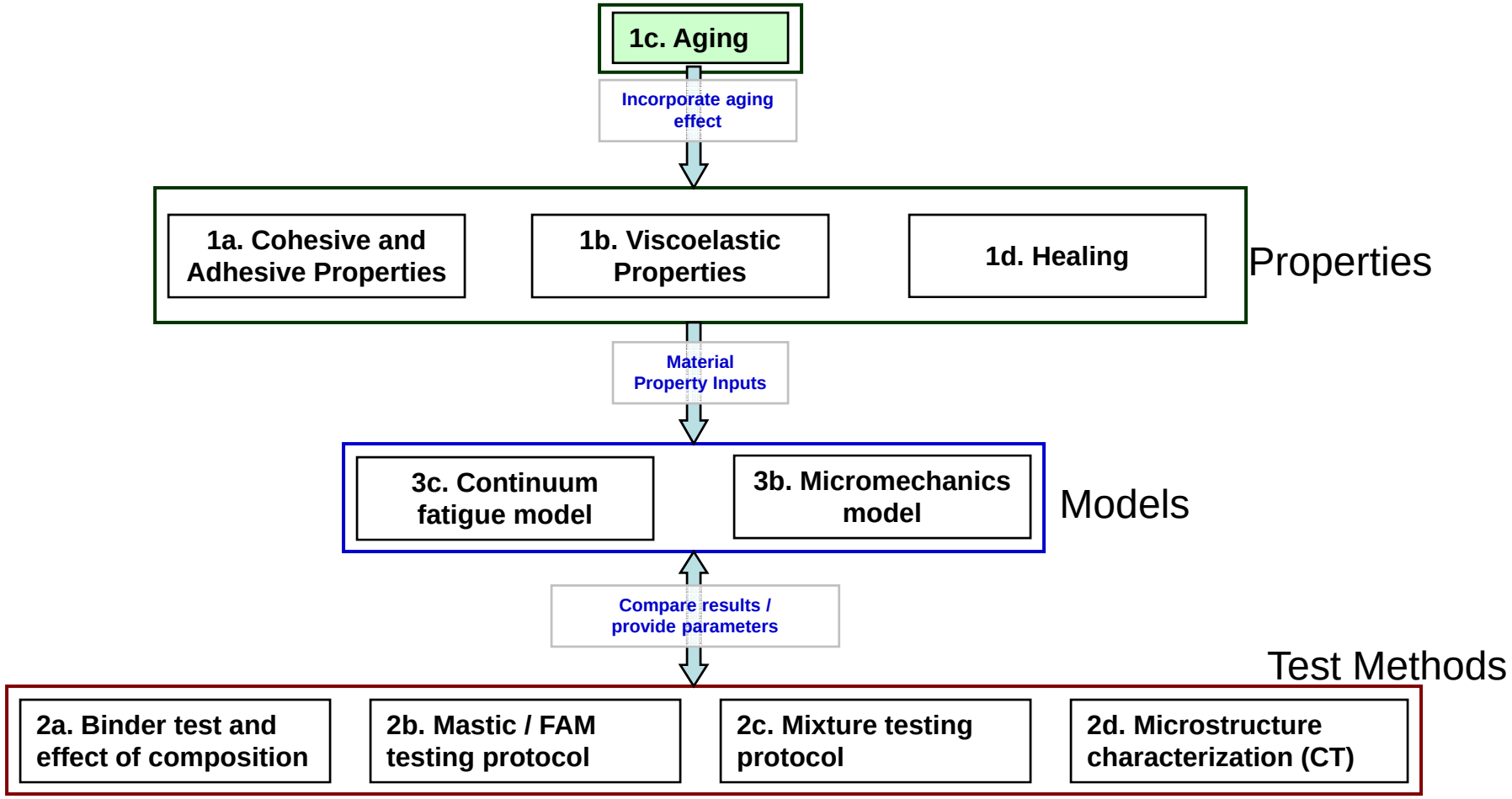
Asphalt Research Consortium

Fatigue

Category	Specific Work Element	Consortium Partner				
		WRI	TTI	UWM	UNR	AAT
F1. Material / Mixture Properties	a) Cohesive and adhesive properties		X			
	b) Viscoelastic properties		X			
	c) Aging		X			
	d) Healing			X		
F2. Test method Development	a) Binder tests and effect of composition			X		
	b) Mastic testing protocol		X			
	c) Mixture testing protocol		X			
	d) Microstructure characterization (X-Ray CT)		X			
	e) Verification (DSR vs. mixture fatigue)		X	X		
F3. Modeling	a) Asphalt microstructure model	X	X	X		
	b) Micromechanics model		X			
	c) Unified continuum fatigue model		X			
	d) Calibration and validation		X	X	X	

