Florida Department of Transport APT and Instrumentation Workshop

Pavement material behaviour and appropriate instrumentation

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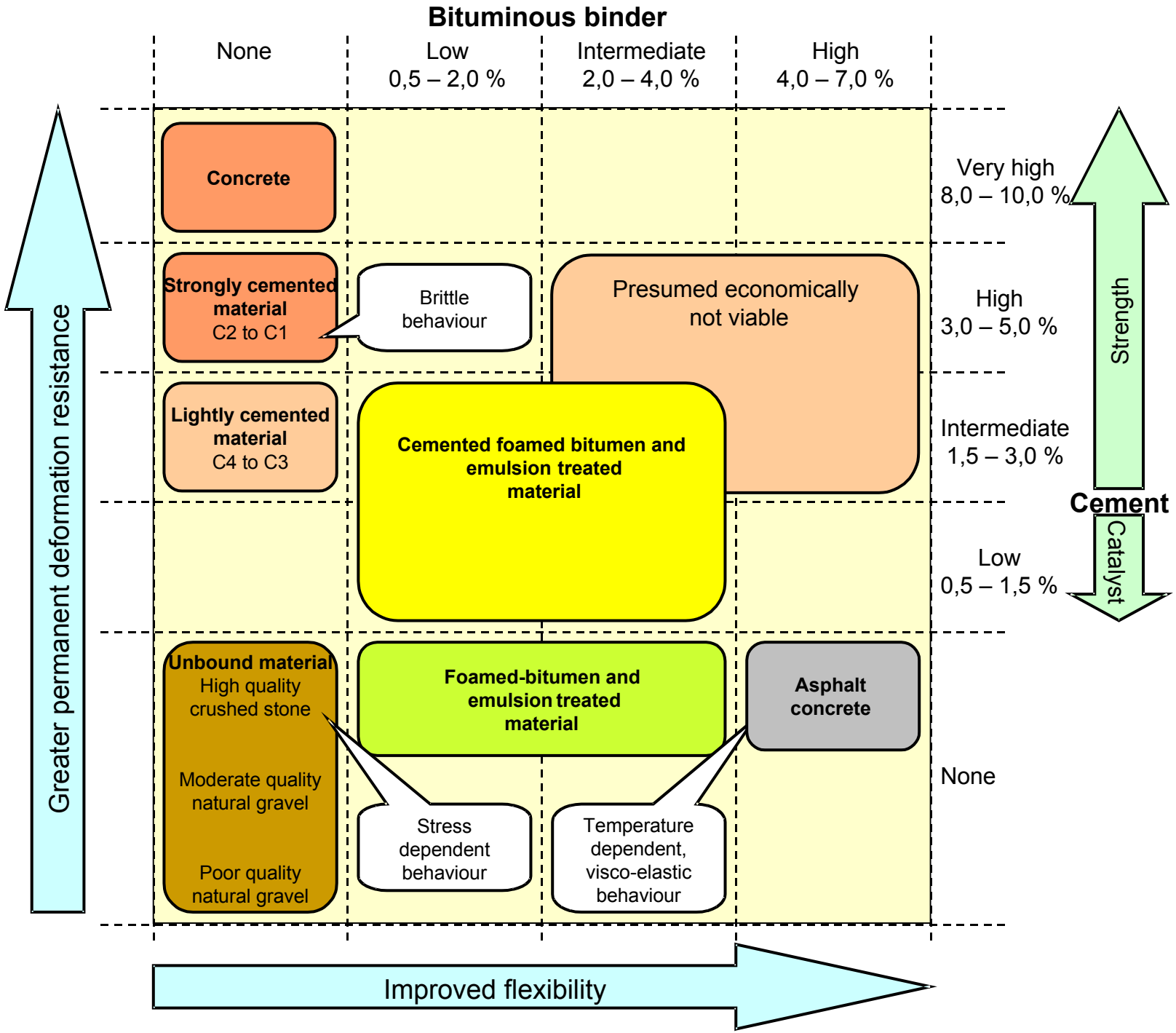
Transportek CSIR

Structure of presentation

- Generic material types and characteristics
- Material behaviour and appropriate instrumentation
  - Focus on flexible pavements
- Accuracy, precision and error
- Down-the-line error

Generic material types and characteristics

Pavement material behaviour and appropriate instrumentation

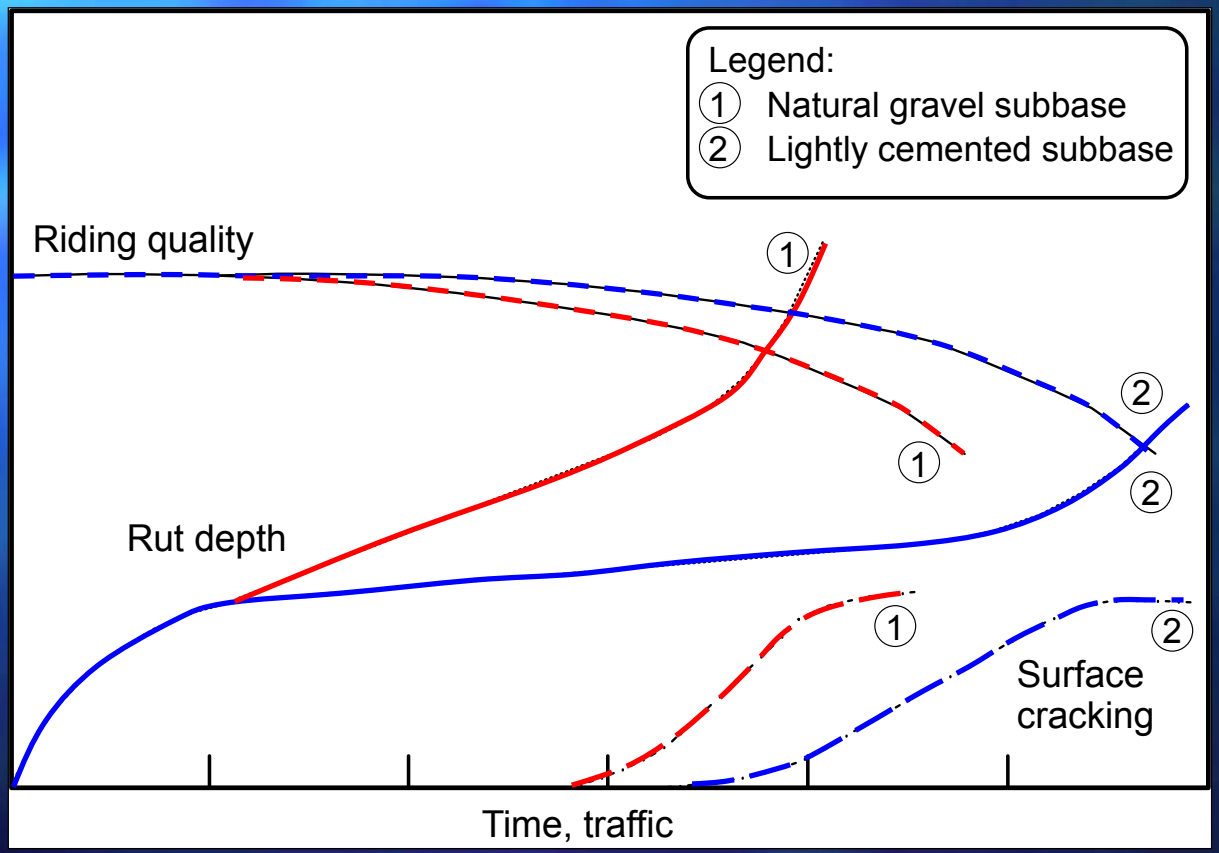

Bituminous binder
None
Low
0,5 – 2,0 %
Intermediate
2,0 – 4,0 %
High
4,0 – 7,0 %
Very high
8,0 – 10,0 %
High
3,0 – 5,0 %
Intermediate
1,5 – 3,0 %
Low
0,5 – 1,5 %
None
Concrete
Strongly cemented material
C2 to C1
Brittle behaviour
Presumed economically not viable
Lightly cemented material
C4 to C3
Cemented foamed bitumen and emulsion treated material
Unbound material
High quality crushed stone
Moderate quality natural gravel
Poor quality natural gravel
Foamed-bitumen and emulsion treated material
Asphalt concrete
Stress dependent behaviour
Temperature dependent, visco-elastic behaviour
Greater permanent deformation resistance
Strength
Cement
Catalyst
Improved flexibility

