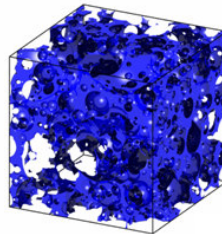


Influence of Relative Humidity on the Durability of Concrete

A Multi Scale Approach



Presentation of MSc Thesis

B. Bruins Slot

Monday, 30 March 2009

Graduation Committee:

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Introduction

Macro Scale

Micro Scale

Practical Applications

Recommendations

Contents

- Introduction
- Macro scale
- Micro scale
- Practical applications
- Recommendations

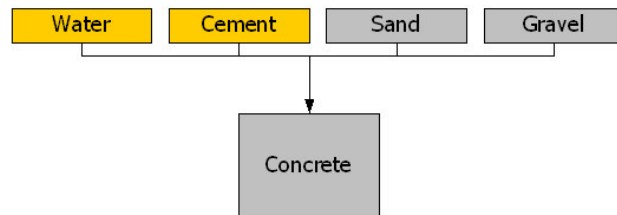
2



Introduction

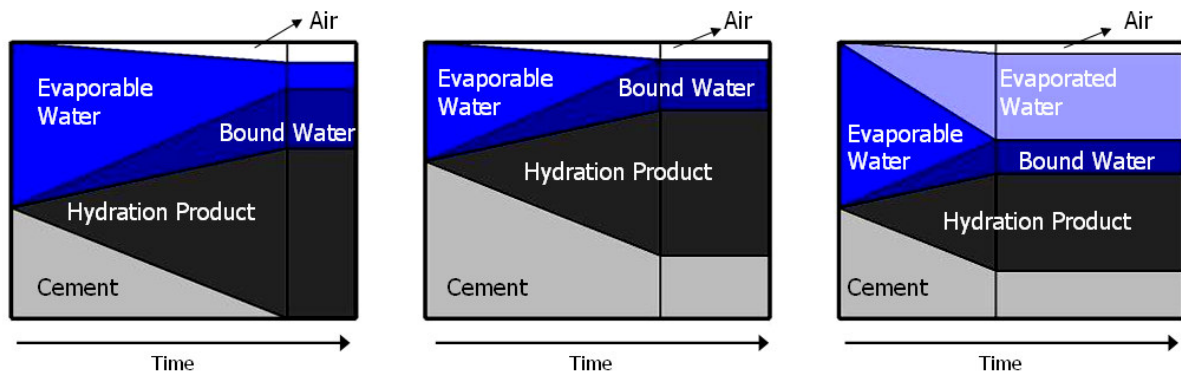


- Concrete
- Hydration process
- Mechanical properties
- Degree of hydration



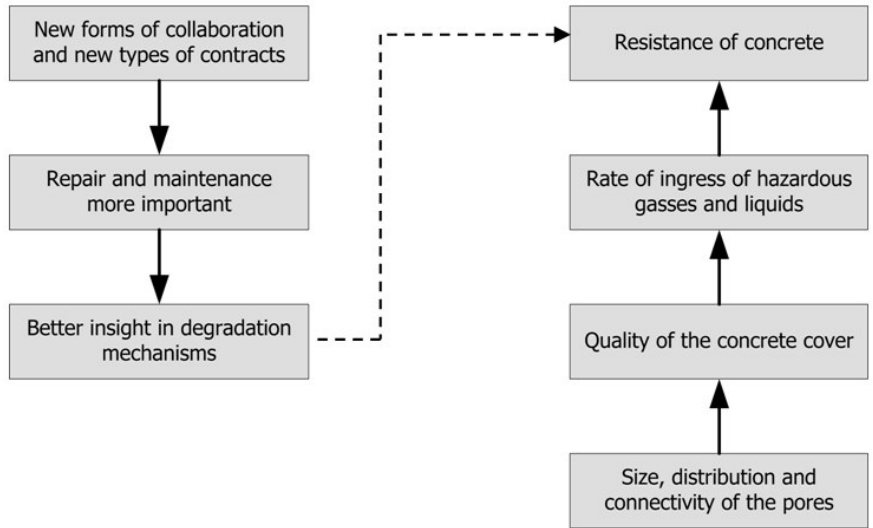
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Introduction



