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School of Engineering

Computational modelling of heterogeneity of asphalt mixtures

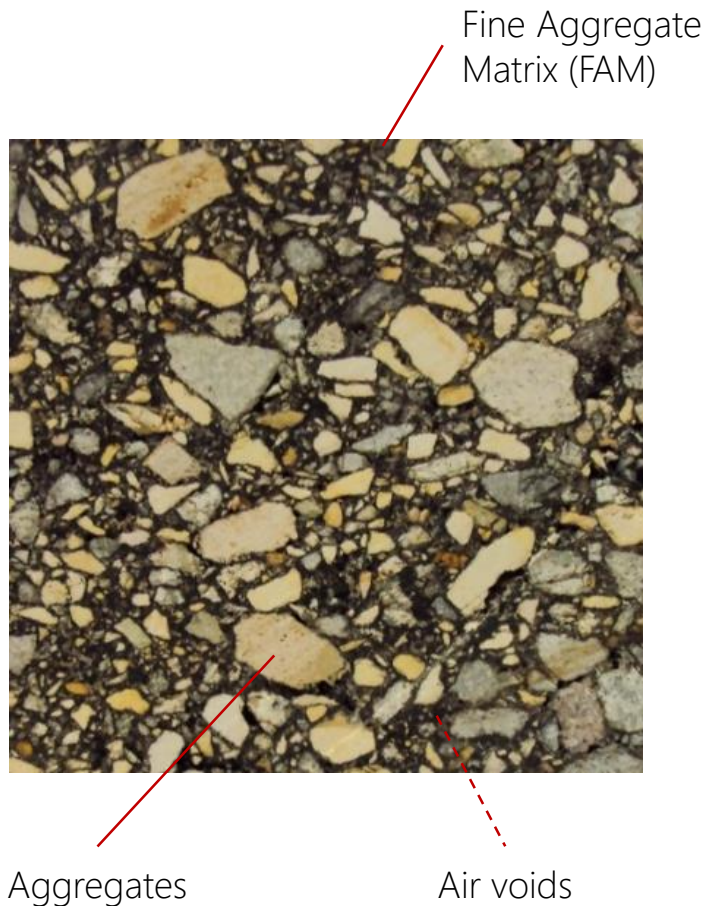
Daniel Castillo

31.05.2018

Transport Research Finland 2018

AC Heterogeneity

Initial considerations



- AC: Mixture and compaction of **bitumen, aggregates and air voids**. Heavily used in construction of road infrastructure, enduring traffic loadings and environmental conditions.
- Differences among AC constitutive phases' **response to mechanical and environmental solicitations**.
- AC is a **heterogeneous** material, and this heterogeneity may induce **variability** in the response.



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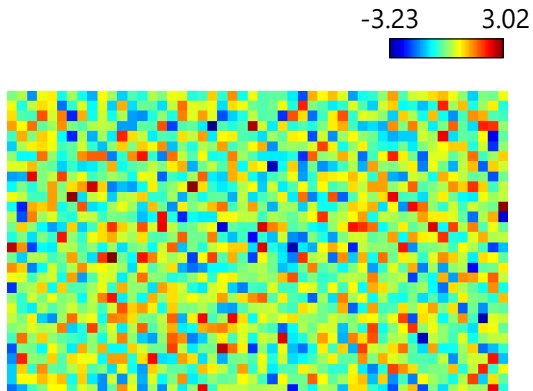
“Macro” approaches

AC Heterogeneity – “Macro”

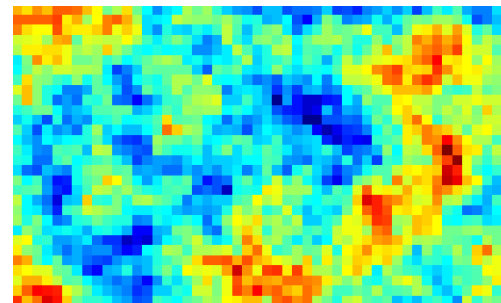


Random fields

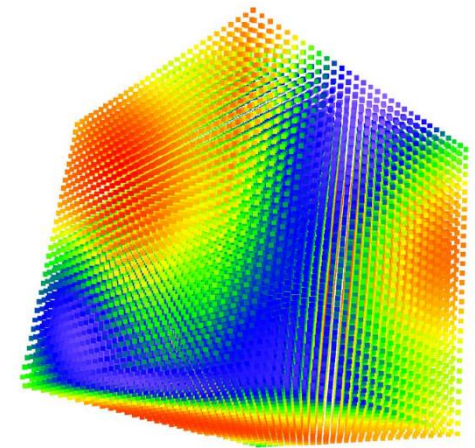
A **random field** is a n -dimensional vector of random values that exhibit spatial correlation.