Material behaviour and appropriate instrumentation

Pavement material behaviour and appropriate instrumentation

Asphalt concrete layers

- Performance parameters

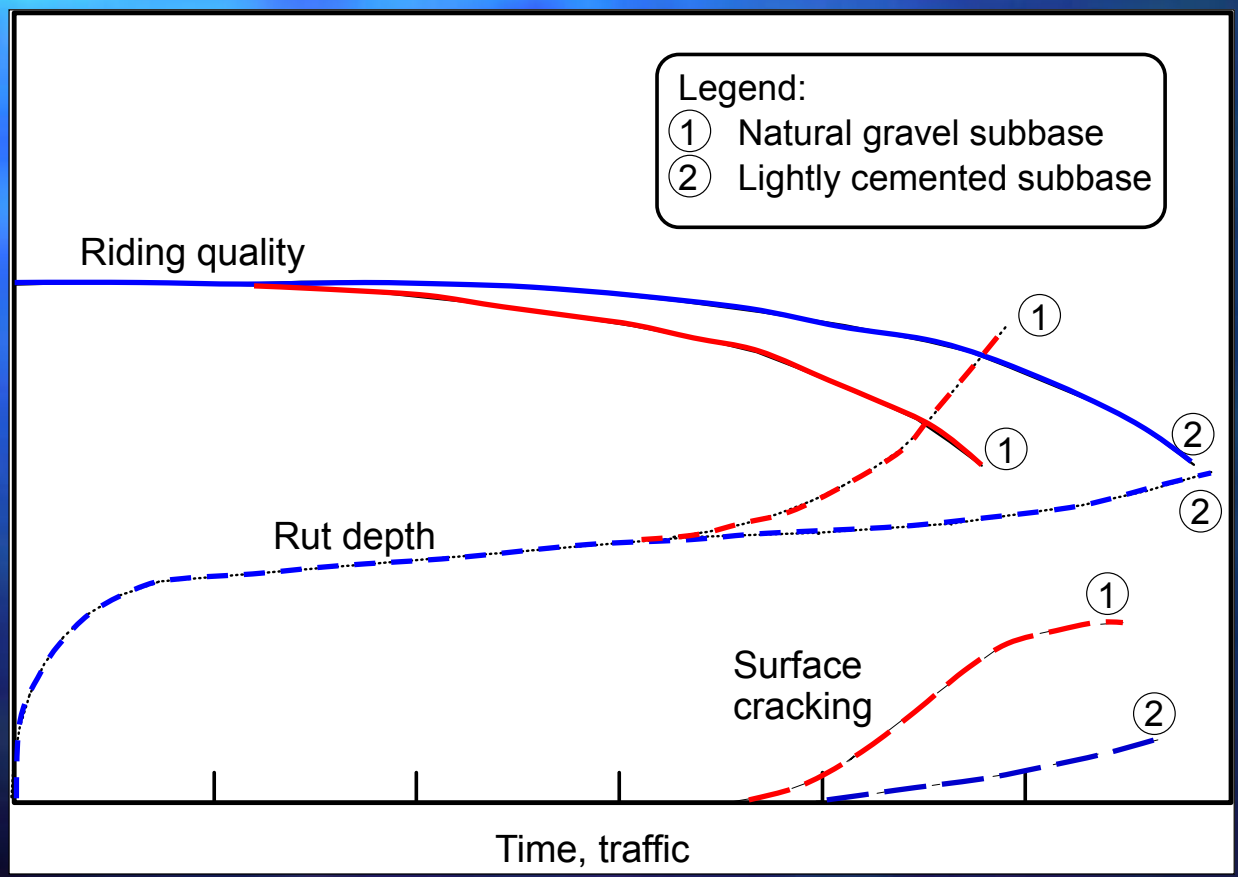


Asphalt concrete layers

- Minimum instrumentation
  - Bowl deflection (RSD/FWD)
  - Surface rut (Straight-edge/laser profilometer)
  - Layer deflection/vertical strain (MDD/strain coils)
    - Elastic and plastic
  - Temperature profile (Buttons/thermocouples)
  - Crack monitoring
- Nice-to-have instrumentation
  - Horizontal strain
  - Vertical stress
  - Crack activity
  - Surface texture

Unbound aggregate base and subbase layers

- Performance parameters

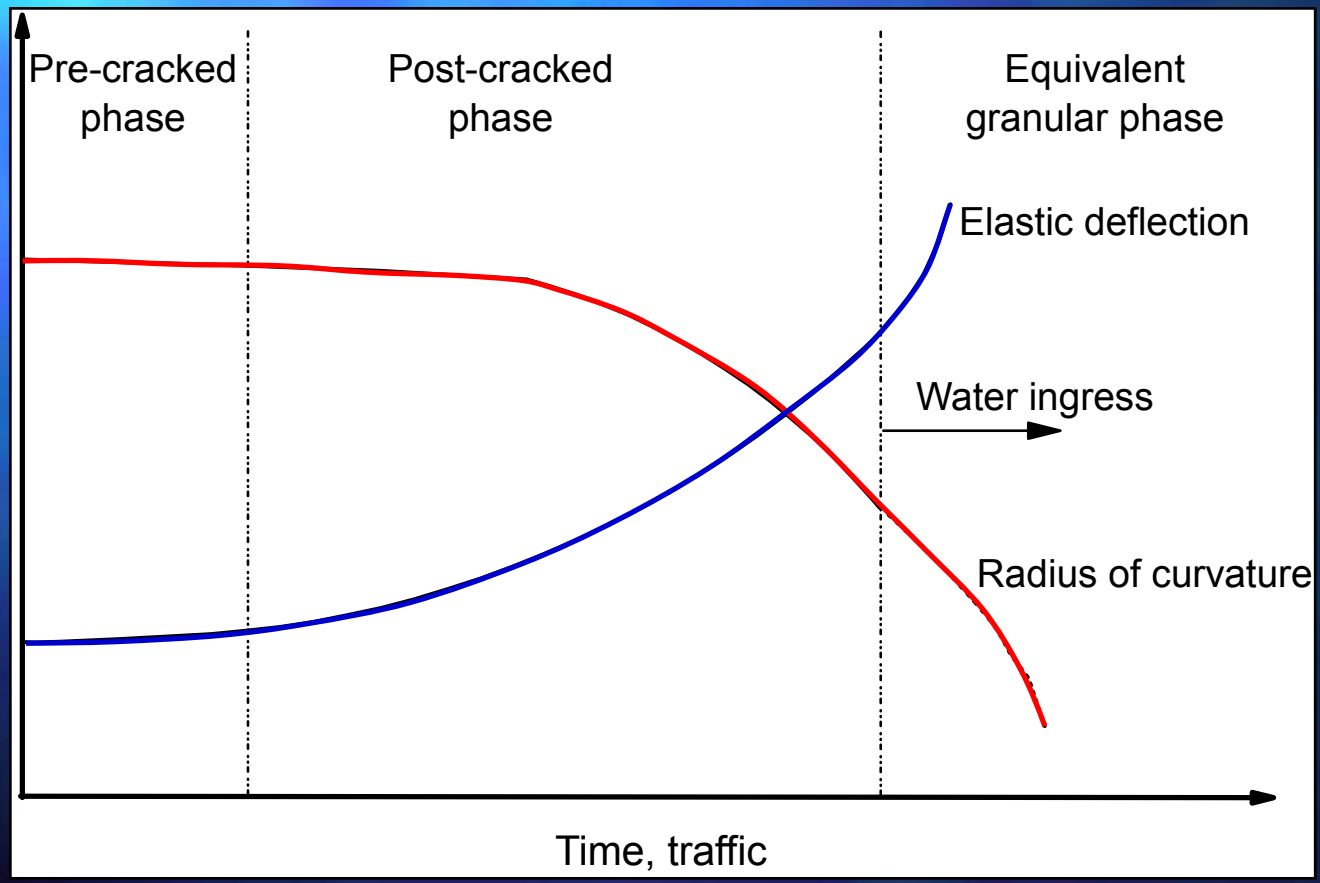


Unbound aggregate base and subbase layers

- Minimum instrumentation
  - Bowl deflection (RSD/FWD)
  - Surface rut (Straight-edge/laser profilometer)
  - Layer deflection/vertical strain (MDD/strain coils)
    - Elastic and plastic
  - Density and moisture content (Nuclear, TDR)
- Nice-to-have instrumentation
  - Horizontal strain
  - Vertical and horizontal stress