Fatigue

Work Elements ⟺ Hypothesis



Fatigue

F1c. Aging

Objectives:

1. To assess material and microstructure characteristics of mixtures as affected by oxidative aging
2. Effect of aging on fundamental material properties

Fatigue

F1c. Aging

Research Approach:

- Literature review and detailed work plan
- Develop a transport model for oxidative aging in pavements based on

  - binder oxidation kinetics,
  - model for calculating temperature as a function of time and depth
  - model for oxygen transport and diffusion in binder

- Determine effect of oxidative aging on material properties such as viscoelastic properties, fracture resistance, and healing (Later Start)

Fatigue

F1c. Aging

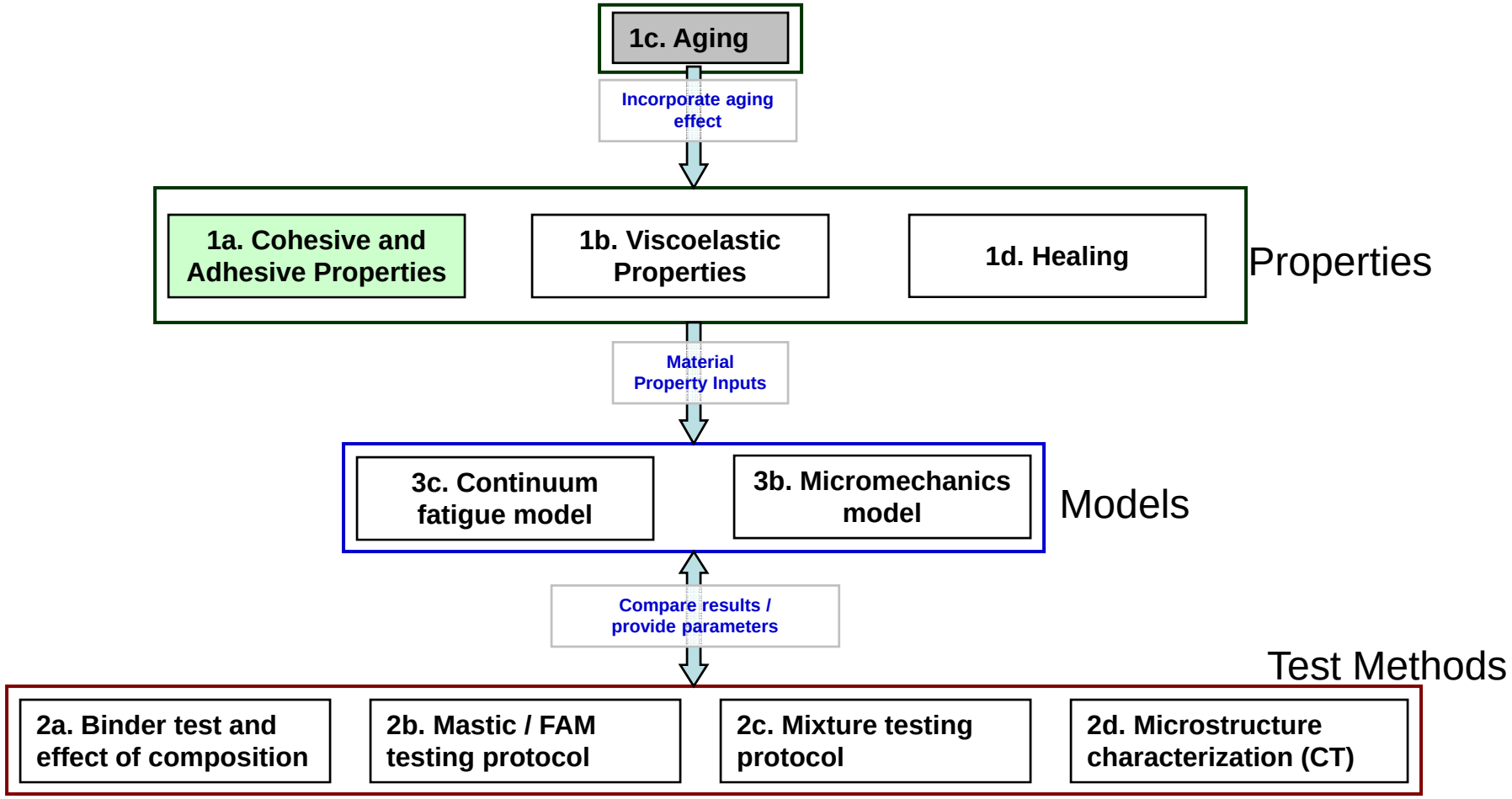
Relevance to Area Goal and Other Work Elements:

