Asphalt Research Consortium

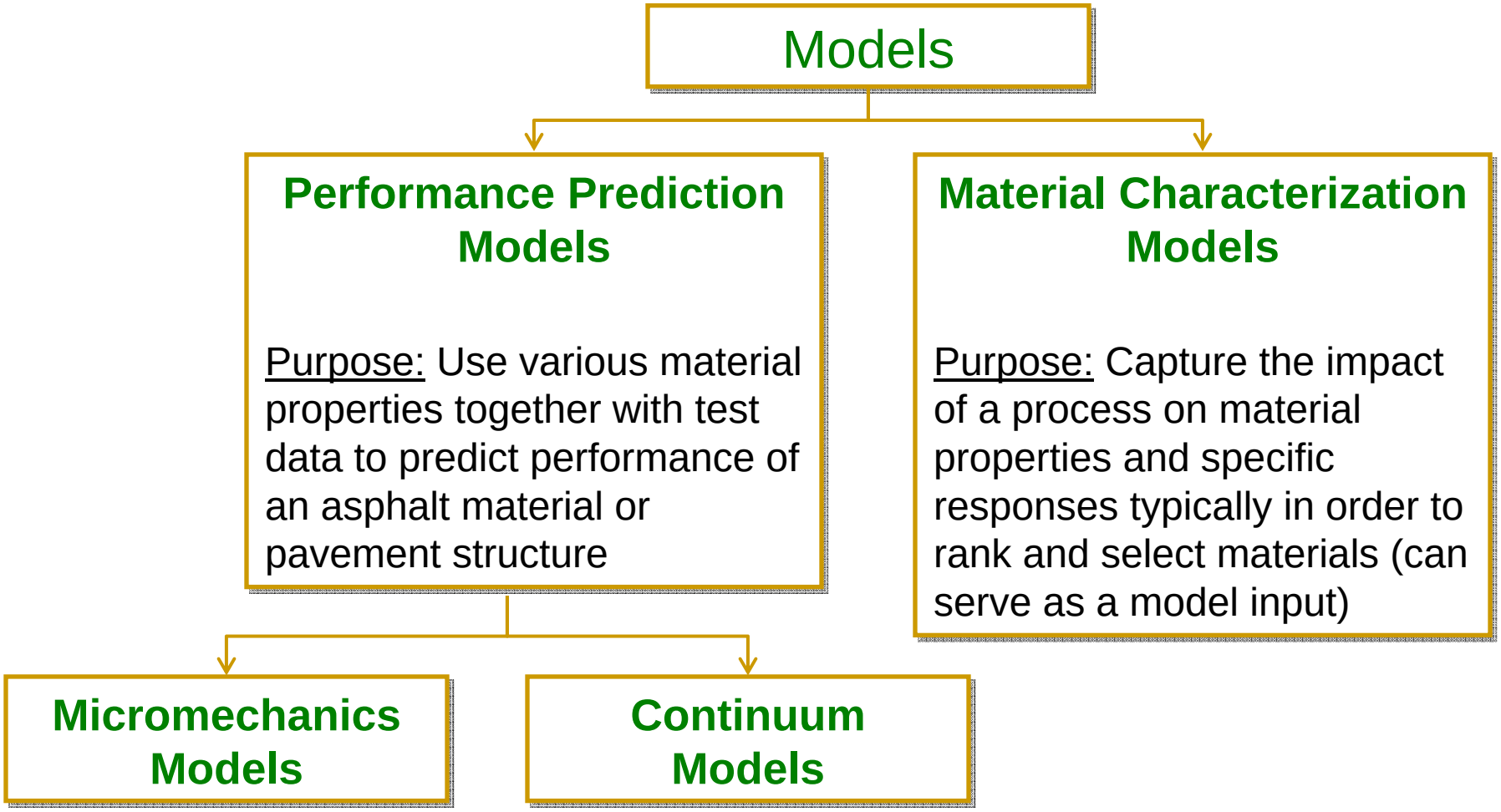
Modeling Approaches

Models ETG – Chicago, June 2008

Background

- ARC modeling approaches should be viewed as components of an overall mechanics approach to predict pavement performance
- Each model contributes to the ability of the approach to reliably predict damage in asphalt pavements
- Some of the models are intended to extract or “filter” material properties from test data or characterize (or even rank order) material behavior (binders, mastic and mixtures)
- Other models are intended to focus on the prediction of performance at a macro-scale