Uncorrelated random normal numbers.



Correlated random field, isotropic.



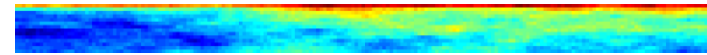
Three dimensional random field, isotropic

AC Heterogeneity – “Macro”

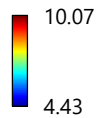
Methodology



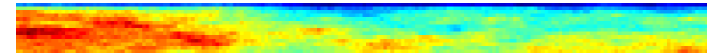
Random field of Air Voids



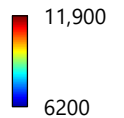
AV [%]



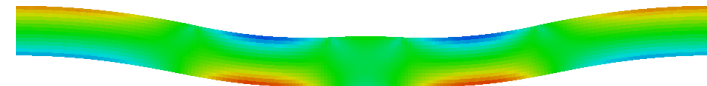
Calculated Linear Viscoelastic properties



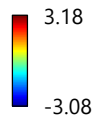
E_o [MPa]



Field of horizontal strains (ϵ_h)



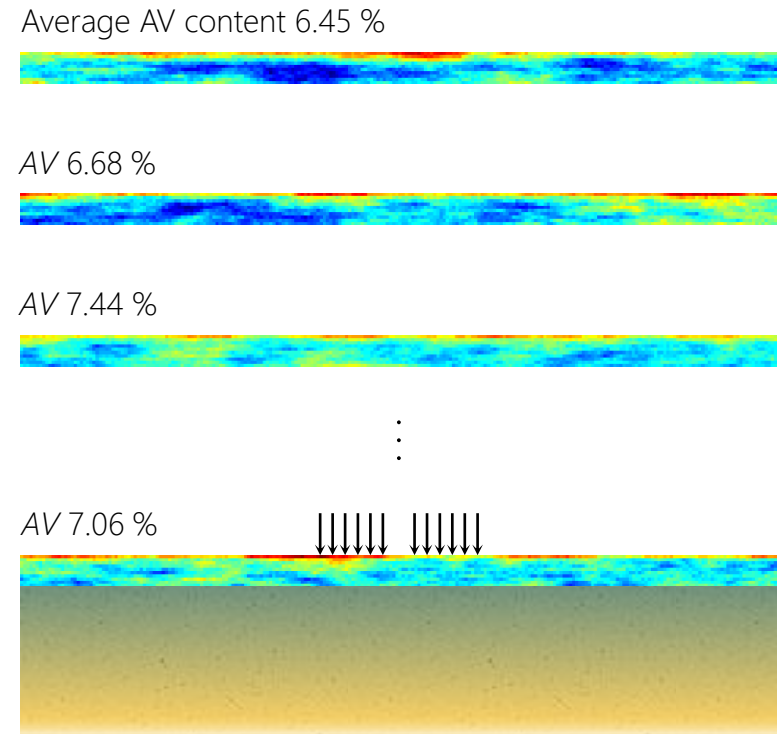
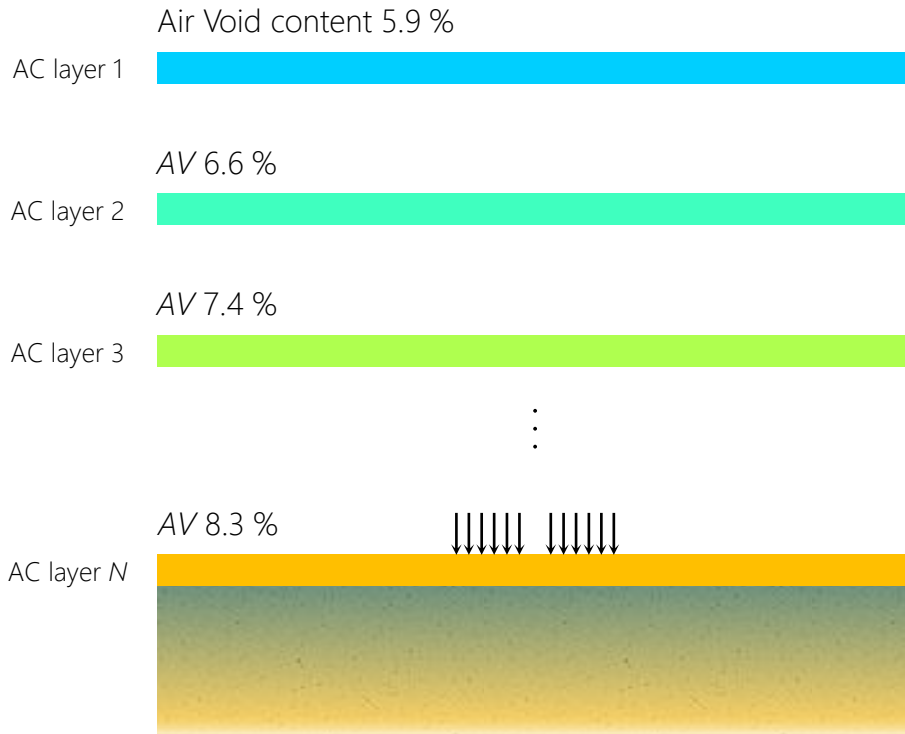
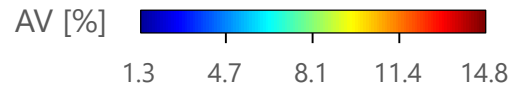
$\epsilon_h \times 10^{-4}$