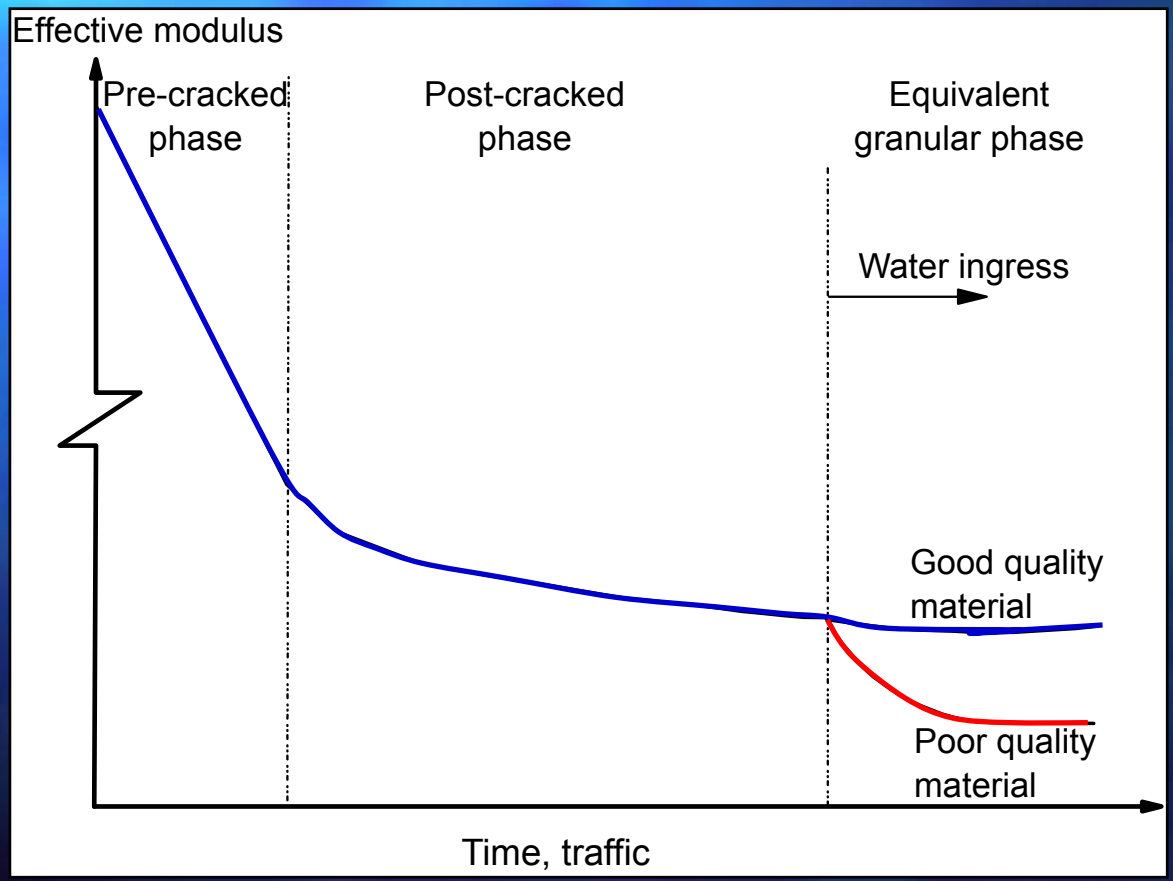
Cement, foamed-bitumen and emulsion-treated base and subbase layers

- Deflection and radius of curvature



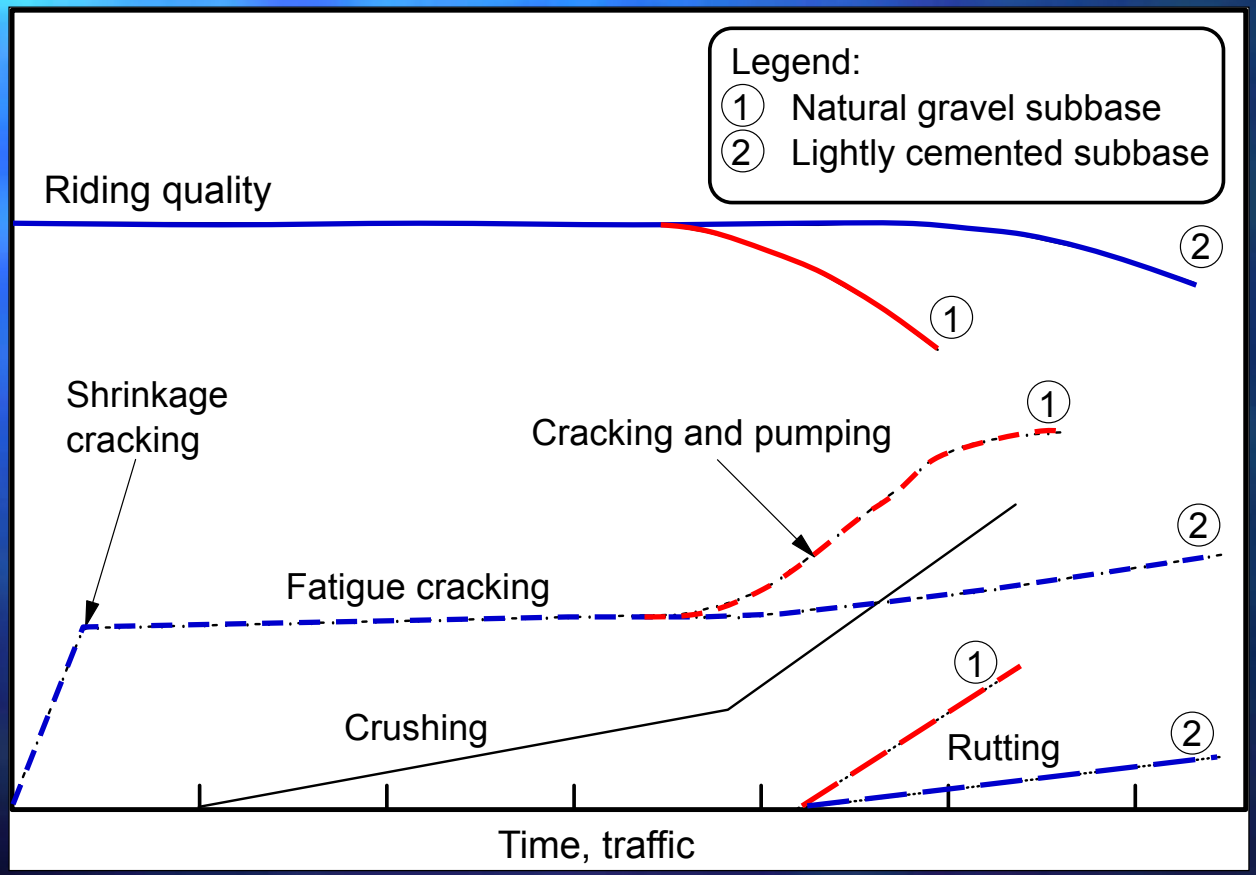
Cement, foamed-bitumen and emulsion-treated base and subbase layers

- Effective resilient modulus



Cement-treated base and subbase layers

- Performance parameters



Cement, foamed-bitumen and emulsion-treated base and subbase layers

- Minimum instrumentation
  - Bowl deflection (RSD/FWD)
  - Surface rut (Straight-edge/laser profilometer)
  - Layer deflection/vertical strain (MDD/strain coils)
    - Elastic and plastic
  - Density and moisture content (Nuclear, TDR)
- Nice-to-have instrumentation
  - Horizontal strain

Supplementary data for all pavement layers

- As much laboratory and field material/environmental data as possible!
  - Most of the mechanical properties (M_r, shear strength, etc) are functions of:
    - Temperature
    - Density
    - Degree of saturation

