Functional Durability-related Bitumen Specification (FunDBitS)

Binder/aggregate interaction

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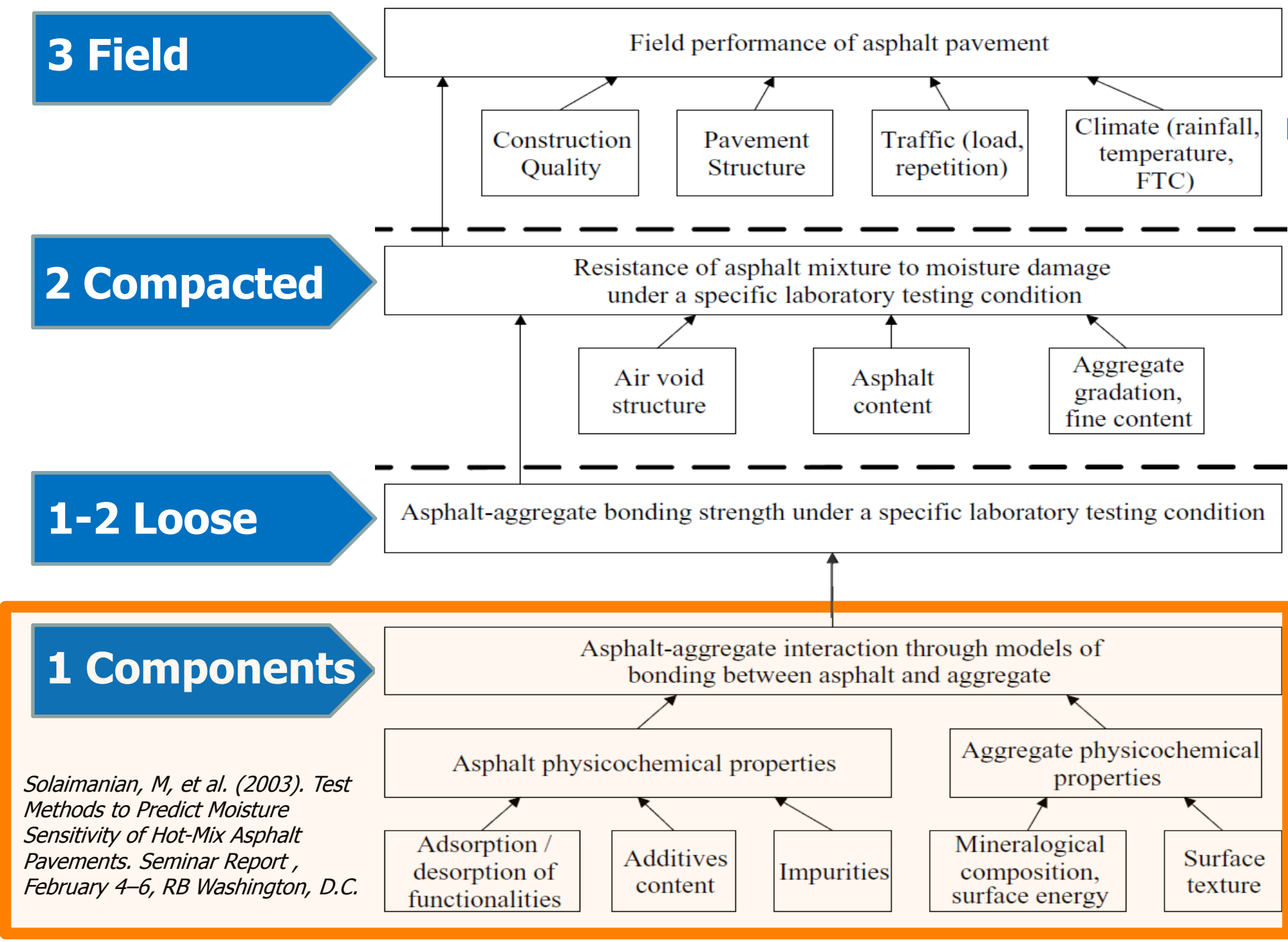
Outline