Background


Models
Performance Prediction Models
Purpose: Use various material properties together with test data to predict performance of an asphalt material or pavement structure
Material Characterization Models
Purpose: Capture the impact of a process on material properties and specific responses typically in order to rank and select materials (can serve as a model input)
Micromechanics Models
Continuum Models

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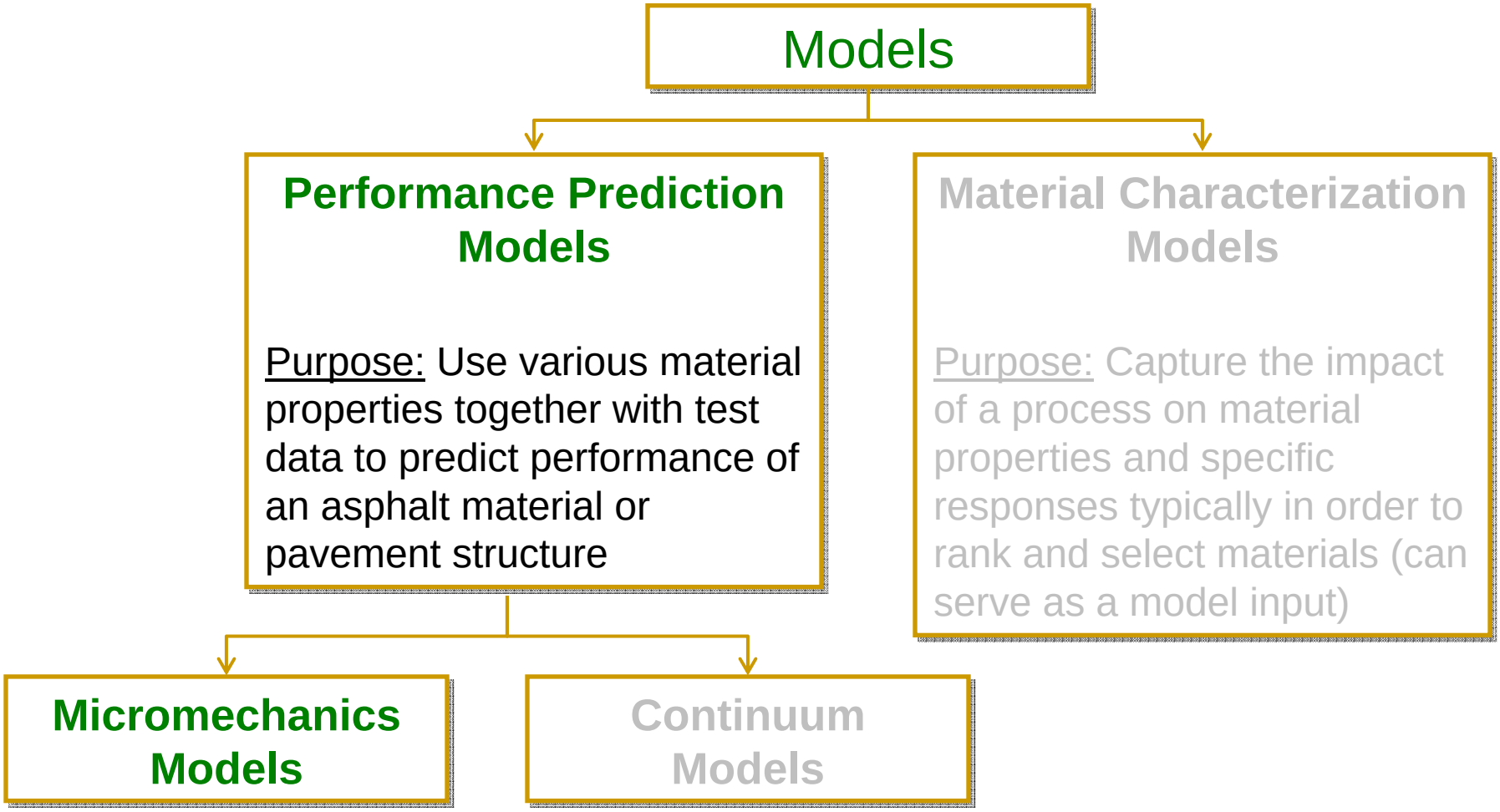
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Micromechanics Models
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Micromechanics Models