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Introduction



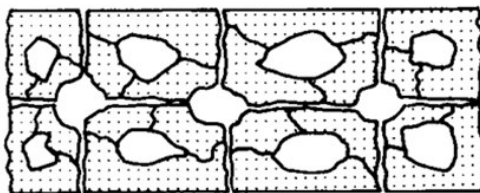
Introduction



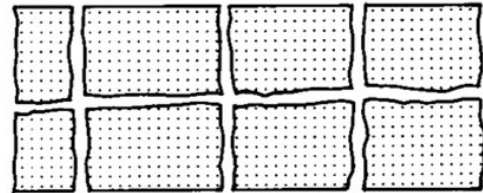
Porous and non-permeable



Porous and permeable

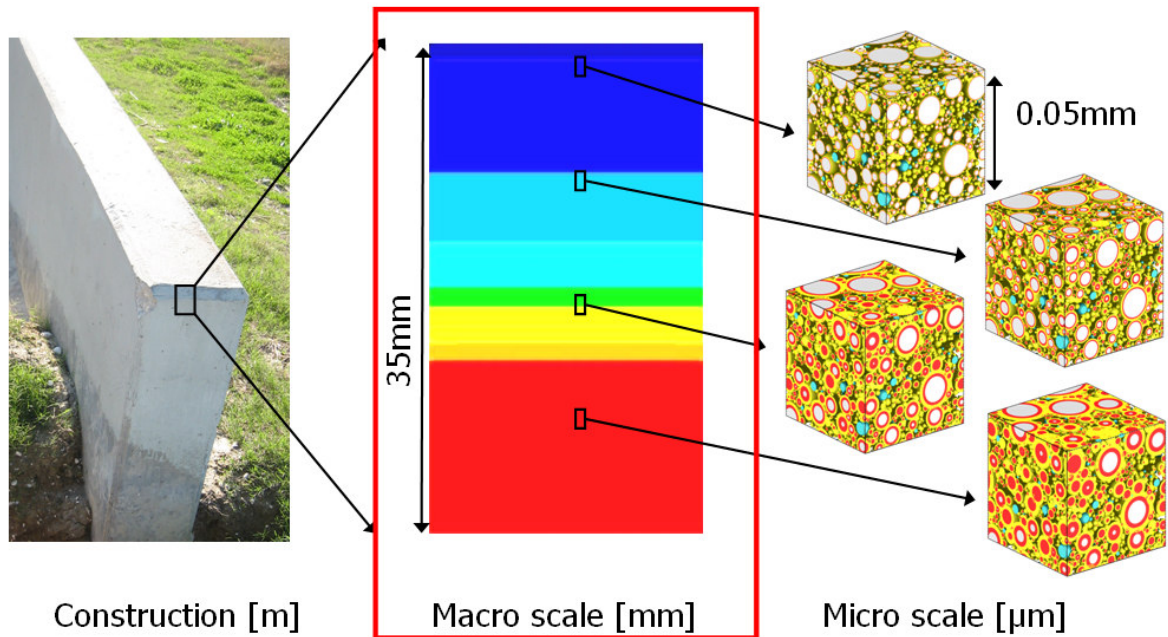


High porosity & low permeability



Low porosity & high permeability

Introduction



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Macro Scale

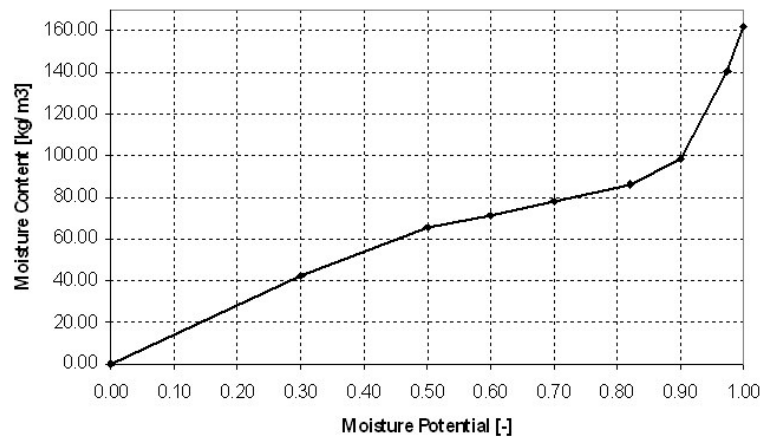
- Use computer program MLS to do macro scale simulations
- Simulate moisture transport
- Input parameters
- Fitting results
- Output from macro scale simulations