1. Transport model can be used to determine the extent of oxidative aging as a function of:
   - climate
   - depth below the asphalt pavement surface
   - microstructure characteristics of the mixture
   - properties of the binder (activation energies, oxygen reaction order values, oxygen diffusion coefficient)

2. Change in material properties as a function of aging is an essential input for long term modeling of pavement performance using continuum models or long term modeling of mixture performance using micromechanics model

Fatigue

Work Elements ⟺ Hypothesis



Fatigue

F1a. Cohesive and Adhesive Properties

Objective:

To provide a fundamental material property for micromechanical modeling of asphalt mixture

Research Approach:

- Refine existing protocols to determine thermodynamic work of adhesion / cohesion
- Evaluate and select models and test methods to quantify mechanical work of adhesion / cohesion
- Develop relationship between thermodynamic work of adhesion / cohesion to mechanical work of adhesion / cohesion for binders and mastics

Fatigue

F1a. Cohesive and Adhesive Properties

Relevance to Area Goal and Other Work Elements:

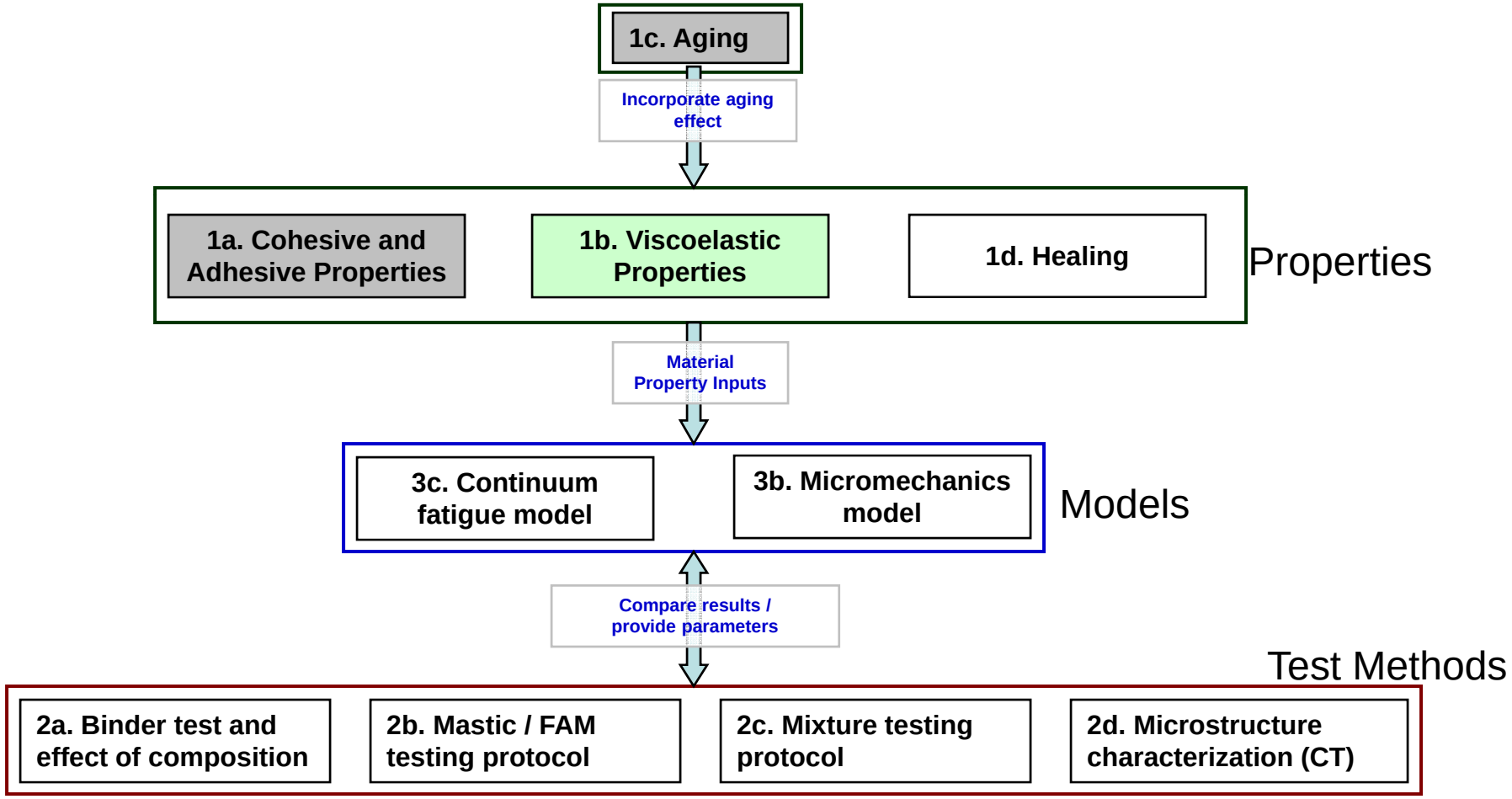
1. Work of cohesion / adhesion is an important material property input for:

- micromechanical models to evaluate mixture performance
- analytical models that can be used as a part of the continuum model to evaluate pavement performance

2. This work element will produce recommendations for the most suitable protocol (thermodynamic or mechanical) to obtain these important material properties

Fatigue

Work Elements ⟺ Hypothesis



Fatigue

F1b. Viscoelastic Properties

Objective:

To determine linear and non-linear viscoelastic properties of asphalt materials

Research Approach:

• Evaluate and select suitable model to capture non-linear effect of viscoelasticity in cyclic loading, eg. Schapery's non-linear model

• Develop a test protocol to determine the parameters required for the model

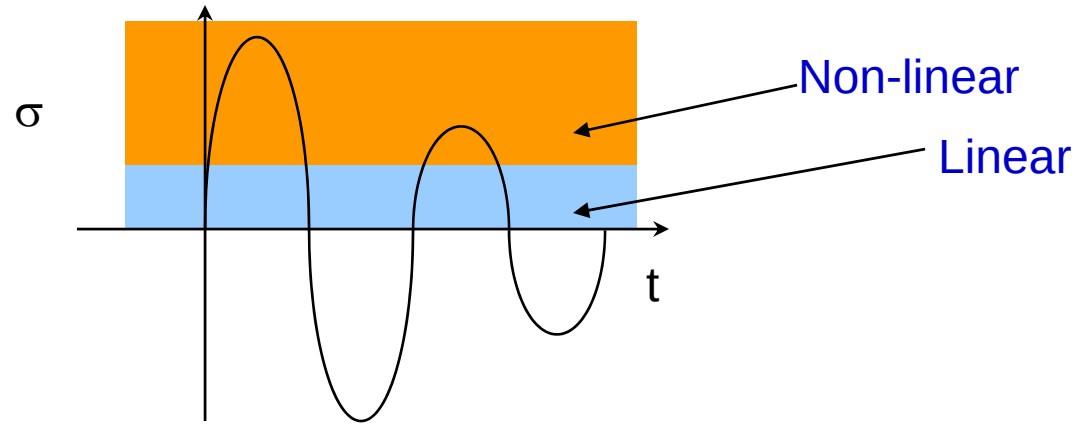
• Conduct cyclic load tests under different stress / strain amplitudes and apply the model to separate viscoelastic properties and damage from the test response

Fatigue

F1b. Viscoelastic Properties

Relevance to Area Goal and Other Work Elements:

1. Non-linearity and damage have similar manifestation in a cyclic load test. Developing a model to capture non-linear viscoelastic response of the material in a cyclic load test is important to differentiate between the two

