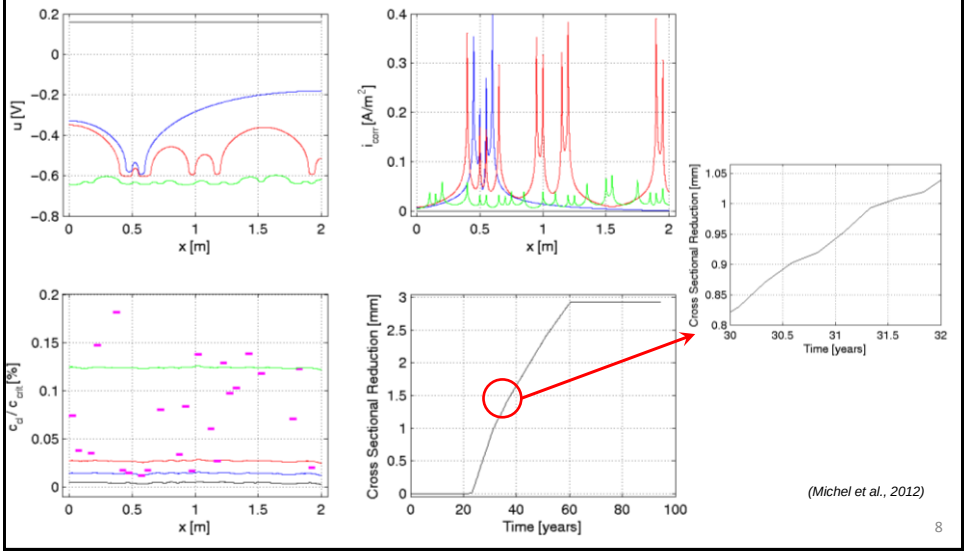
Examples - un-cracked / cracked concrete

Results for selected times (black - 18.6 years, blue - 21.8 years, red - 24.8 years and green - 37.3 years)



(Michel et al., 2012)

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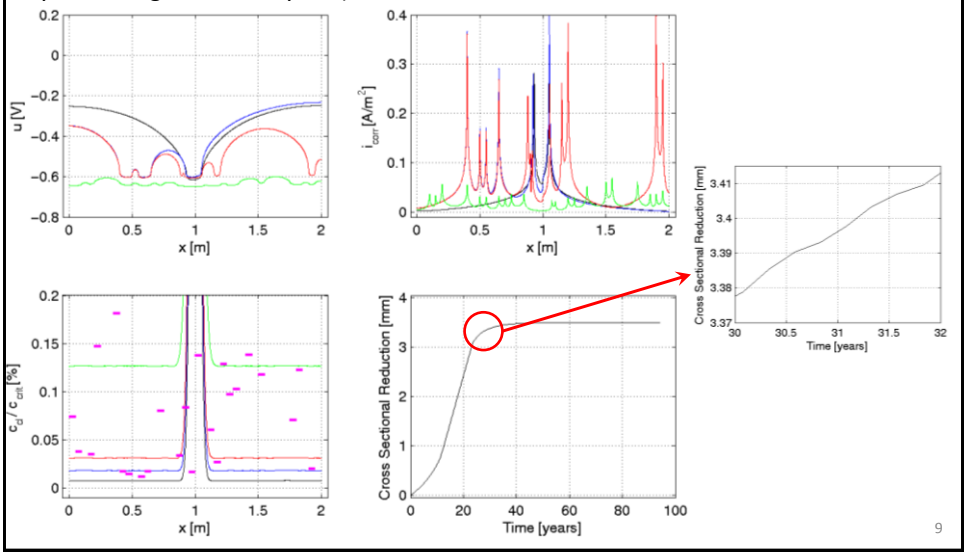
Examples - un-cracked / cracked concrete

Results for selected times (black - 18.6 years, blue - 21.8 years, red - 24.8 years and green - 37.3 years)



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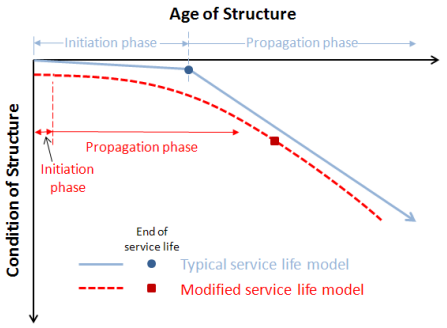
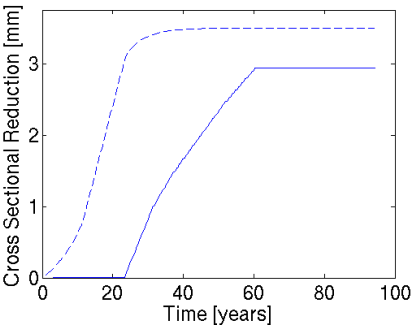
Examples - un-cracked / cracked concrete