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Macro Scale: Input Parameters

Desorption Curve

- Determine weight at different relative humidities

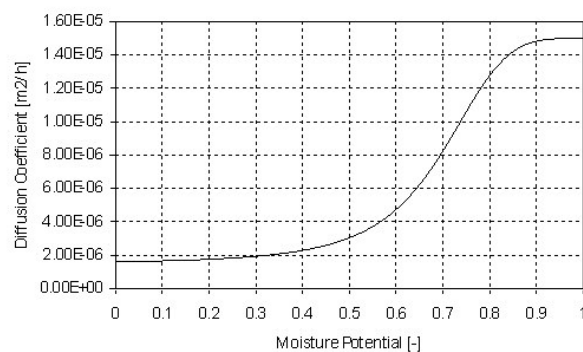


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Macro Scale: Input Parameters

Diffusion Curve and Transfer Coefficient

- Boundaries found in literature
- Diffusion curve
 - Bažant and MLS
- Transfer coefficient
 - Carmeliet



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Macro Scale: Fitting Results

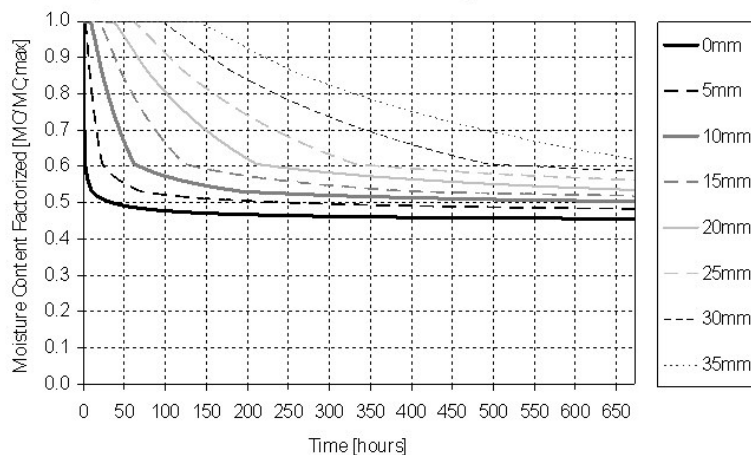
- Evaporation experiments
- Mortar specimens
- Water uptake for an hour
- Measurement of weight loss over time
- Temperature dependent measurements



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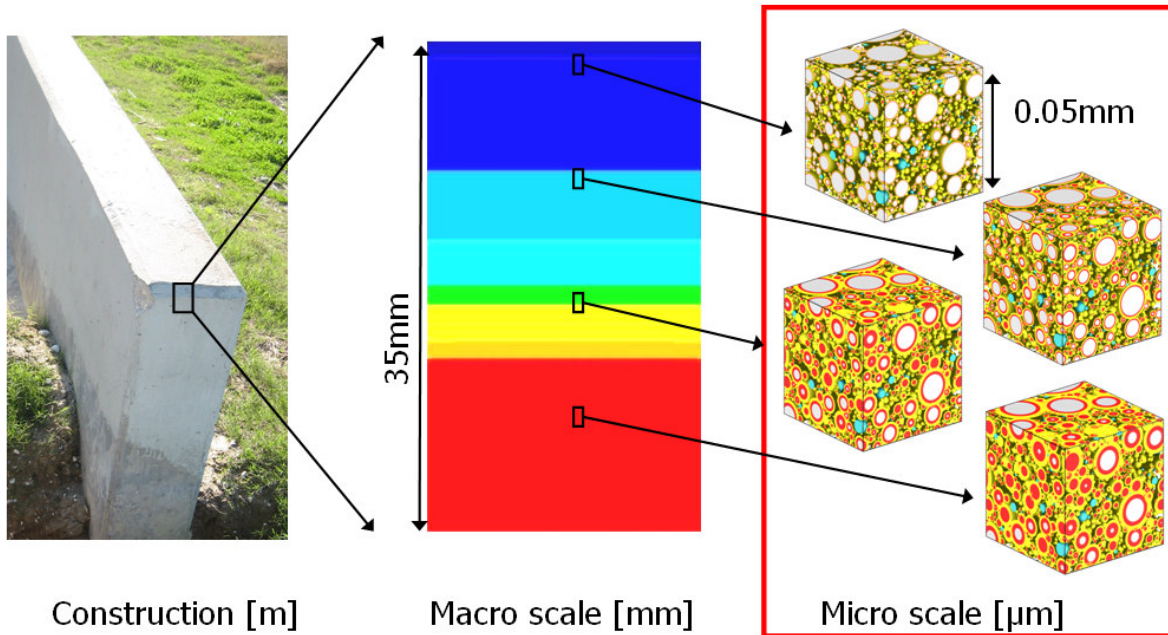
Macro Scale: Output