- Definition – Analyze a composite or heterogeneous material on the level of the individual phases that constitute the material
- Goal – Predict the responses of the composite
- Benefit – Determine behavior without resorting to testing of composite – predict full-scale, multi-axial properties

Micromechanics Models

- Purpose in ARC approach

  Serve as computational models that:

  - develop basic understanding of nucleation and propagation of micro cracks and their effect on overall stiffness,
  - link to continuum models, which predict pavement performance, and
  - form the basis for specification tool: i.e., estimate the binder's resistance to fatigue cracking when used with various aggregate types and gradations

Micromechanics Models

- Typical model inputs
  - material properties,
  - geometry: internal microstructure of asphalt mixtures (aggregates, air void distribution within the mixture, asphalt phase surrounding aggregates), and
  - load: any external boundary conditions imposed by loads and/or displacements
- Typical model outputs
  - stress, strain, & displacement,
  - mixture geometry (internal microstructure of bulk mixtures and geometry of mixture components), after application of process and
  - composite properties after application of process

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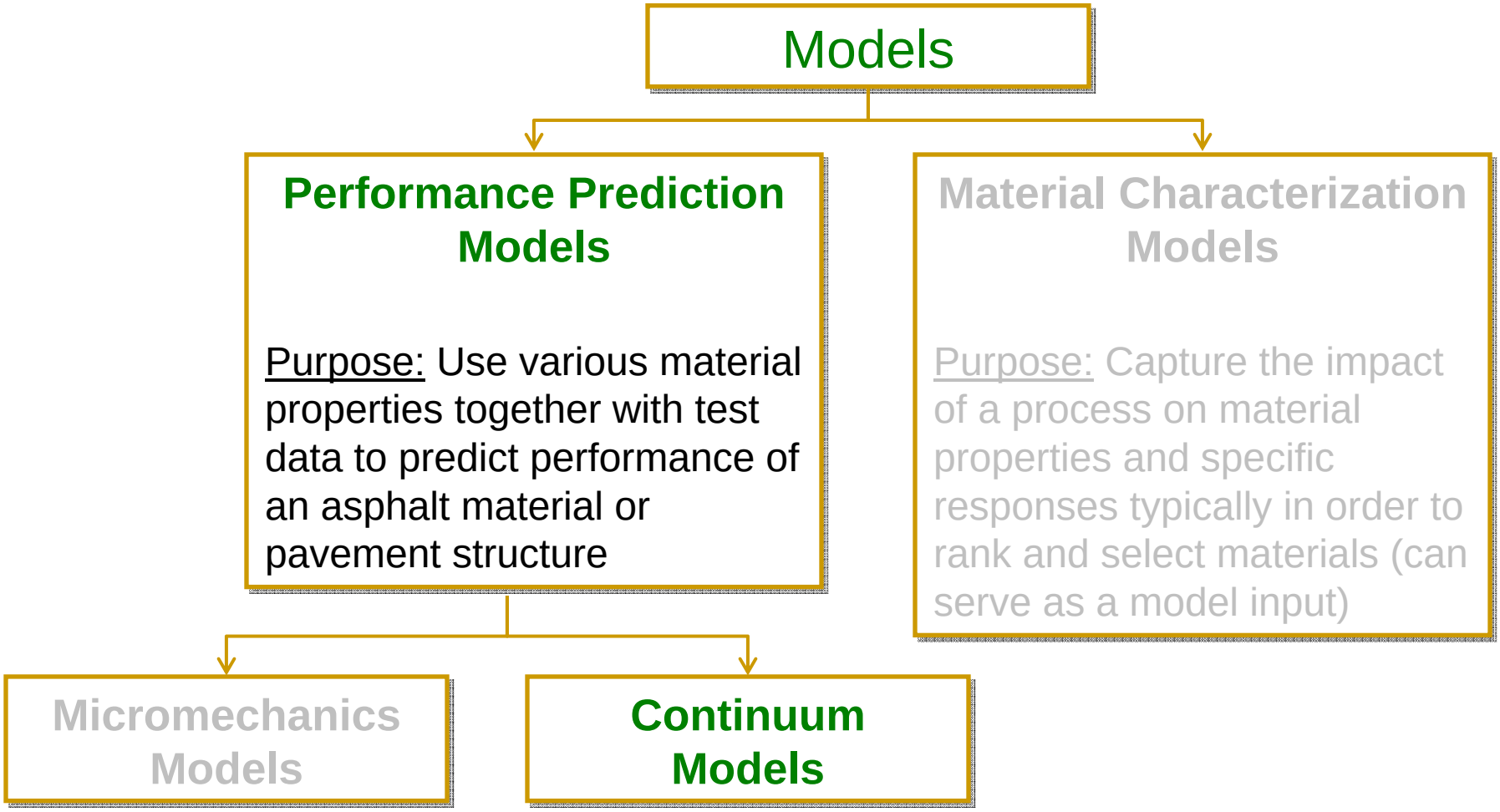
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Continuum Models