AC Heterogeneity – “Macro”

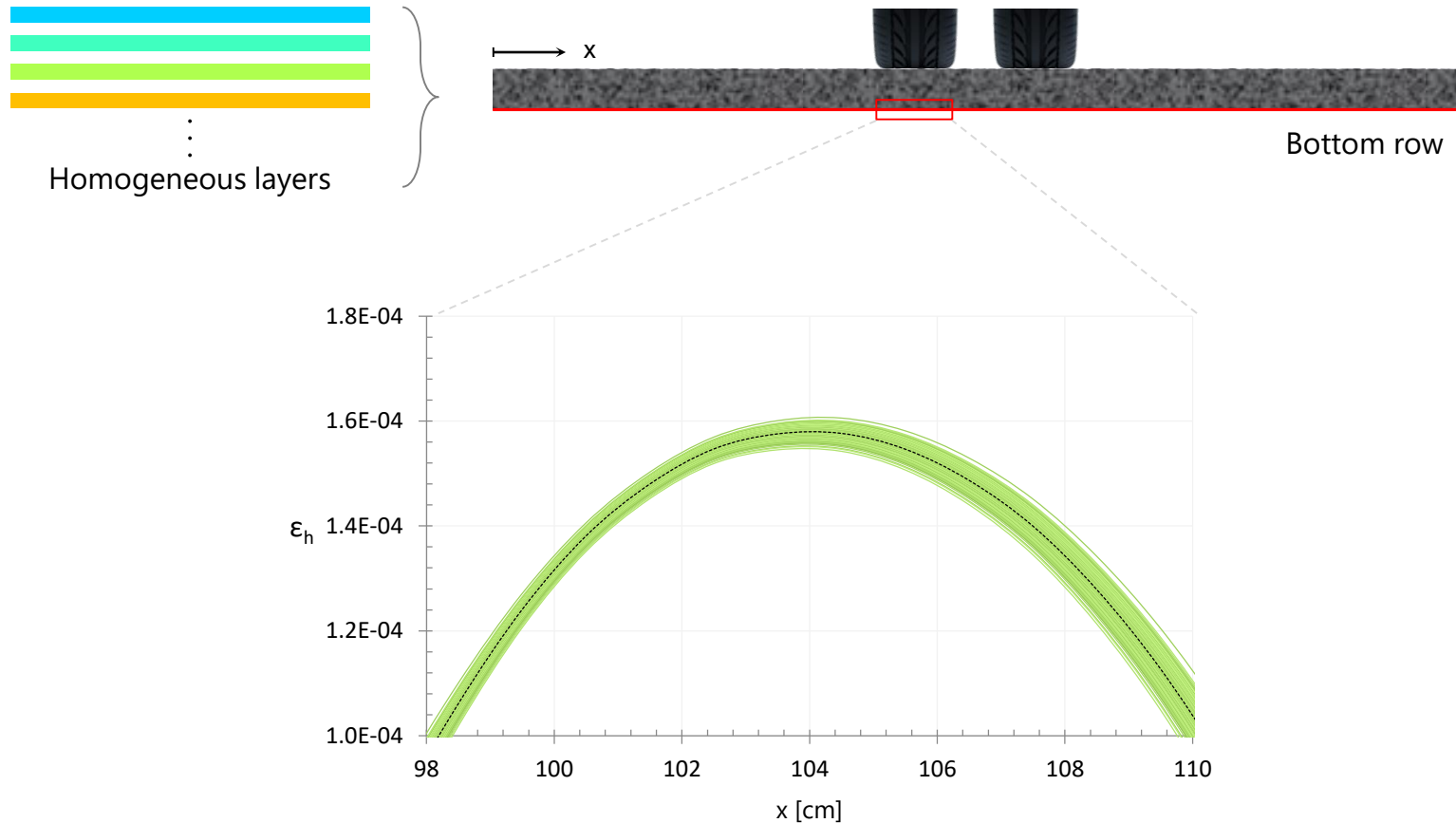


Computational applications



AC Heterogeneity – “Macro”