Comparison of cross sectional reduction for un-cracked and cracked concrete



(Pease et al., 2012)



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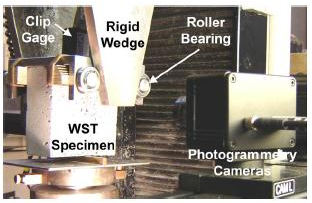
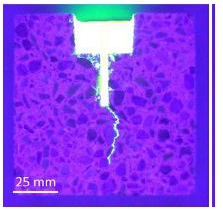
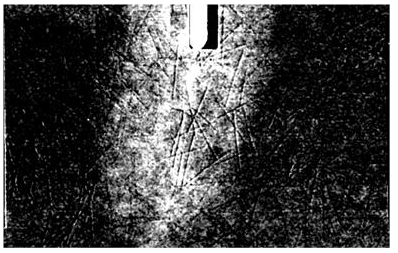
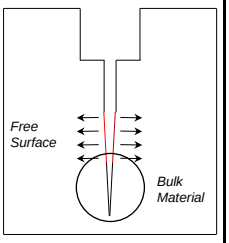
Impact of cracks - Transport of matter

Experimental and numerical investigations to quantify the impact of cracks on the transport of matter







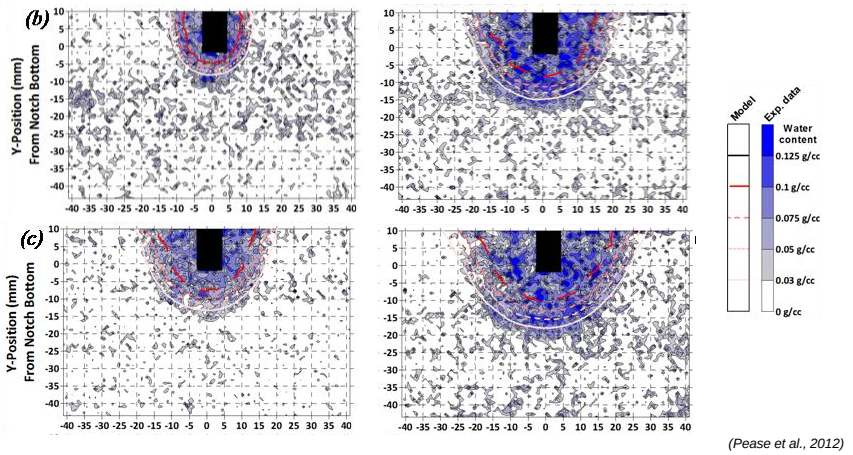


(Pease, 2011)

Impact of cracks - Transport of matter

Comparison between experimental and numerical moisture transport in cracked specimens

- un-cracked test specimen

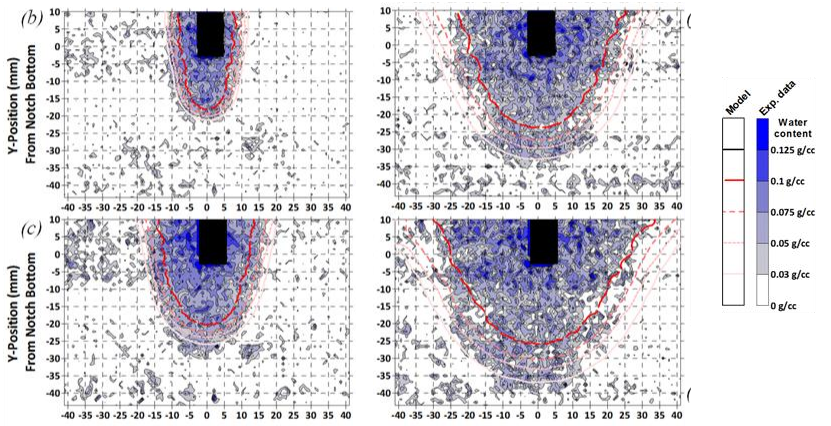


(Pease et al., 2012)

Impact of cracks - Corrosion

Comparison between experimental and numerical moisture transport in cracked specimens

- cracked test specimen - 0.1 crack width at surface



(Pease et al., 2012)