- Definition – Analyze kinematics and mechanical behavior of materials modeled as a continuum. Assumes that the substance of the body is distributed uniformly
- Goal – Express physical quantities in a form for computational convenience
- Benefit – Can be implemented in computational systems, i.e., finite element computer models

Continuum Models

- Purpose in ARC

  Develop three-dimensional visco-elasto-plastic continuum damage models and implement it in finite element method to predict permanent deformation, fatigue cracking and moisture damage. More specifically these models will be used to:

  - predict performance of asphalt concrete and asphalt pavement structure,
  - design of mixtures and pavements with high resistance to distress, and

Continuum Models

Performance Prediction

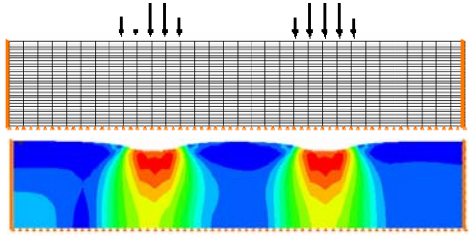
Material Characteristics
- Aggregate shape
- Anisotropy
- Adhesive and Cohesive bond strengths
- Healing
- Binder rheology

Pavement Structure
- Thickness
- Sub grade type

Environmental Factors
- Temperature
- Humidity differential
- Rainfall

Loading Conditions
- Type of loading
- Tire pavement interaction

FEM Modeling



Calibration (minimize shift factor dependency)

Prediction of material distress

Continuum Models

- Typical model inputs
  - material properties,
  - relationship between damage evolution and mixture response, and
  - yield and failure criterions
- Typical model outputs
  - permanent deformation,
  - fatigue cracking, and
  - deterioration due to moisture damage