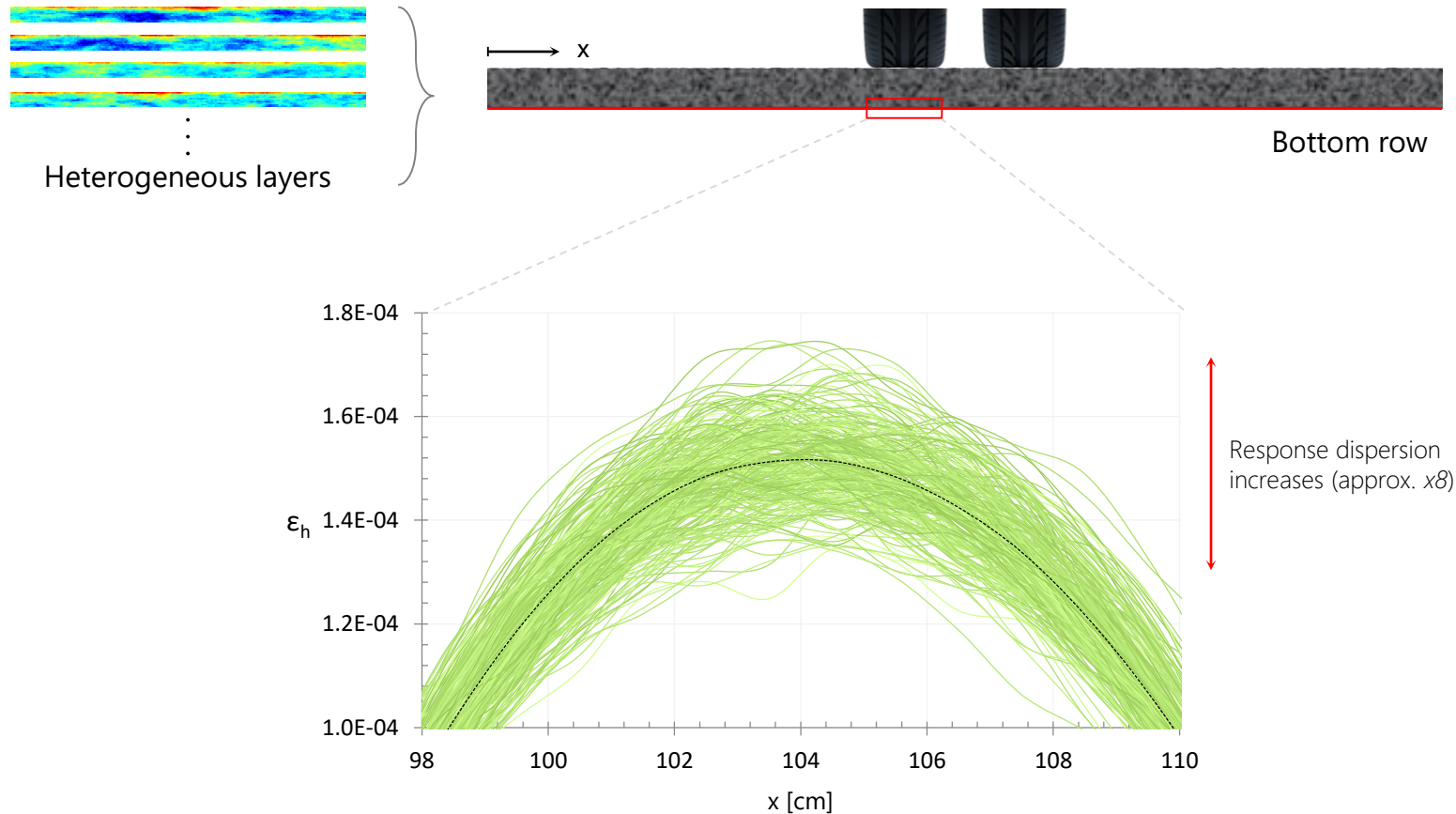
Computational applications



AC Heterogeneity – “Macro”