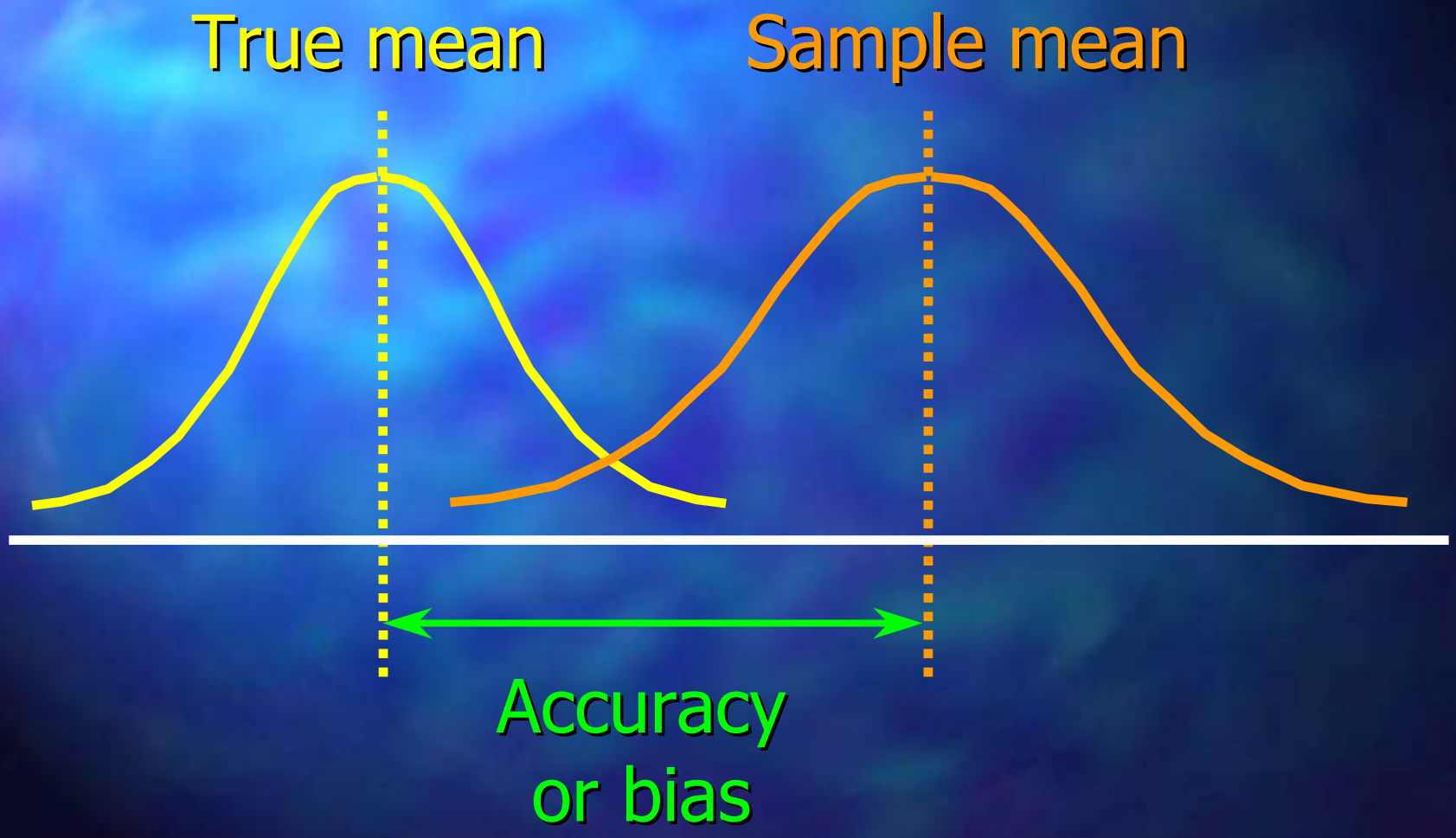
Accuracy, Precision and Error

Pavement material behaviour and appropriate instrumentation

Important instrumentation parameters

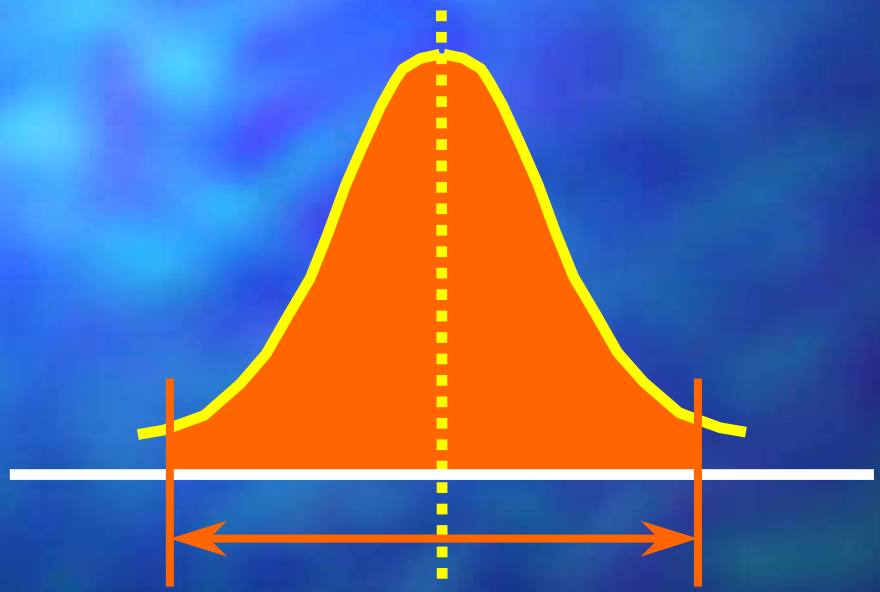
- Bias or accuracy
- Error
- Precision or repeatability