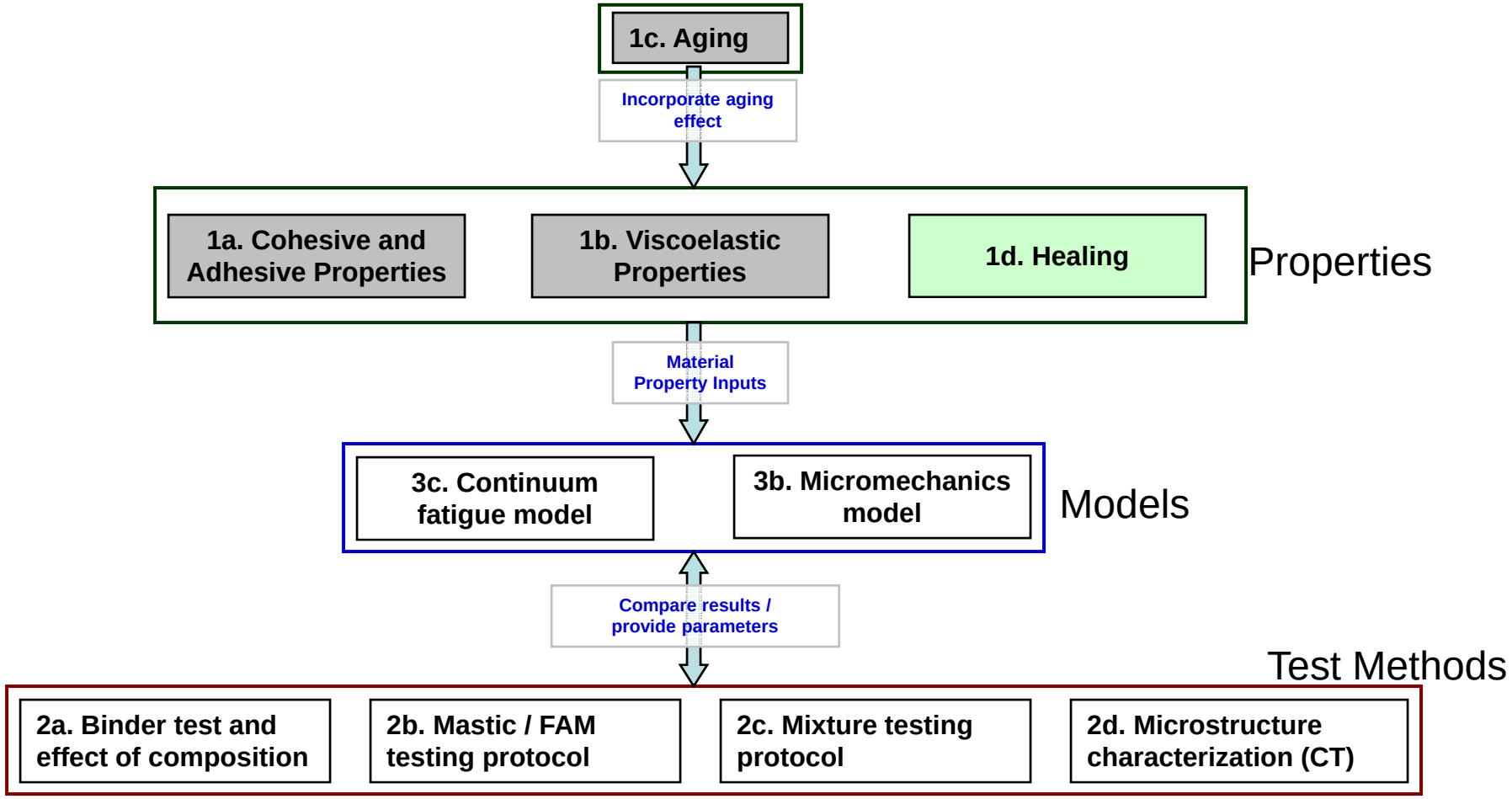


Phase angle from cyclic load test is an averaged representation of linear & non-linear response, therefore it cannot be extended from one stress/strain amplitude to another

2. This analytical model can be combined with crack propagation criterion for use in a continuum model to predict fatigue cracking performance of a pavement subjected to different magnitudes and rates of loading.

Fatigue

Work Elements ⟺ Hypothesis



Fatigue

F1d. Healing

Objective:

1. To determine a time dependent material property that can be used to characterize the net healing between crack surfaces, and
2. To determine the relationship between these properties, healing, and endurance limit

Research Approach:

• Evaluate mechanisms of healing and select materials that best represent these mechanisms

• Review and select test methods that measure properties related to healing or a time dependent material property that quantifies healing

• Express healing in a form that can be readily accommodated in existing analytical models for crack growth

• Measure endurance limit for different materials and evaluate its relationship to healing parameter