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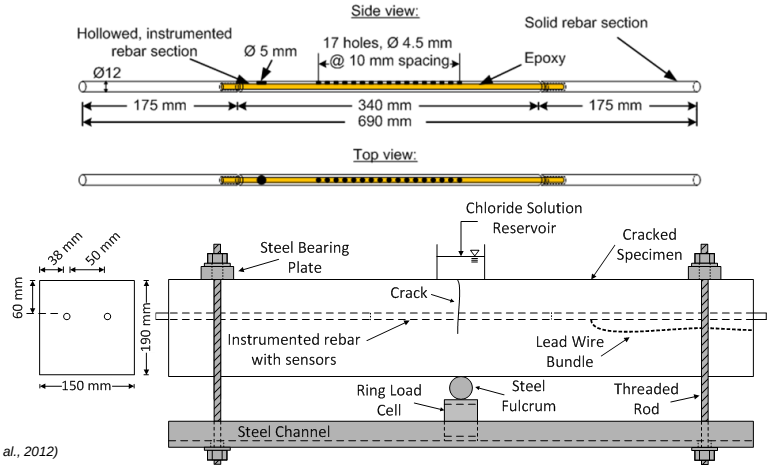
Impact of cracks - Corrosion

Hypothesis: Controlling the concrete-reinforcement interfacial condition can be used as a single reliable indicator for the impact of cracks on the risk of corrosion initiation along the reinforcement



(Michel et al., 2012)

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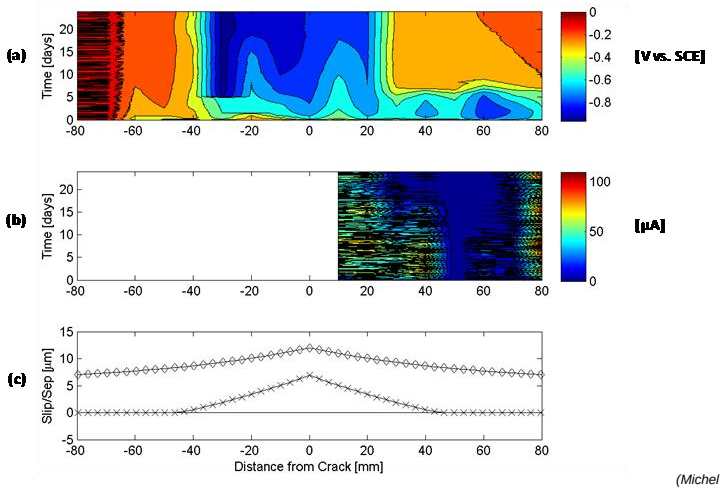
Impact of cracks - Corrosion

Experimental results concrete

- crack width at surface = 0.069 mm



(Michel et al., 2012)

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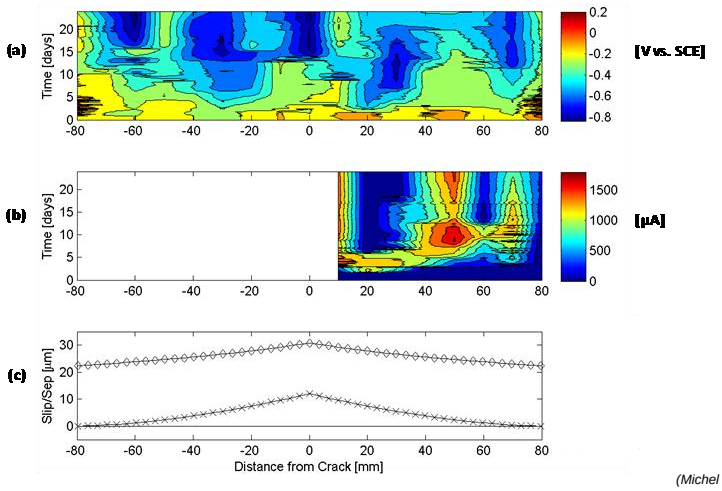
Impact of cracks - Corrosion

Experimental results 0.5 Vol % SFRC

- crack width at surface = 0.12 mm



(Michel et al., 2012)

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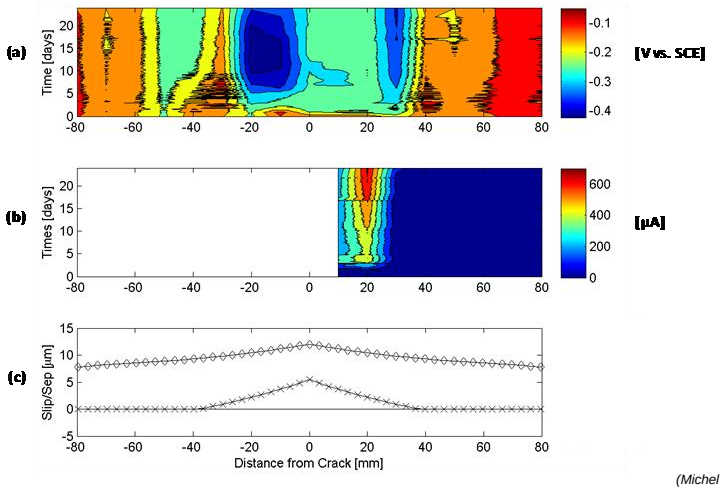
Impact of cracks - Corrosion