- Drying files
- Example: 50% relative humidity



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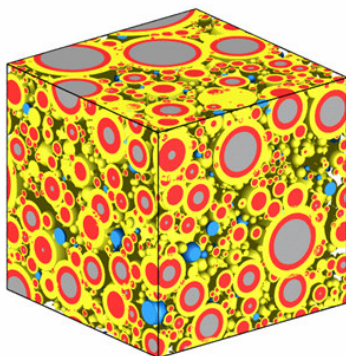
Micro Scale



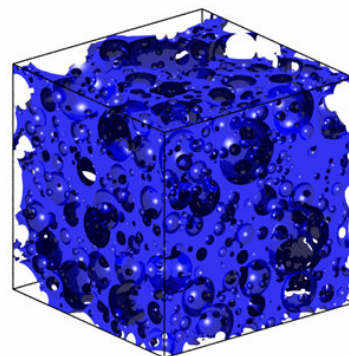
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Micro Scale: HYMOSTRUC

- Simulate formation of microstructure



Created by B. Bruins Slot



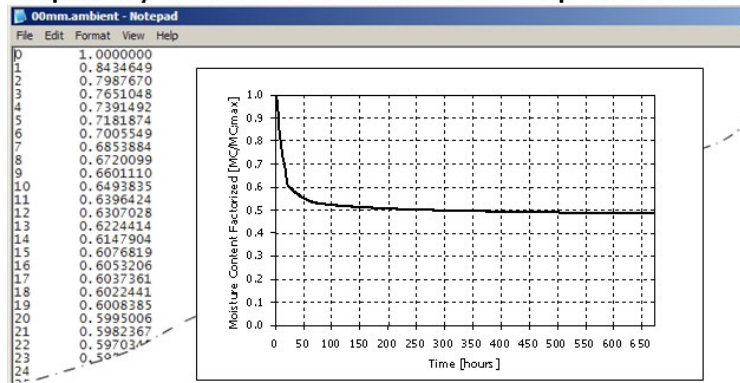
Created by B. Bruins Slot

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Micro Scale: Extensions

Simulating Evaporation

- Standard HYMOSTRUC is a closed system
- Capillary water is reduced interpolated from this file

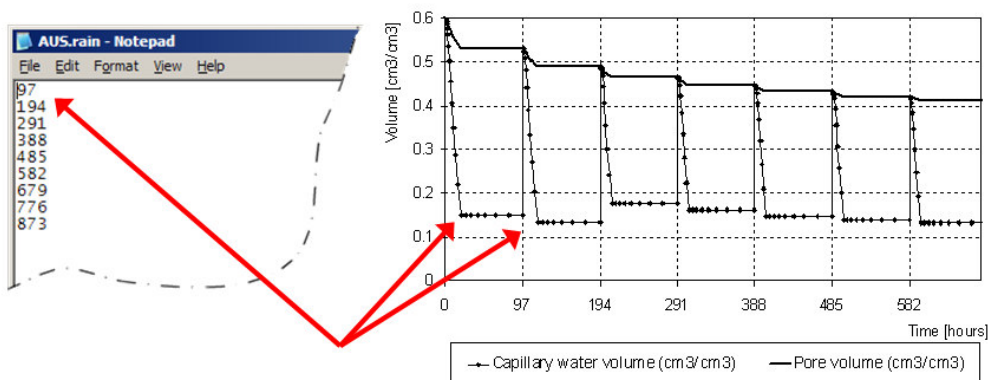


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Micro Scale: Extension

Simulating Rain

- Rain is modelled as saturation
- Rain fills all pores in 1 time step of the simulation