Bias/accuracy



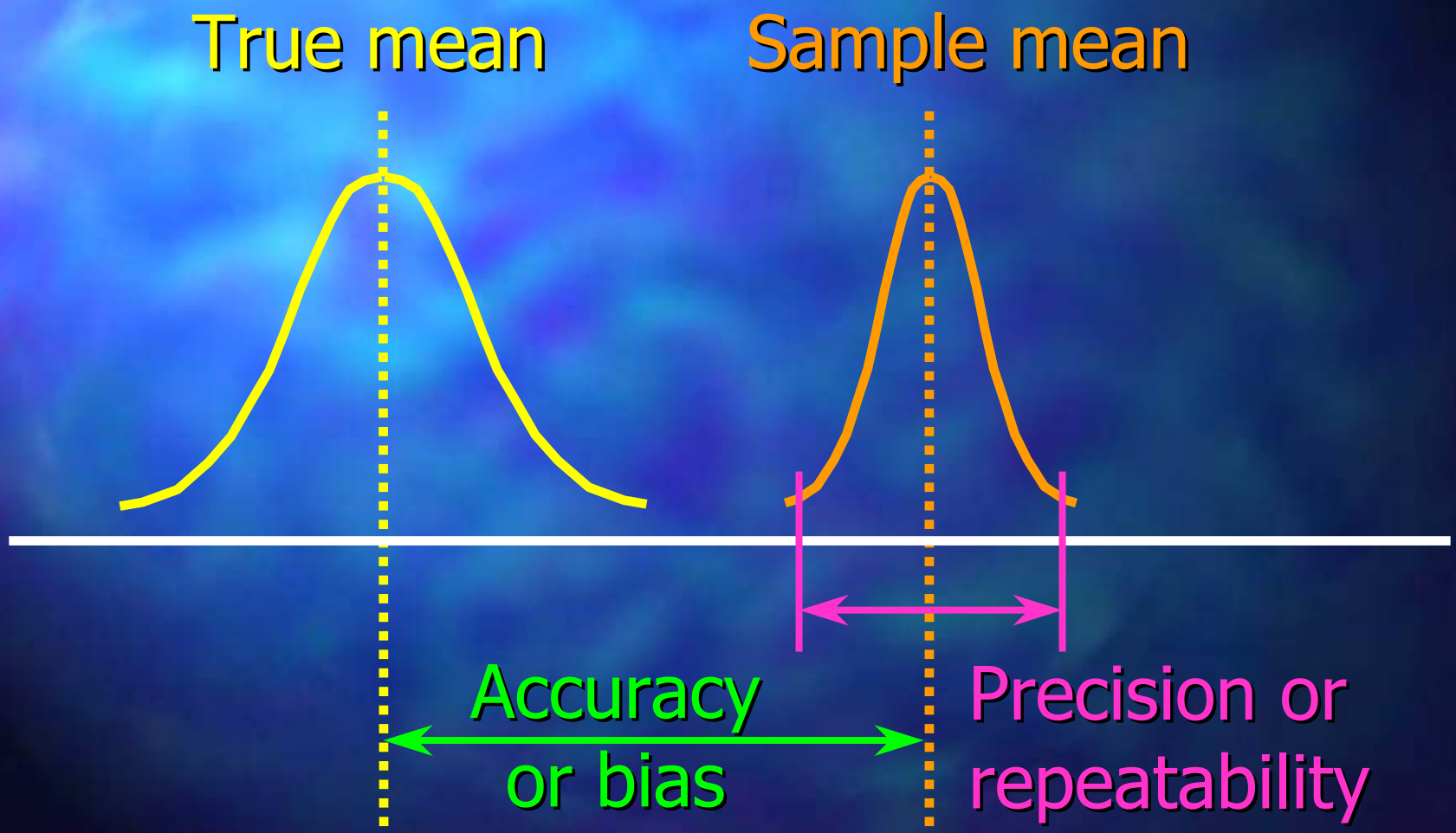
Error as a measure of accuracy

$$\text{Error}_i = \text{Actual}_i - \text{Sample}_i$$



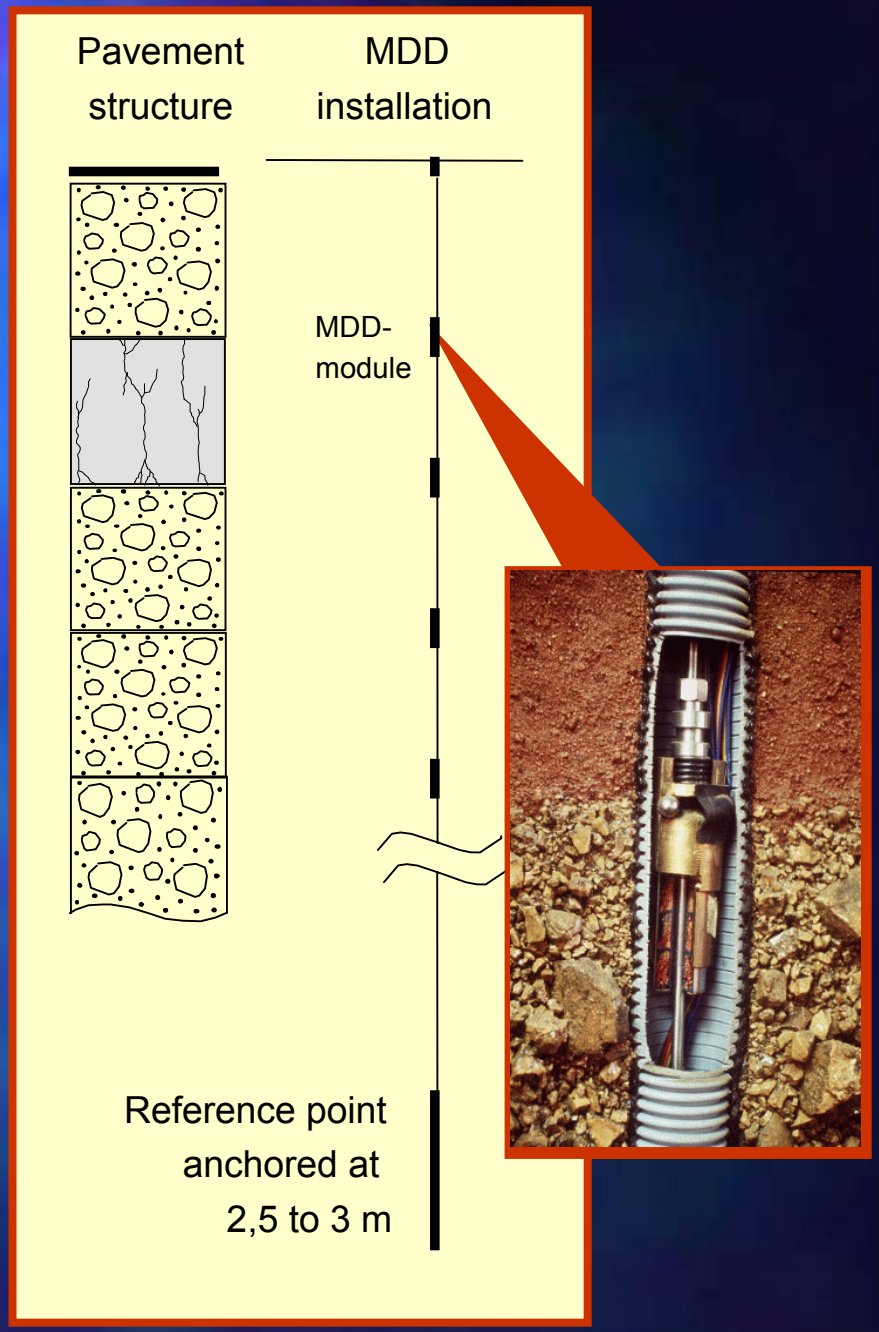
Error at a certain level of confidence

Precision/repeatability



MDD system

- HVS testing in SA rely mostly on the MDD system
  - MDD modules
  - MDD stack

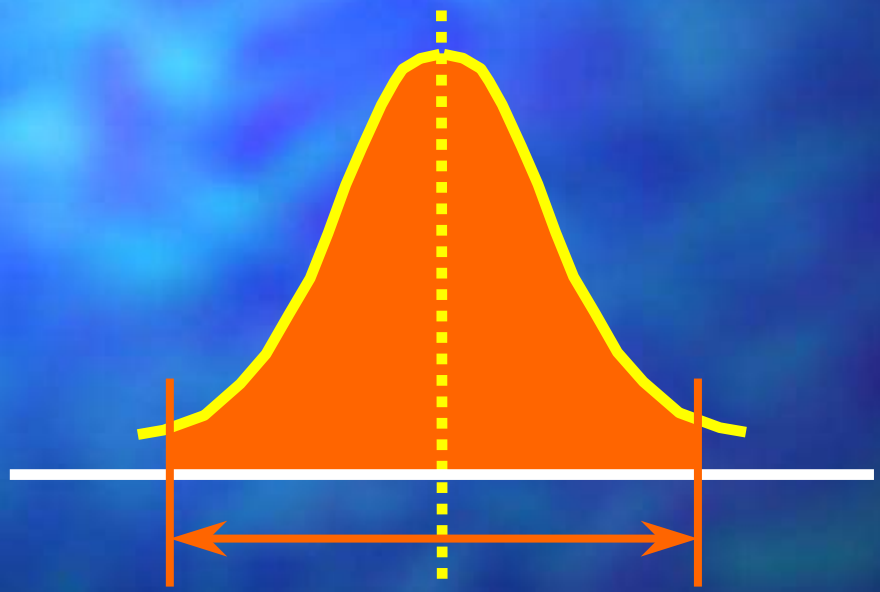


Accuracy, error and precision of the MDD system

- Accuracy
  - MDD system accuracy – undetermined
  - MDD module accuracy – calibration
- Error
  - MDD system error – undetermined
  - MDD module error – check after calibration
- Precision
  - MDD system precision – determined
  - MDD module precision – determined