Fatigue

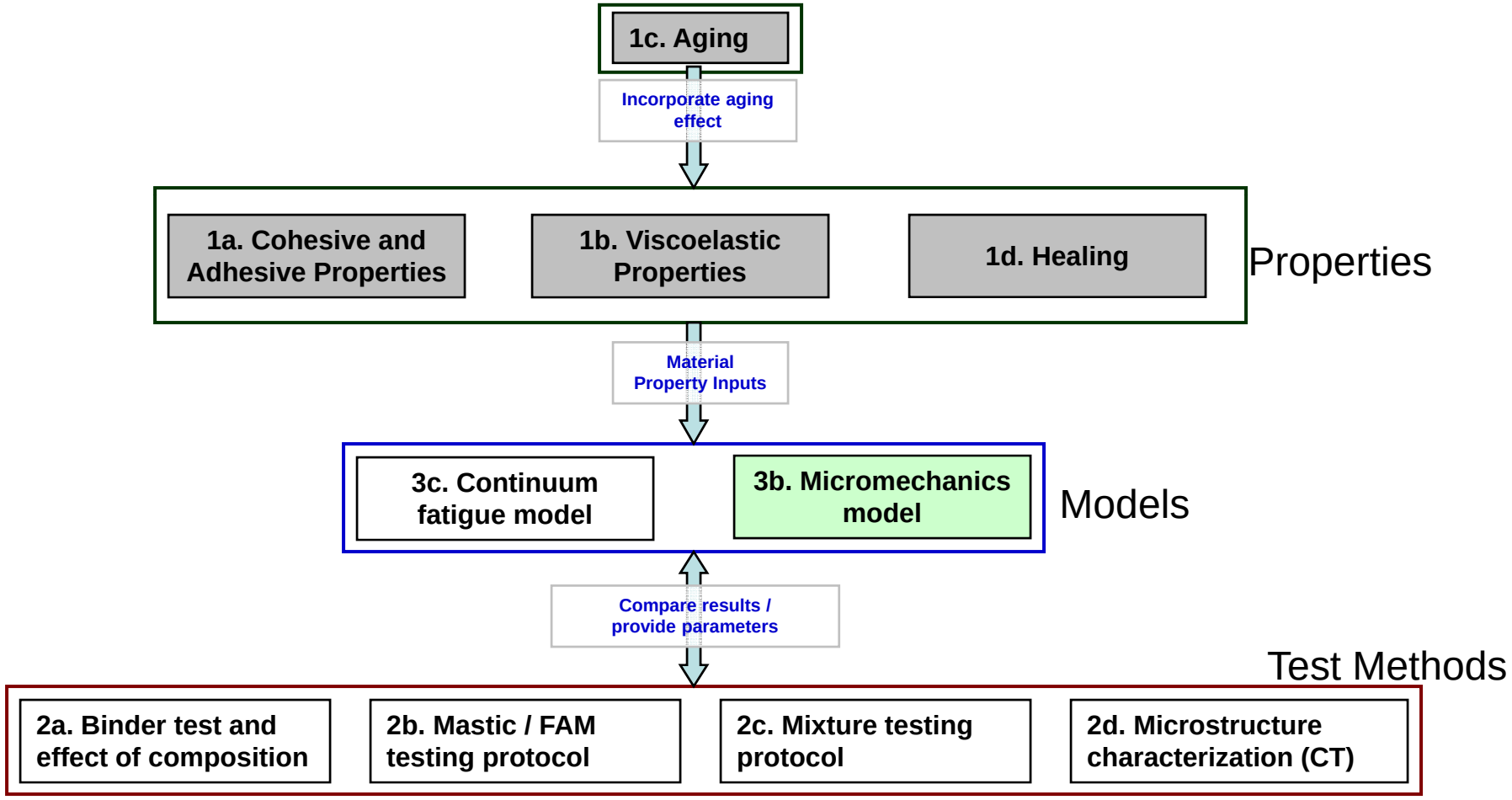
F1d. Healing

Relevance to Area Goal and Other Work Elements:

Healing is an integral part of the fatigue process. Determining a parameter that represents the time dependent healing characteristics of different asphalt materials is an essential input for any micromechanical or continuum model

Fatigue

Work Elements ⟺ Hypothesis



Fatigue

F3b. Micromechanical Models

Objective:

To develop a micromechanical model that will unify material and mixture properties to predict the performance of a mixture

Research Approach:

- Two approaches of DEM and FEM will be considered
- Two different length scales will be considered in each model:
    - o use of binder and filler properties to predict performance of mastic
    - o use of mastic and aggregate properties to predict performance of the mixture
- The models will be validated / calibrated using a combination of mechanical tests and NDT such as X-Ray CT