Experimental results 1.0 Vol % SFRC

- crack width at surface = 0.069 mm



(Michel et al., 2012)

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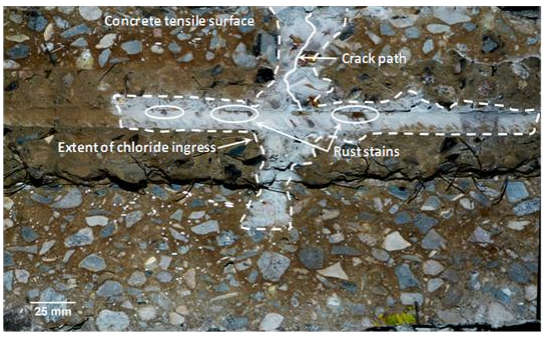
Impact of cracks - Corrosion

Experimental results - visual observations



(Michel et al., 2012)

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Further needs

- What's *complete* to this point and what's still needed?
- *Electrochemically controlled reinforcement corrosion model developed for concrete with and without cracks*
  - Pre-selection of electrochemical processes is a limitation
  - Addition of more thorough multi-species ingress model
- *Corrosion-induced cracking model developed*
  - Improved mechanical models

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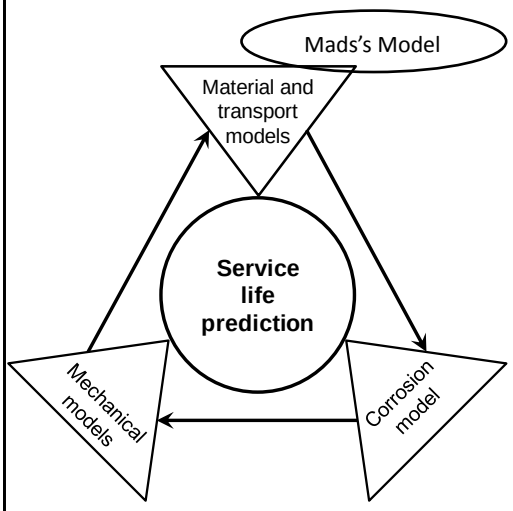
Further needs - Improved transport and chemical models



(Michel et al., 2010)

PhD-project: Mads Mønster Jensen. Advisors: Björn Johansson, Mette Geiker and Henrik Stang (DTU Byg)

- Modeling of ionic transport processes in the pore system
- Modeling of chemical equilibrium states between solids and pore solution
- Combine the transport and chemical model for long term simulations
- Validation of model with experimental data

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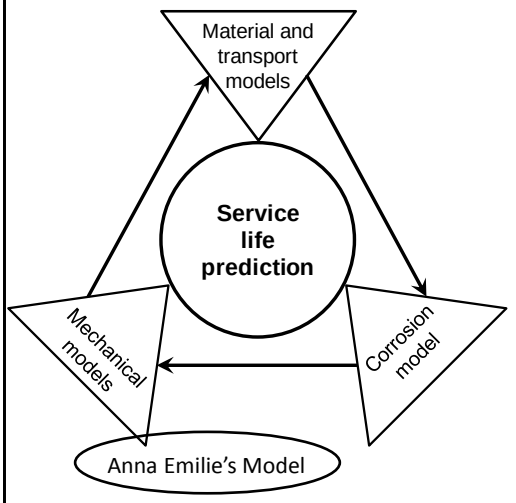
Further needs - Improved mechanical models



(Michel et al., 2010)

PhD-project: Anna Emilie A. Thybo. Advisors: Henrik Stang, Mette Rica Geiker and John Forbes Olesen (DTU Byg) and Lars Nyholm Thrane (Danish Technological Institute)

- Further develop and finalize an already existing deterministic corrosion model.
- The main additions to the model include:
  - Conditions for corrosion initiation in the modeling scheme
  - Realistic and verified description of typical initial defects (e.g., concrete cracks and defects at concrete-steel interface)
  - Consideration of corrosion-induced deterioration in service life

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