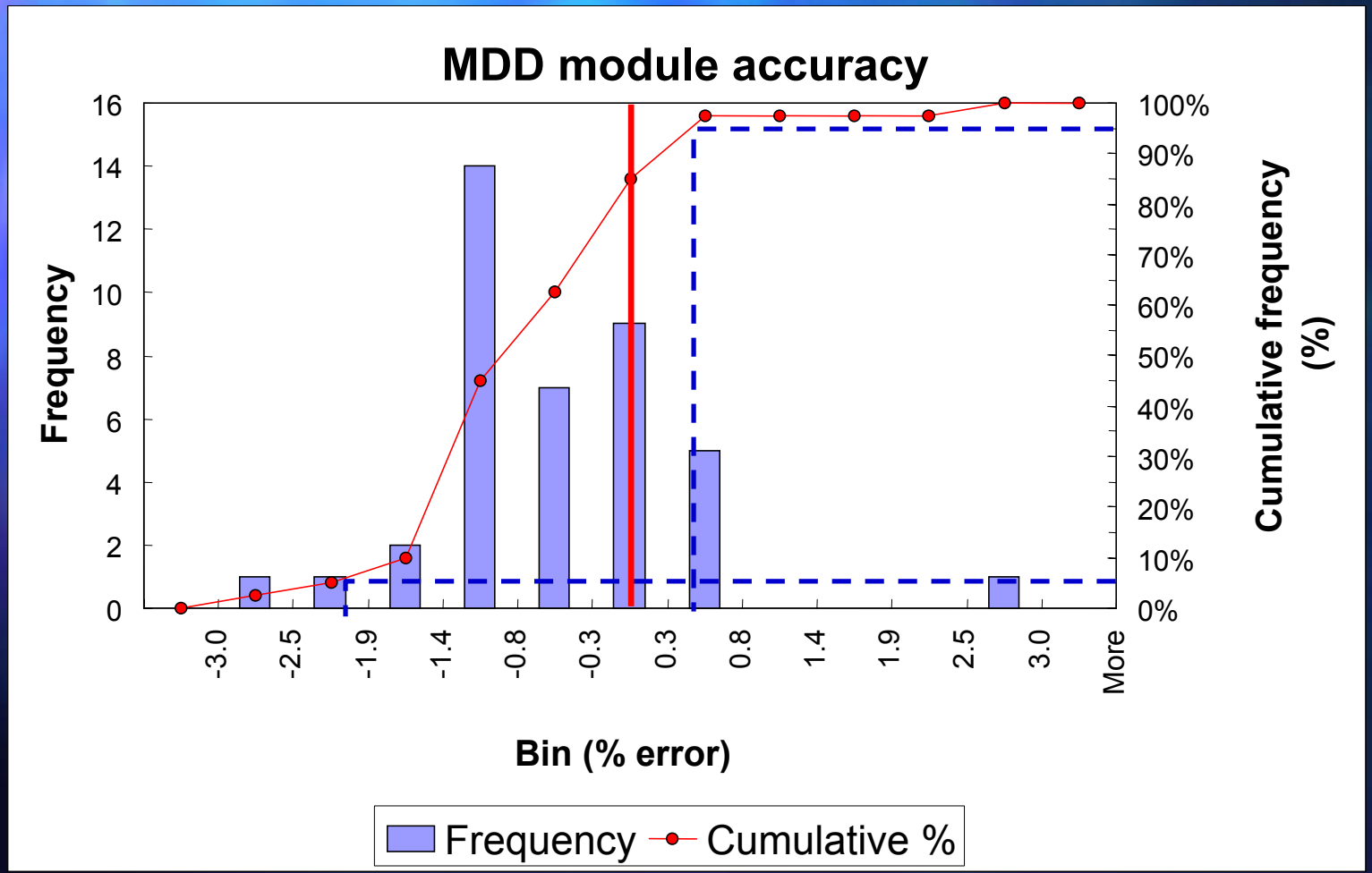
Error as a measure of accuracy

$$\text{Error}_i = \text{Actual}_i - \text{Sample}_i$$

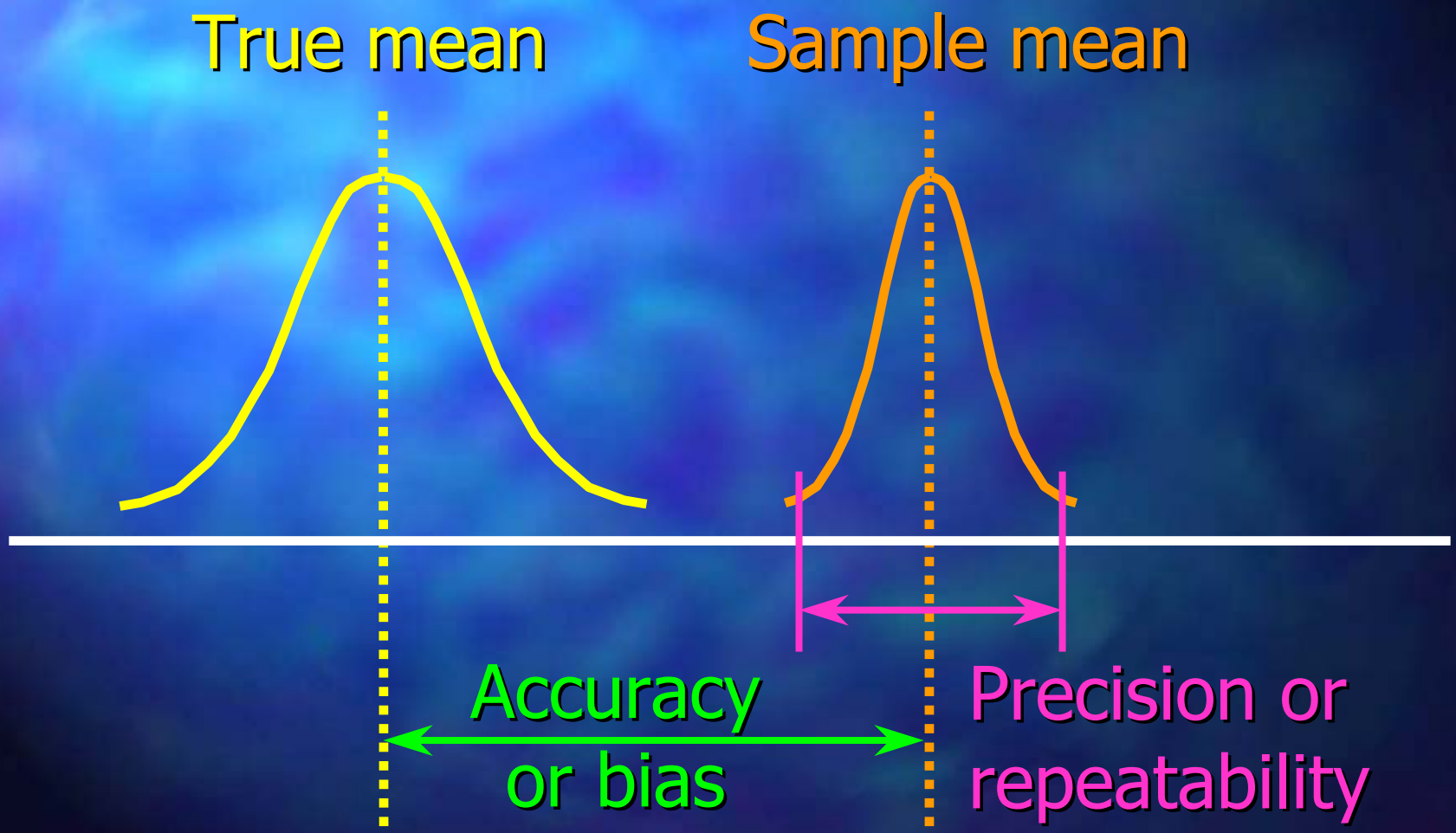


Error at a certain level of confidence

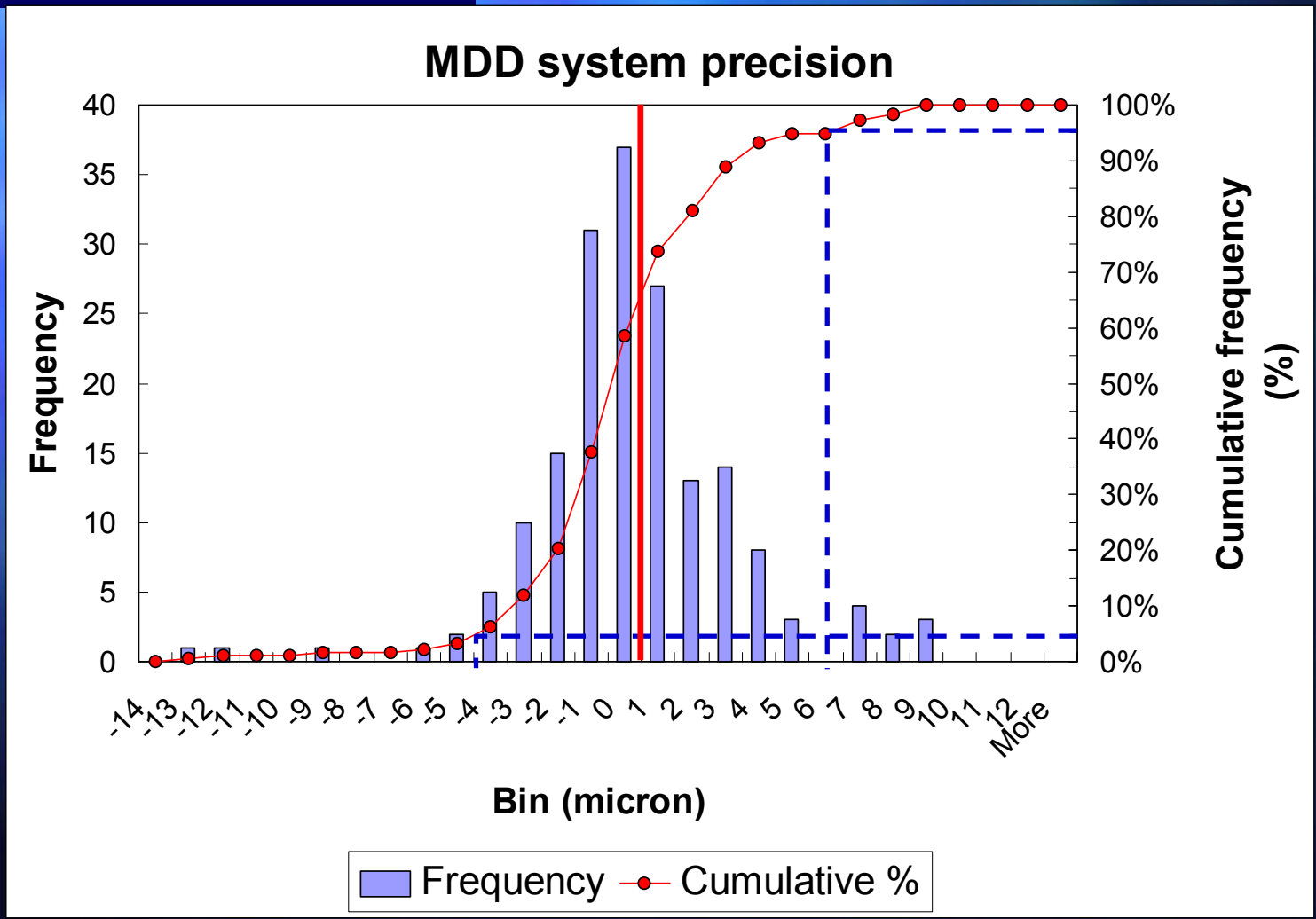
Error of the MDD module: -2,0 +0,7 @ 90 % probability