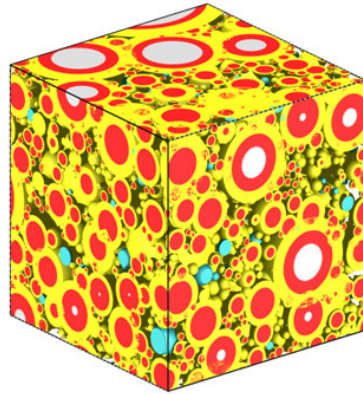


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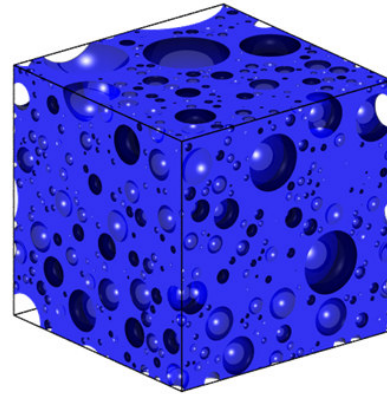
Micro Scale: Extension

Rendering Output

- Rendering using POV-Ray for Windows 3.6



Solids



Pores

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Results

A model to simulate:

- the effects of relative humidity
- on the hydration process
- in the concrete cover



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Practical Applications

- Environments
 - De Bilt, The Netherlands
 - Adelaide, Australia
 - Comparison
 - Experimental results
- Relevance of curing time

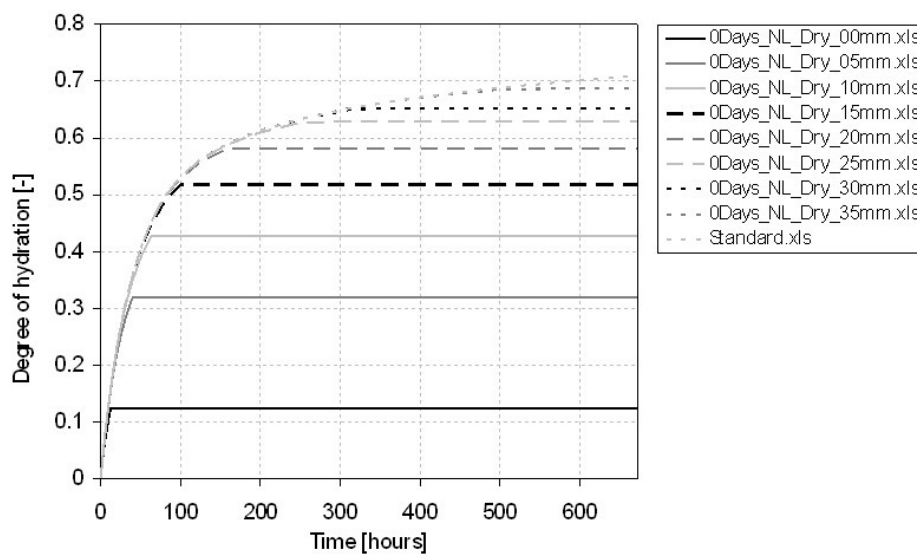
	De Bilt	Adelaide
RH	80%	60%
Rain	Every 68 hours	Every 98 hours

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Practical Applications: Environments