Computational applications



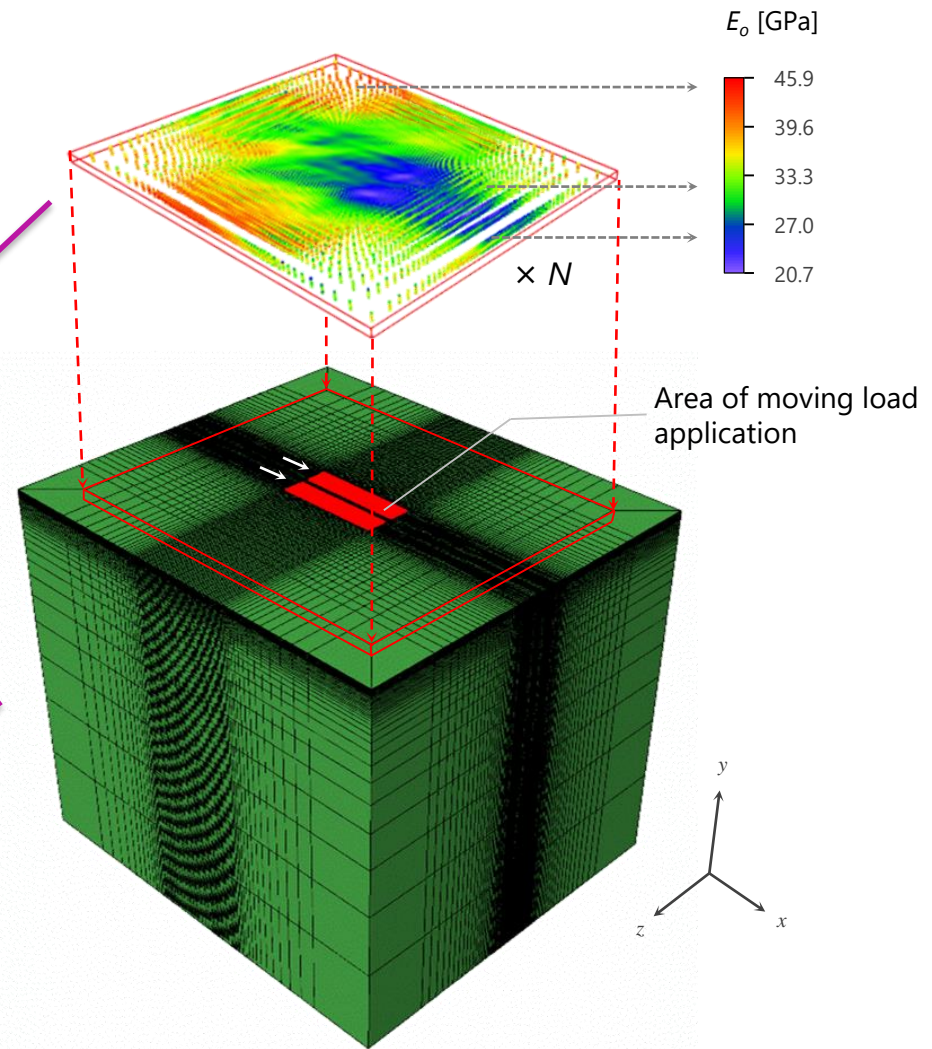
AC Heterogeneity – “Macro”

Computational applications



Heterogeneity in the asphalt material (3D RF)

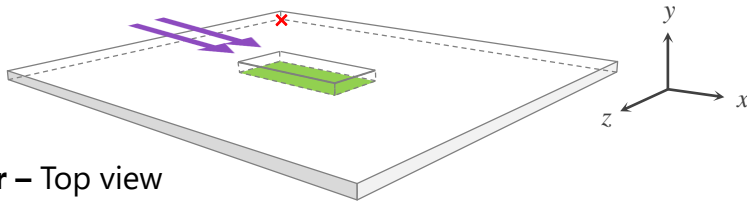
Heterogeneous FE model of the pavement structure



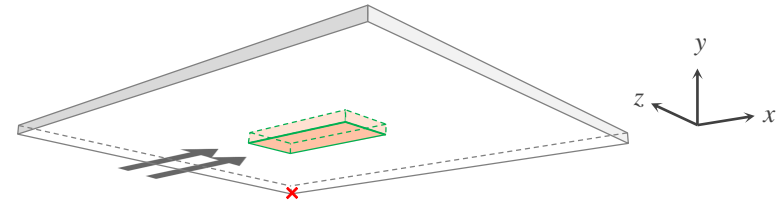
AC Heterogeneity – “Macro”