Precision/repeatability



Precision of the MDD system: -4,4 +6,0 @ 90 % probability

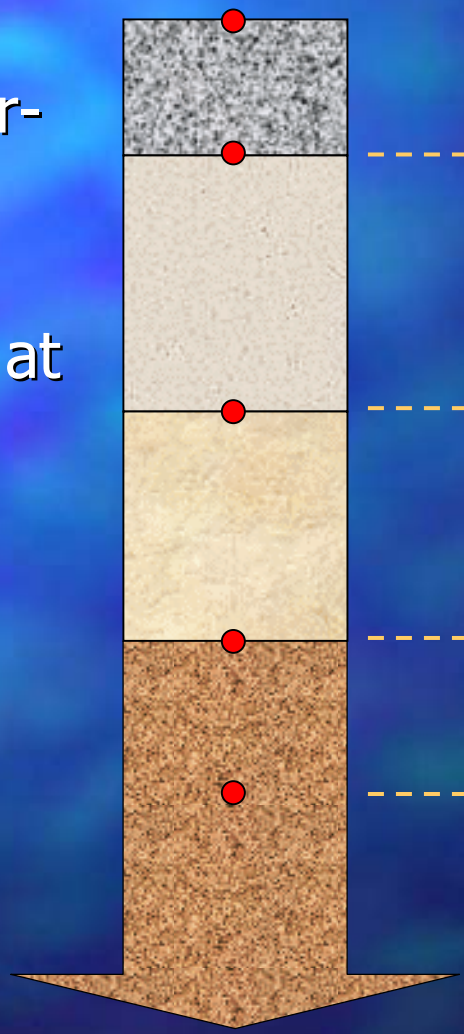


Down-the-line "error"

- Need instrumentation that is
  - easy to install (often after construction)
  - robust
  - not too expensive
- Often measure deflection and model other parameters
- How accurate are these parameters?
  - Down-the-line accuracy and error

Down-the-line error: Back-calculated resilient modulus

- Assume perfect linear-elastic, multi-layer system
- Calculate deflections at layer interfaces
- Generate deflection data from base set
  - Using MDD precision
  - 100 % accuracy
- Do back-calculation