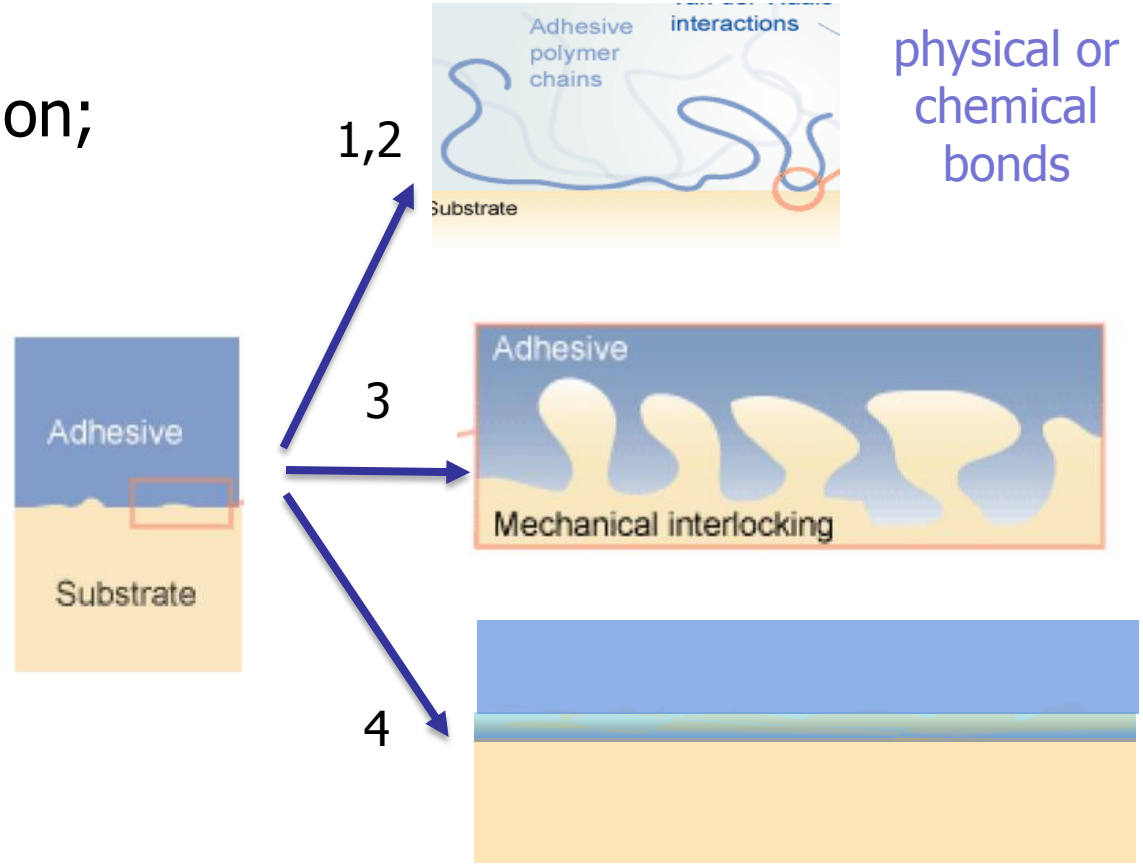
- Levels of binder/aggregate (adhesion) assessment
- Adhesion mechanisms
- Level 1: components
  - Surface free energy concept (SFE)
- Levels 1-2: loose mixture
  - Pull-off tests
  - Rolling bottle test
  - Boiling water test
- Levels 2 and 3: compacted asphalt mixtures



Solaimanian, M, et al. (2003). Test Methods to Predict Moisture Sensitivity of Hot-Mix Asphalt Pavements. Seminar Report , February 4–6, RB Washington, D.C.

Bitumen-aggregate adhesion; Proposed mechanisms:

1 **Physical adsorption,**
2. **Chemical bonding,**
3. **Mechanical interlocking,**
4. **Weak boundary layers**



Parker, R. S., Adhesion and Adhesives, New York: Pergamon Press, 1966.