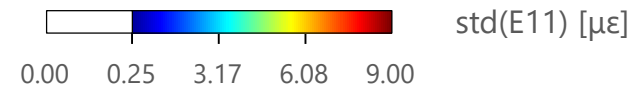
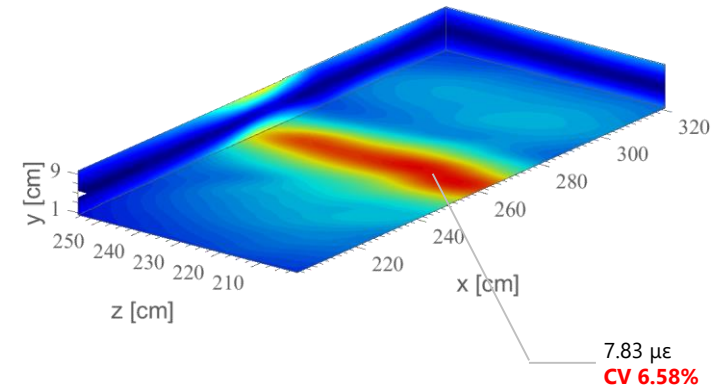
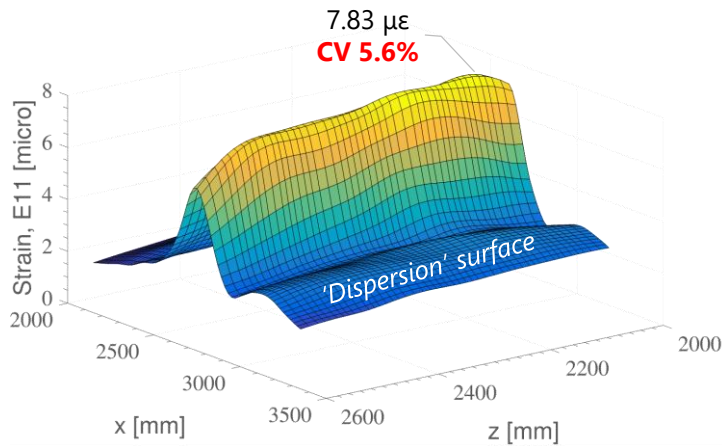
Computational applications



AC layer – Top view



AC layer – Bottom view





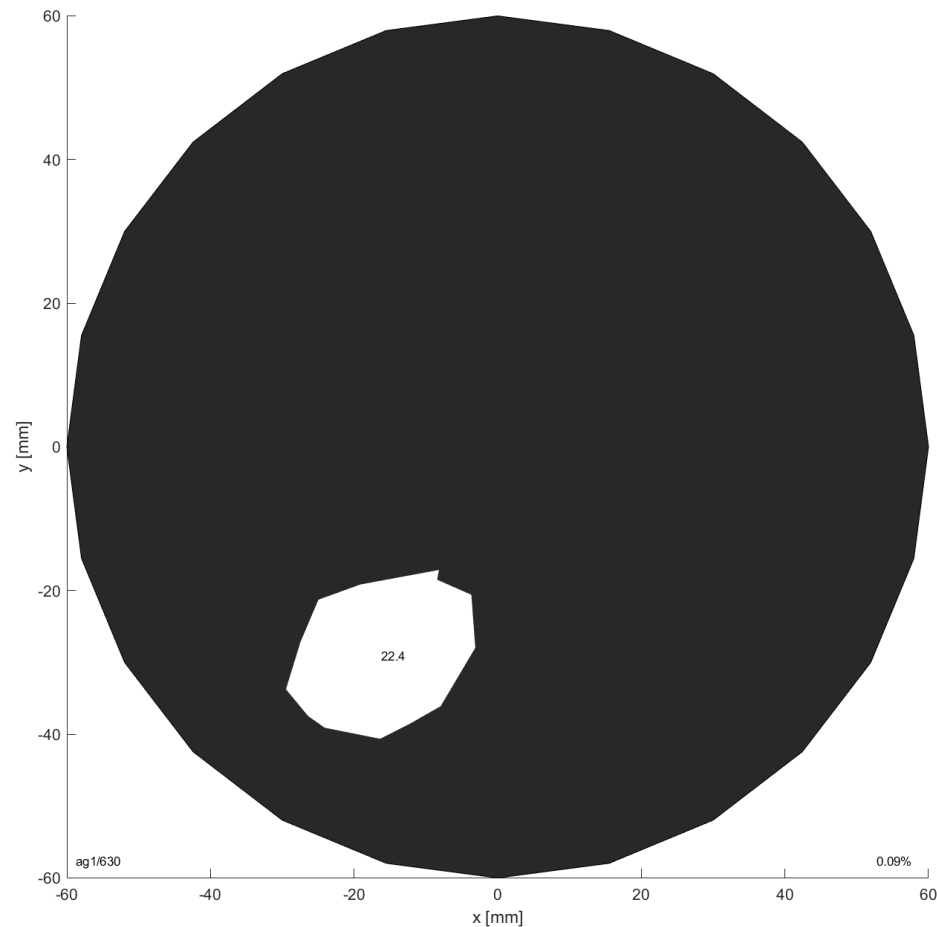
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“Micro” approaches