The Netherlands DRY

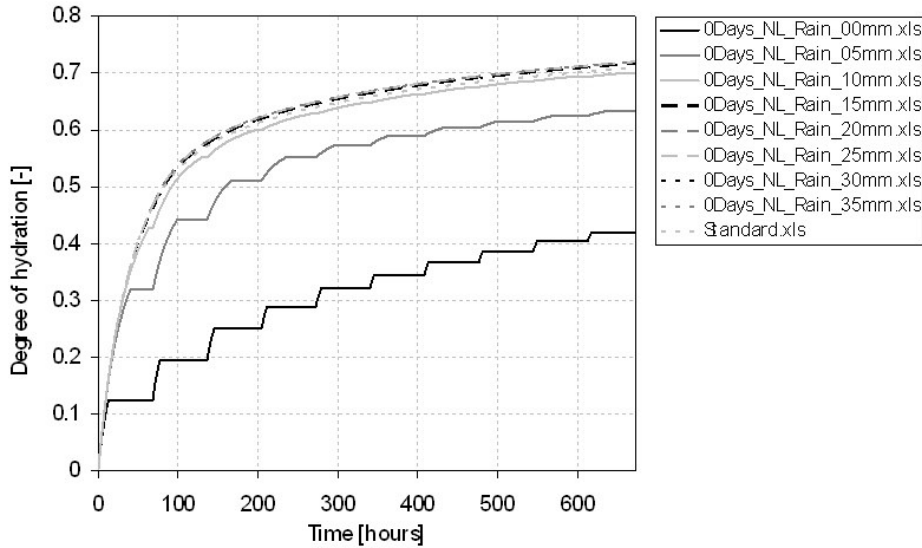


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Practical Applications: Environments

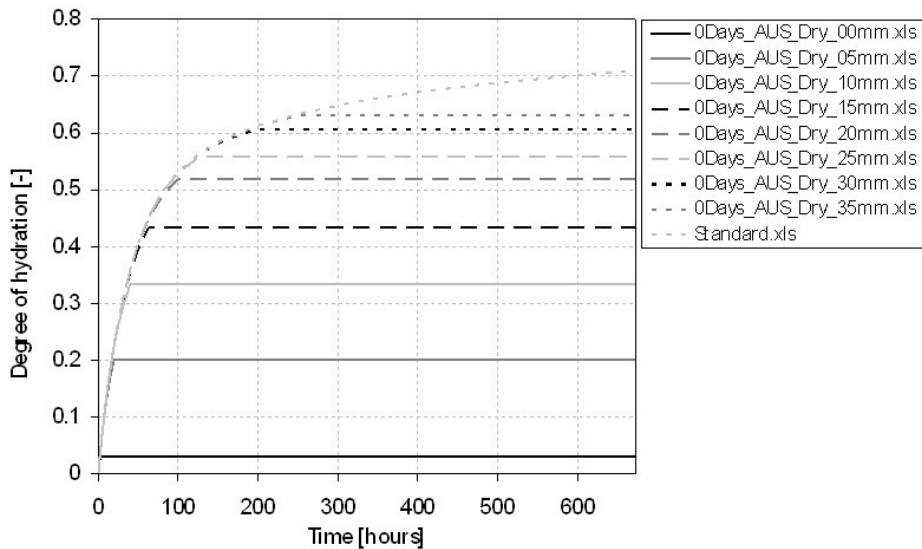
The Netherlands RAIN



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Practical Applications: Environments

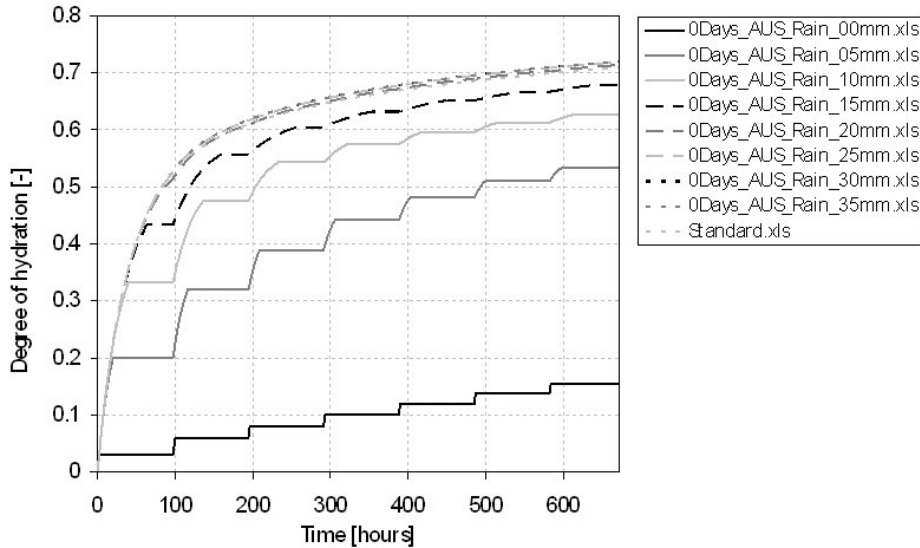
Australia DRY



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Practical Applications: Environments