Different theories have been applied to bitumen–aggregate systems, among them the most popular one:

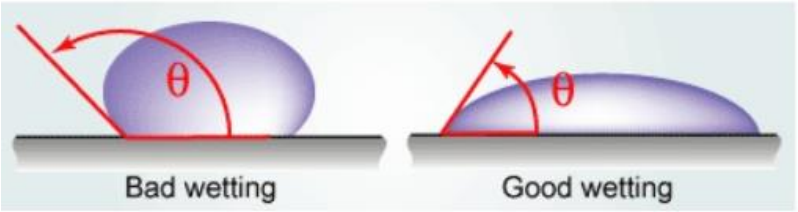
* Three component surface energy concept: dispersive, acid & base interactions (electron-acceptor and electron-donor interactions)

Three component surface energy (SFE) concept:

1. The SFE components are determined on the aggregates and on the bitumen in separate experiments (using probe materials)

2. Allows to calculate the DRY adhesive bond strength between bitumen and aggregate

3. Allows to calculate the WET adhesive bond strength between bitumen and aggregate



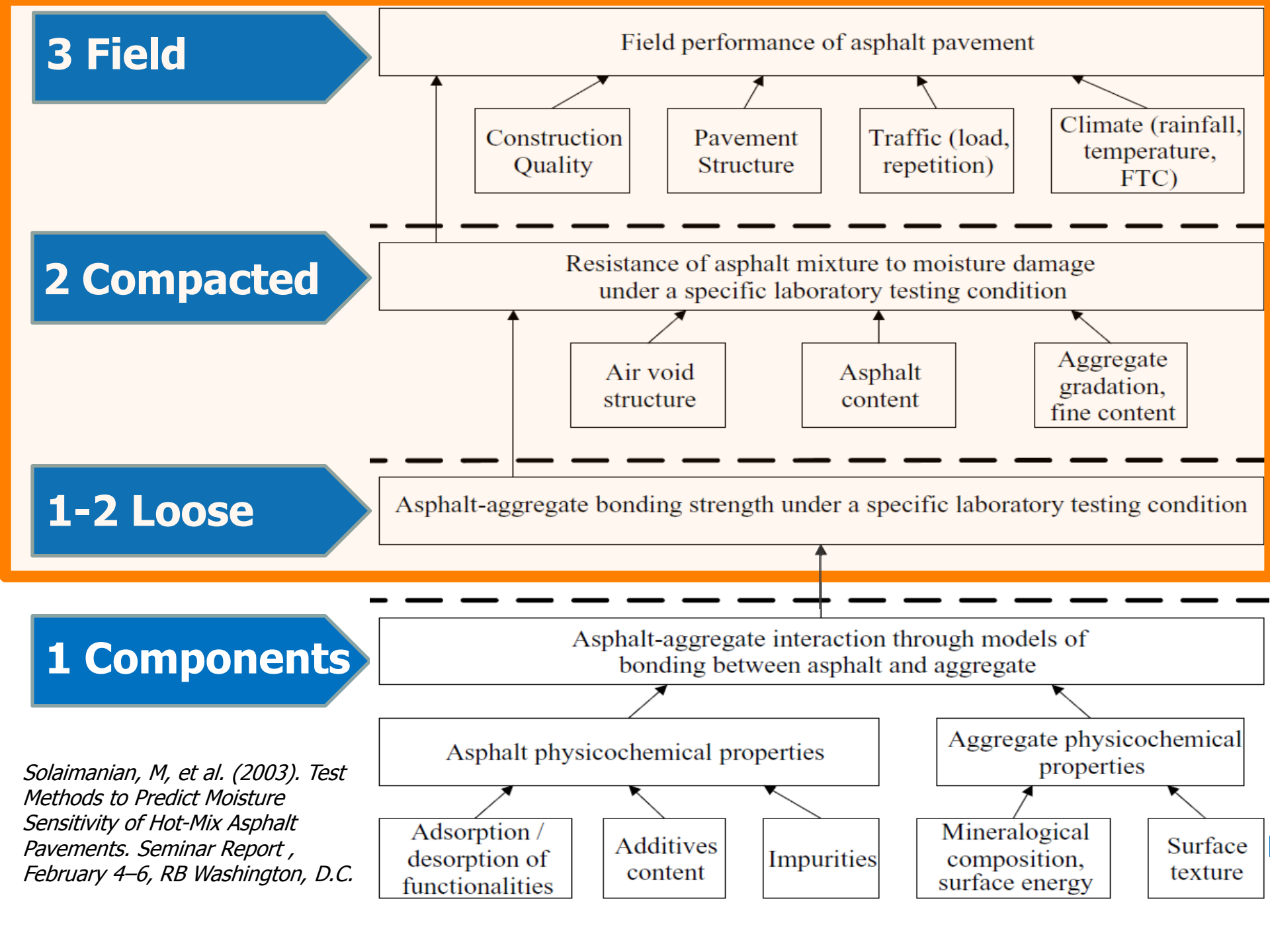
PROs:

- Theory has been applied successfully to other industries
- Good correlations have been observed (lab & field tests) between calculated bond energy ratios and performance

CONs:

- Test methods: test precision, how exact can SFE component be determined in bitumen and aggregates? Variations between test methods, dependency on sample pre-treatments and sample preparations.
- Correlations: a number of studies do not find a correlation between calculated bond energies and water sensitivity tests.
- Fundamental questions:
  - Are the surfaces, investigated by SFE, the ones that provide the adhesion?
  - Aggregate texture and mechanical interlock? How important is this?
  - Is adhesive failure the main failure mechanism?

Procedures are promising but not ready for implementation



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Pull-off tests

- BBS (Bitumen Bond Strength – AASHTO TP-91 – PATTI (Pneumatic Adhesion Tensile Testing Instrument – ASTM D4541)
- Qualitative indication of consistent results with contact angles measurements + water sensitivity asphalt mixes
- No quantitative correlations – only impact of bitumen demonstrated
- $\Rightarrow$ limiting use to ranking or identification of risks

Pull-off tests

- Concerns:
  - Probing for adhesive properties of bitumen only in wet (water) environment – in dry conditions: cohesive failure mode
  - Use of artificial aggregate substrate
  - Poor precision
  - Difficulties to interpret exact failure mode (adhesive ↔ cohesive)

Neither test can currently be considered for normalization or to establish requirements

Rolling bottle test (EN 12697-11 clause 5)

- A quantitative correlation with asphalt performance test is lacking
- Identification of extreme cases is possible e.g. poorly performing bitumen/aggregate combinations
- Poor reproducibility of the test method ⇒ low discriminating power

Application limited to screening test - high-risk combinations or relative ranking

Take up in future a (semi)automatic digital image analysis to replace the subjective visual assessment of stripping

Boiling water test (ASTM D3625)

- Potential to link stripping of binder to water sensitivity of corresponding asphalt mixture
- Major concerns:
  - Low discriminating power due to poor reproducibility
  - Subjective visual interpretation of the stripping degree
- Important effect of bitumen viscosity (kinetics dominating?)

Use method as screening test - high-risk combinations or relative ranking
Implement (semi)automatic digital image analysis to replace the subjective visual assessment of stripping

Indirect Tensile Strength Ratio (ITSR)

- Large experience both in EU (12697-12 part A) and in US (modified) Lottmann test (AASHTO T283)
- Concerns/drawbacks:
  - Rather high spread of test results
  - Large effect of other parameters on test result (e.g. air voids)
  - Static conditioning applied

Keep at all times all parameters/materials of a given asphalt mixture constant (except for binder) in case test is intended for evaluating binder/aggregate interaction ⇒ ranking possible

New test procedures: CAST and MIST

- Coaxial Shear Test (CAST):
  - Induction of mechanical damage due to repeated loading, T-cycles and water conditioning of gyratory compacted specimens
  - Better simulation of field conditions?
- Moisture Induced Sensitivity Tester (MIST):
  - Long- and short term moisture damage by generating cyclic pressures
  - Evaluation of the diffusion of water

Tests under development (academic level) – need for more (field) validated data before considering tests for standarization

Thanks for your attention