AC Heterogeneity – “Micro”



Random generator of microstructure (MG)

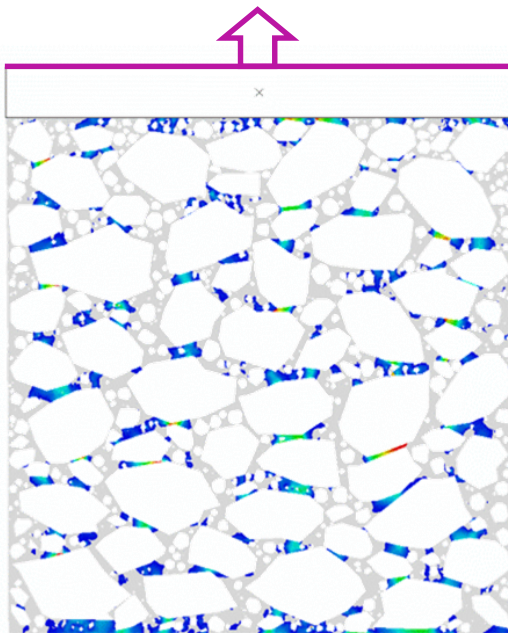
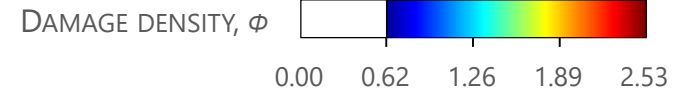


Random 2D
asphalt concrete
microstructure

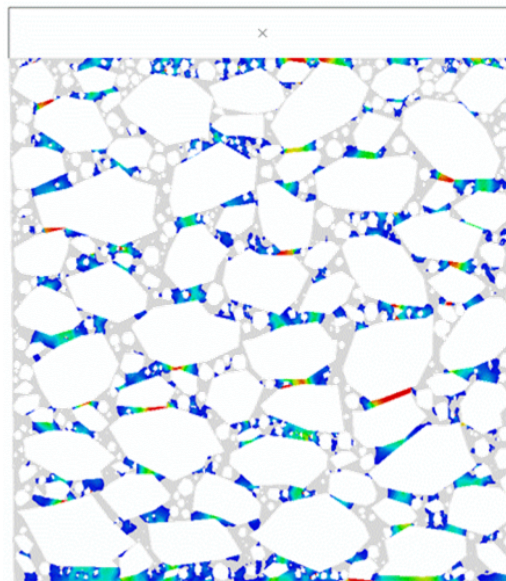
AC Heterogeneity – “Micro”



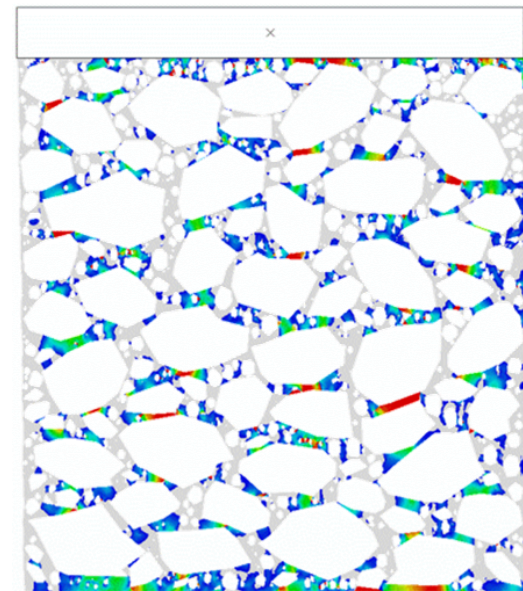
Random generator of microstructure (MG)