Fatigue

F3b. Micromechanical Models

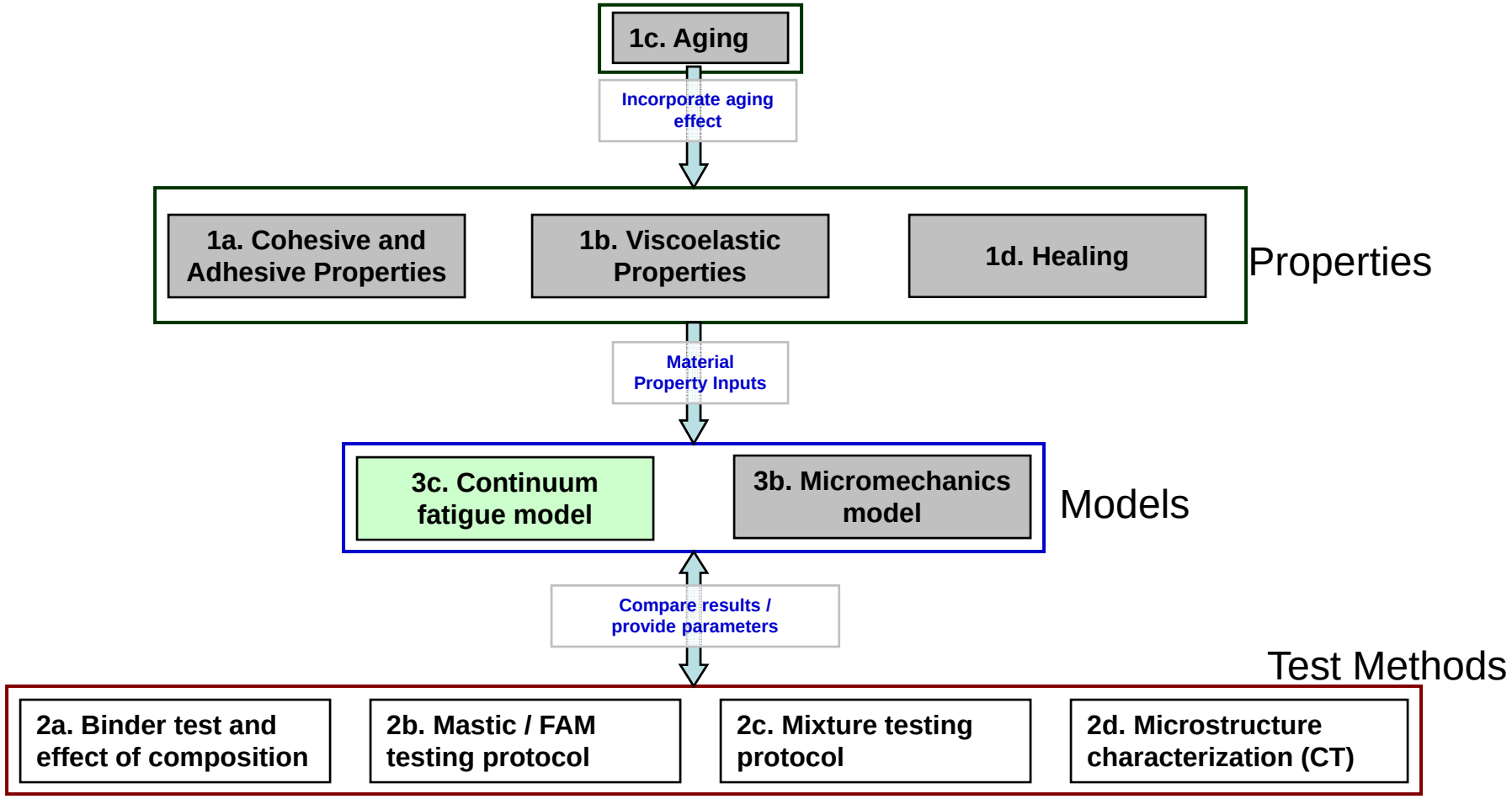
Relevance to Area Goal and Other Work Elements:

Micromechanical models are important to evaluate and predict the material performance

In most cases, once the material properties for a suite of different materials is available, it would require only computational work to determine material proportions and binder – filler – aggregate combinations that yield the most optimal performance for a given service condition.

Fatigue

Work Elements ⟺ Hypothesis



Fatigue

F3c. Continuum Fatigue Model

Objective:

To develop a continuum fatigue model that will unify material and mixture properties to predict the pavement performance in terms of fatigue and plastic or permanent deformation

Research Approach:

- Two approaches, a viscoelastic-viscoplastic model and the ???