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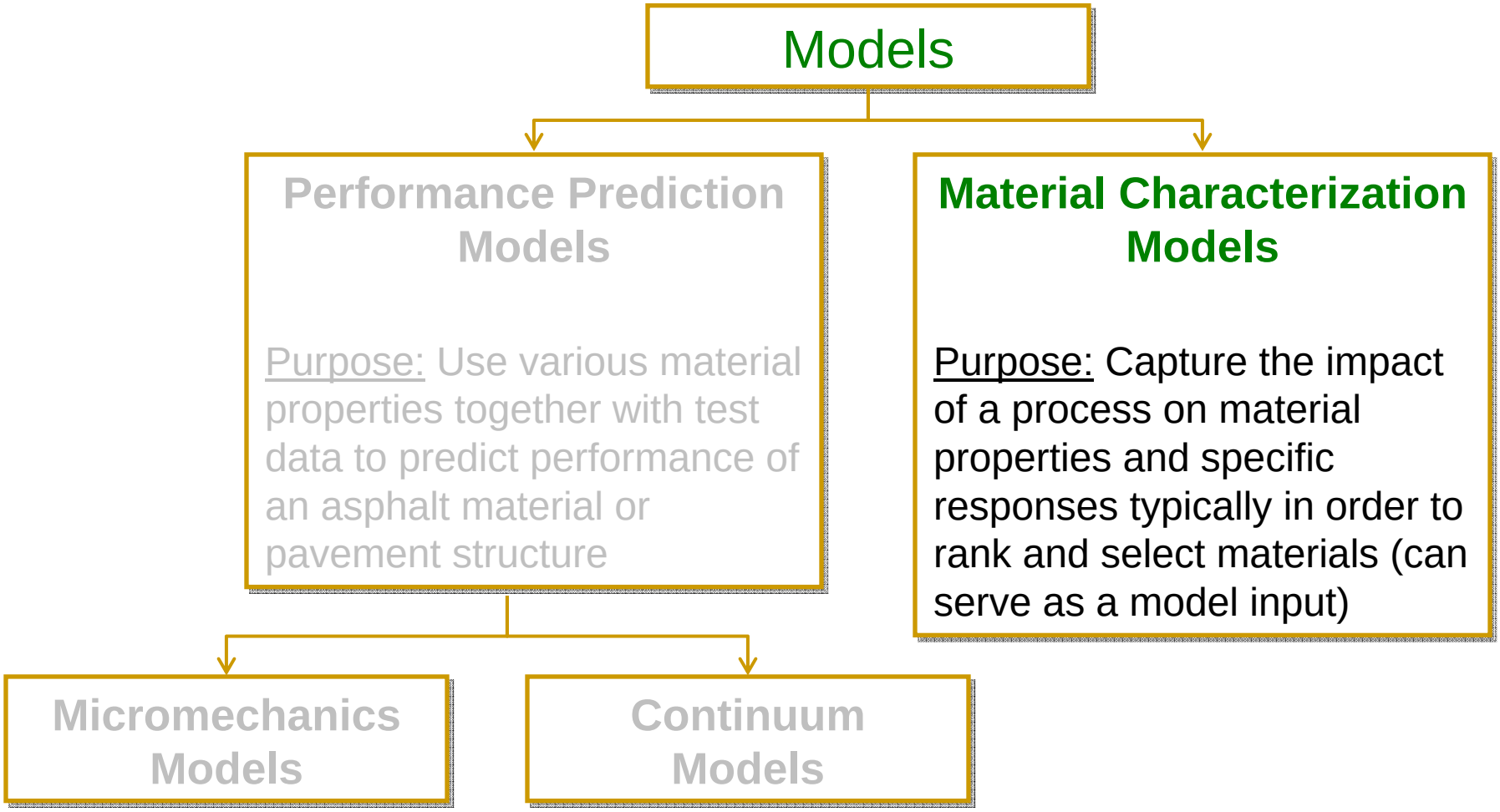
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Material Characterization Models

- Purpose

  Capture the impact of a process or processes that alter the material properties and consequently the engineering response of the material or composite

- Examples of Models

  - oxygen diffusion through the matrix of the asphalt mixture *(aging)*,
  - rate of asphalt binder oxidation *(aging)*,
  - moisture diffusion through the binder, mastic or mixture at different length scales *(moisture damage)*,
  - rate of crack wetting and/or intrinsic healing of asphalt binders *(healing)*, and
  - mechanical response of the asphalt mixture based on the response of its individual components and vice-versa *(engineered materials)*