t = 150 s



t = 225 s



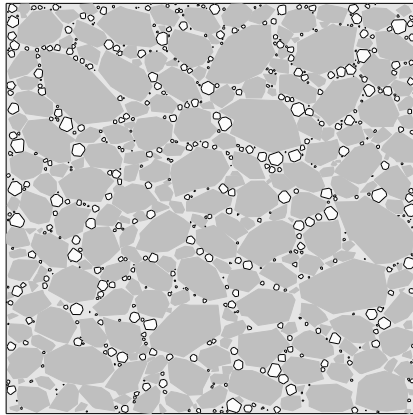
t = 300 s



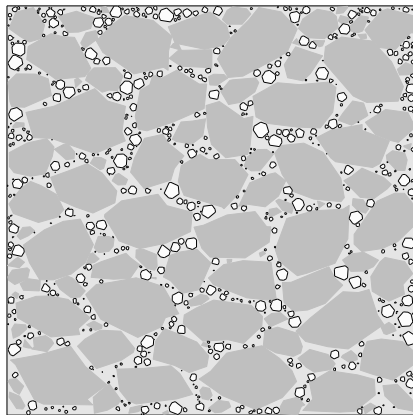
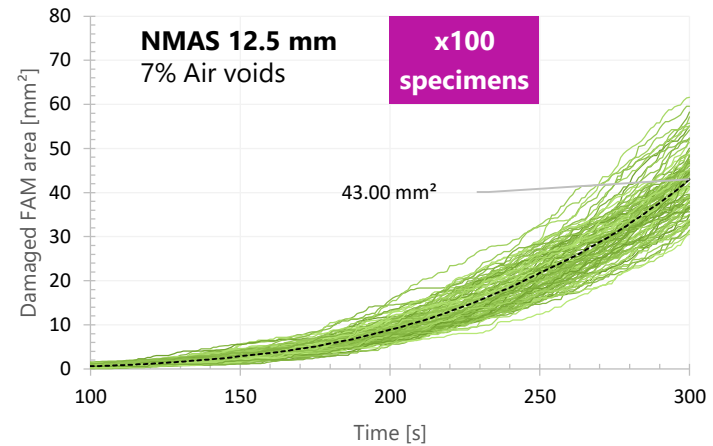
Pavement Analysis using **Nonlinear Damage Approach**

AC Heterogeneity – “Micro”

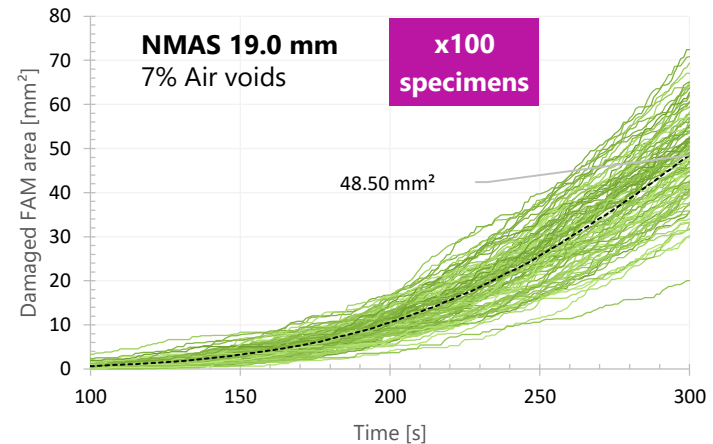
Random generator of microstructure (MG)



x100



x100



In summary...

■ *What did we do?*

We considered AC heterogeneity implicitly/explicitly into our computational models.

■ *Why did we do it?*

Heterogeneity has an important, measurable effect on the variability of material response. This is particularly true for a material as highly heterogeneous as asphalt concrete. Uncertainty data on mechanical properties/response is traditionally scarce.

■ *What can we do with it?*

- Several applications come to mind. In the previous modelling studies we just generated hundreds (!) of specimens, at random, with a degree of 'control' over properties that only a computer can provide. This can be seen as an **alternative to complement the laboratory work**, which requires resources (effort, time and materials – money). Also, traditional as well as non-traditional materials and mechanical properties can be tested (RAP, aged materials, aggregate shapes). Some sources call this “**virtual laboratory**”.
- Apart from the previous modelling studies, it is possible to apply the tools when developing **specifications**, and for **quality control**.
- We can estimate new **data on uncertainty in response**, which is difficult or sometimes impossible to obtain in the laboratory or the field.
- The tools provide a framework for approaching the modelling of heterogeneity to any existing/new materials; they have applicability to a **variety of infrastructure and building materials**.

Materials in nature are heterogeneous. Artificial materials, even more! We need to study and include this heterogeneity as an intrinsic part of our computational models.