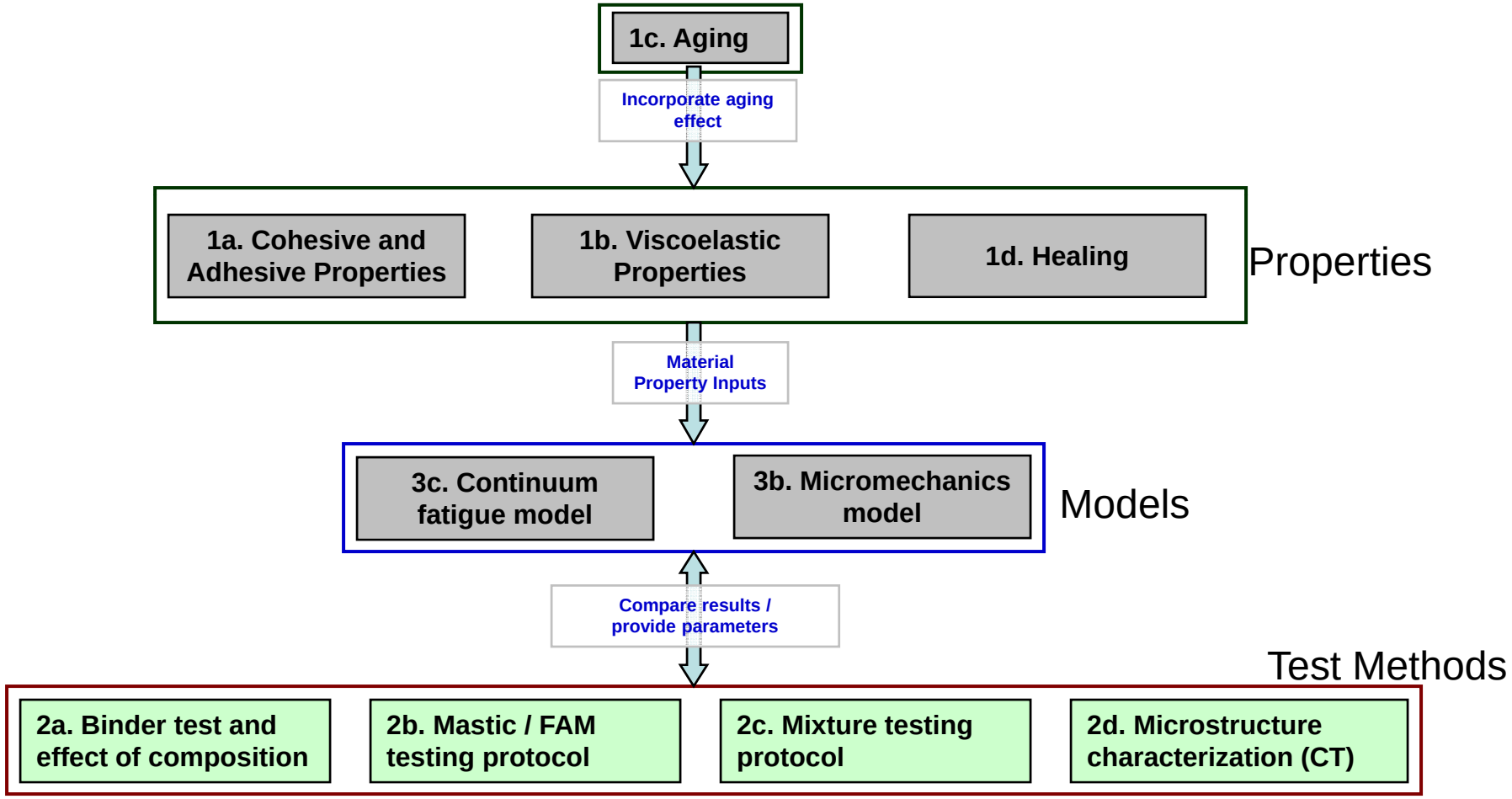
Fatigue

F3c. Continuum Fatigue Model

Relevance to Area Goal and Other Work Elements:

Fatigue

Work Elements ⟺ Hypothesis



Fatigue

F2. Test Methods

Objective:

1. To qualify and select materials during the mixture design process
2. To obtain material property inputs required for micromechanical and continuum modeling
3. To validate and/or calibrate micromechanical models

Research Approach:

Test methods and multi scale modeling will be conducted at different length scales:

- materials
- mastic
- fine aggregate matrix
- mixture