Australia RAIN



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Practical Applications: Environments

Comparison Between The Netherlands and Australia

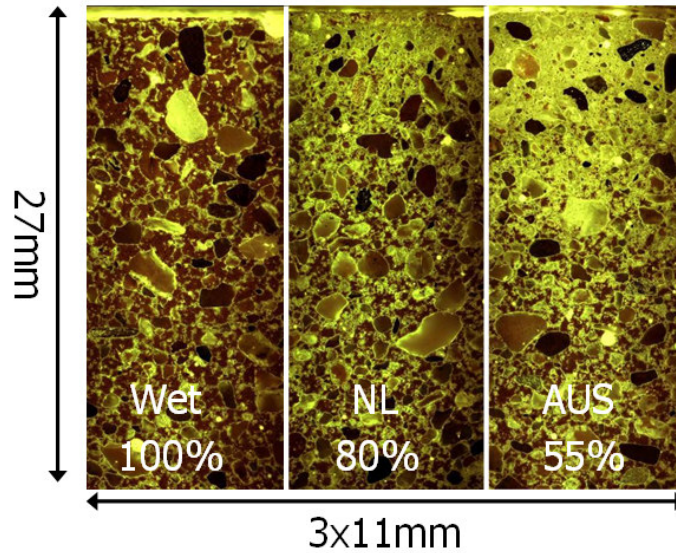
- Comparison between The Netherlands and Australia
- The case where there is rain
- Outer 1st centimeter

Distance from Edge	Degree of Hydration - NL	Degree of Hydration - AUS
0mm	0.42	0.16
5mm	0.64	0.54
10mm	0.70	0.63
Standard (no evaporation and no rain)		0.71

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Practical Applications: Experiments

Experimental Results



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Practical Applications: Curing

Relevance of Curing Time

- Curing time
 - Time in the mould
 - Time with measurements against evaporation

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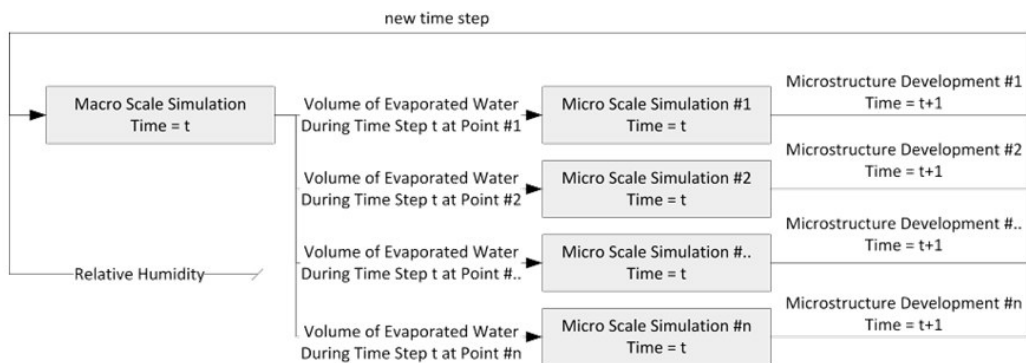
Recommendations

- Recommendations regarding:
 - The model
 - The input parameters for the model

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Recommendations: Model

- Full coupling between Macro and Micro Scale
- For every time step



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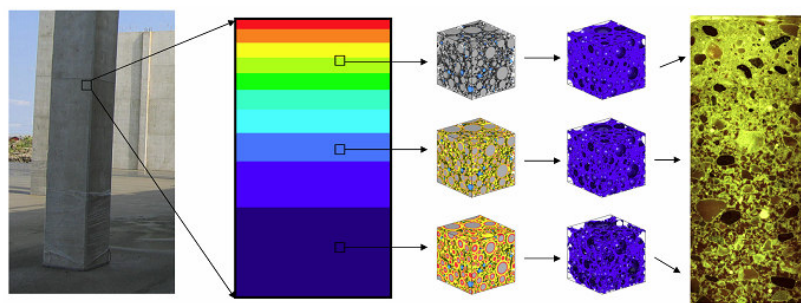
Recommendations: Input Parameters

- Input Parameters for MLS as a Function of the Degree of Hydration
- Fitting Data as a Function of the Degree of Hydration
- Material: Mortar versus Concrete

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