137 mm HMA
2500 MPa, 0.40

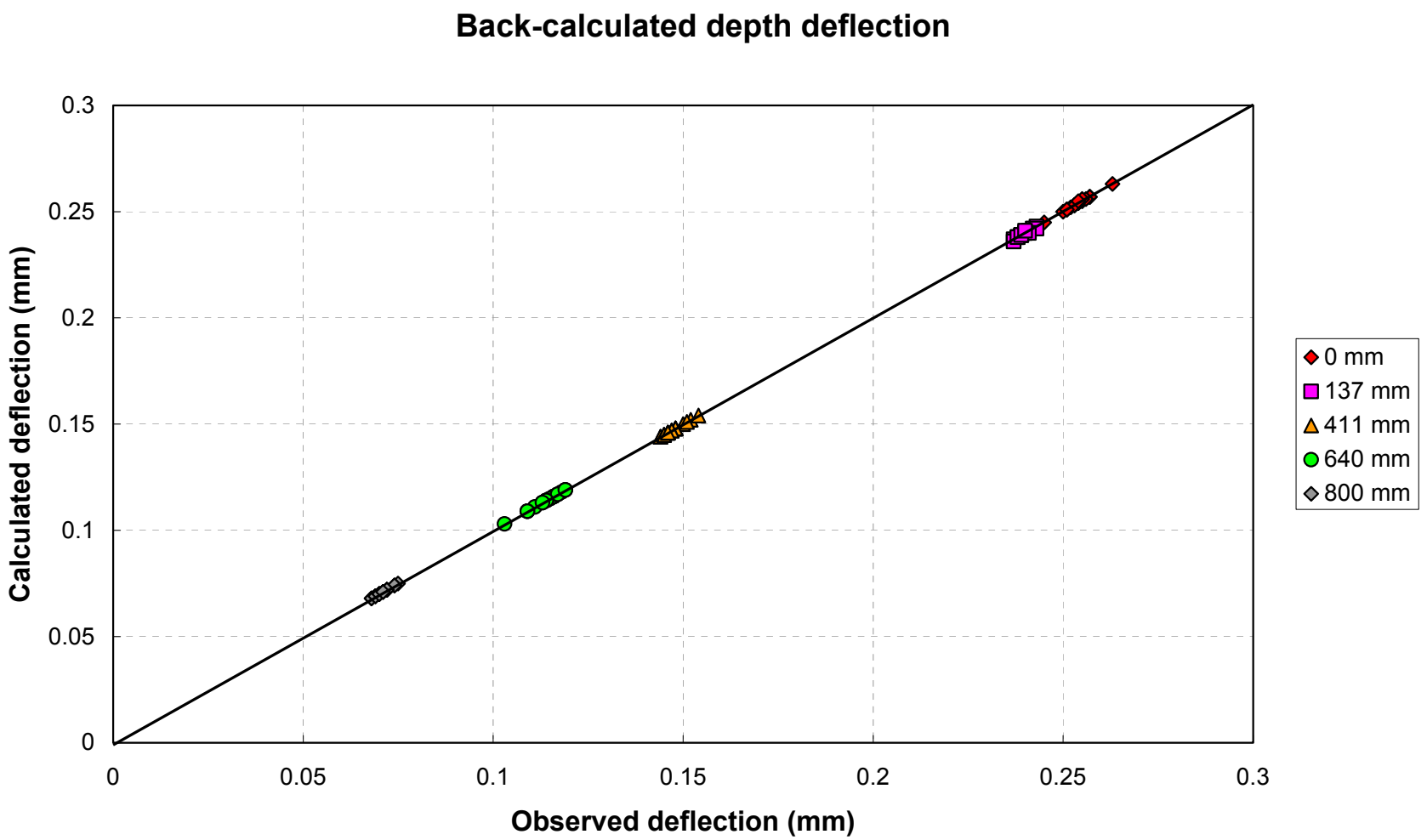
274 mm aggregate base
350 MPa, 0.35

229 mm aggregate subbase
350 MPa, 0.35

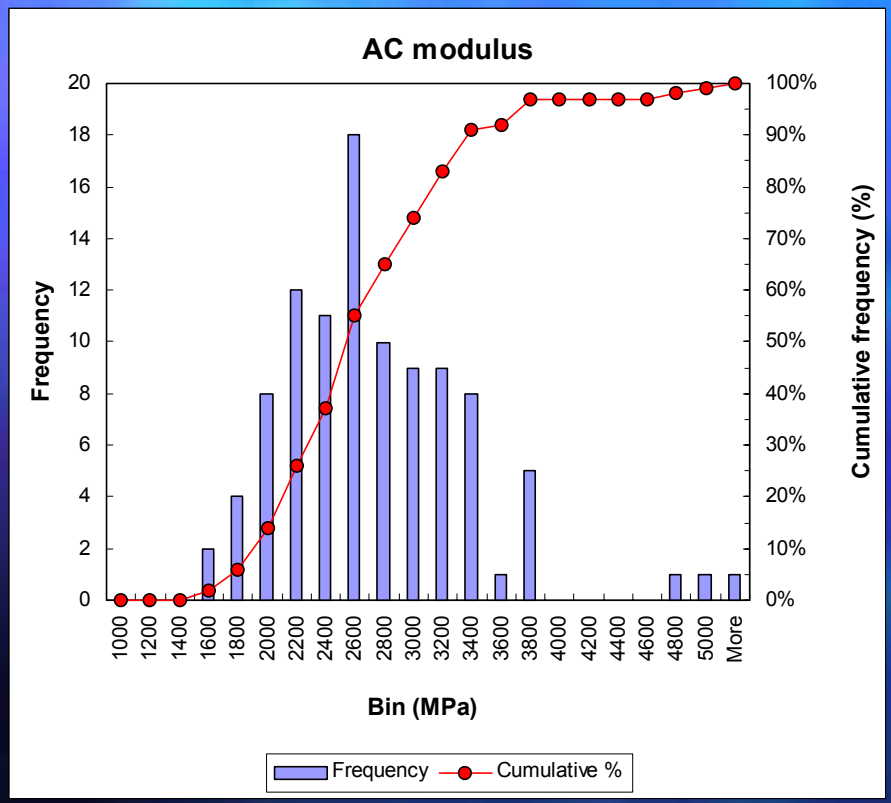
160 mm upper subgrade
60 MPa, 0.35

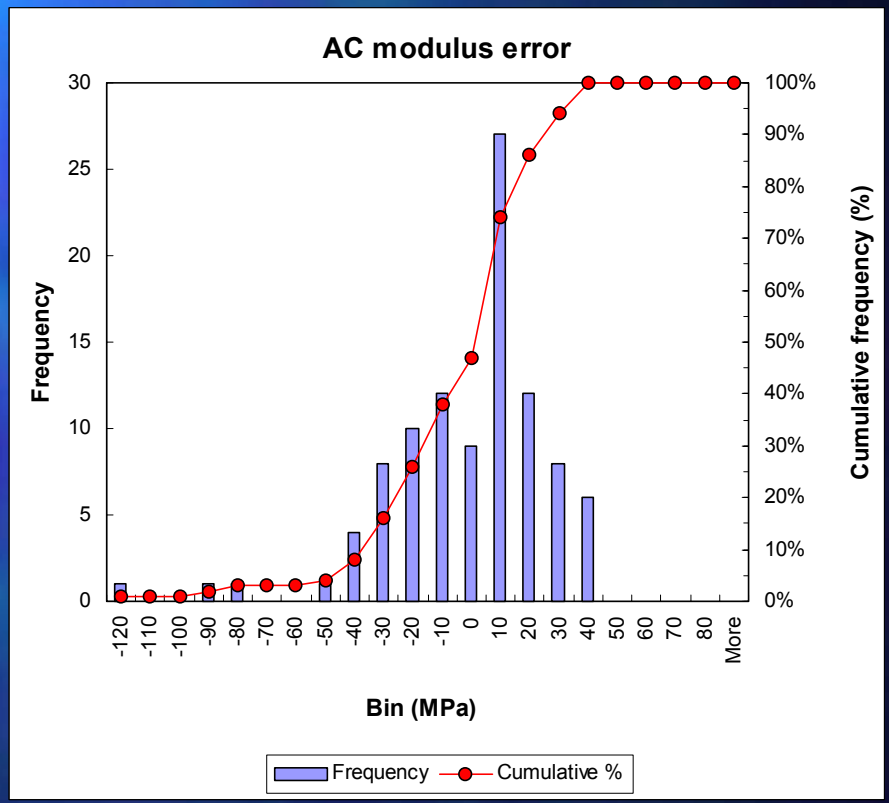
2200 mm lower subgrade
180 MPa, 0.35

Down-the-line error: Back-calculated deflection

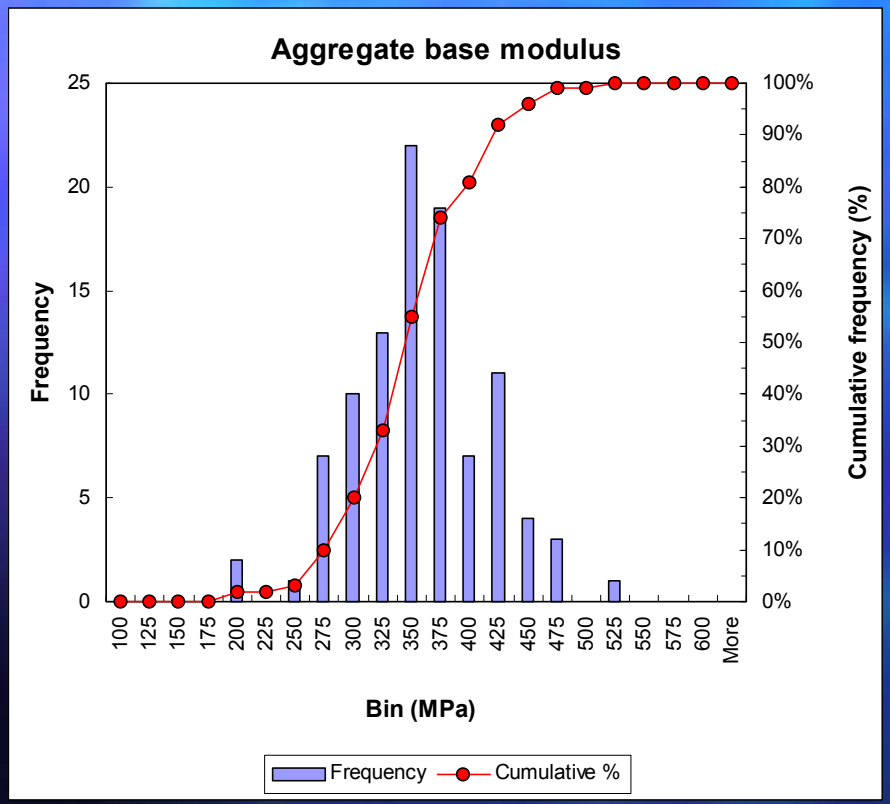


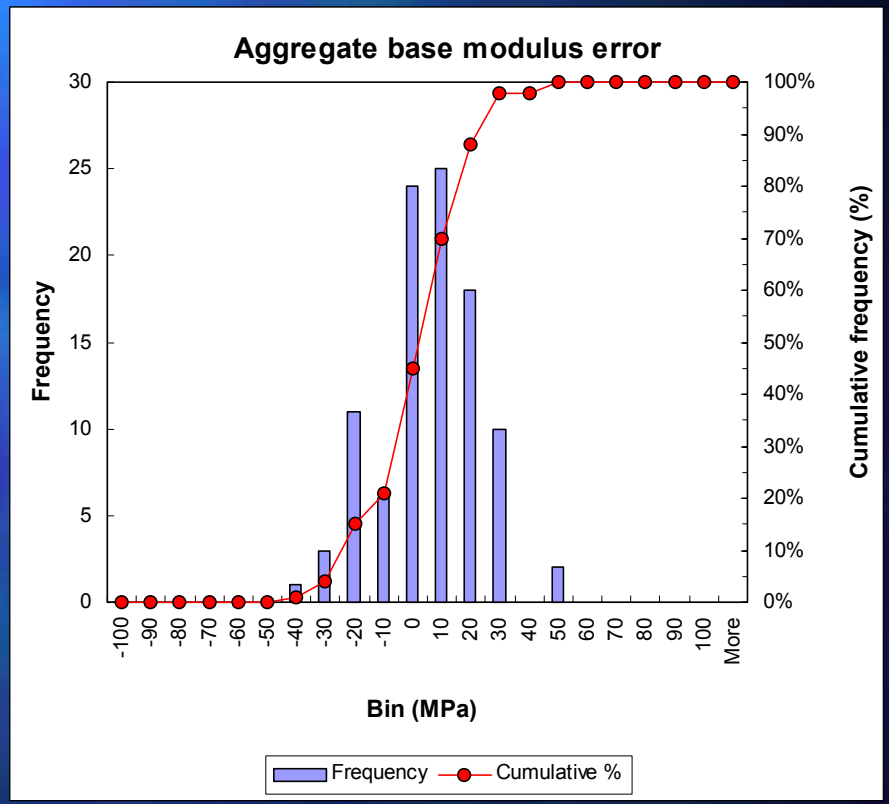
Down-the-line error: HMA resilient modulus



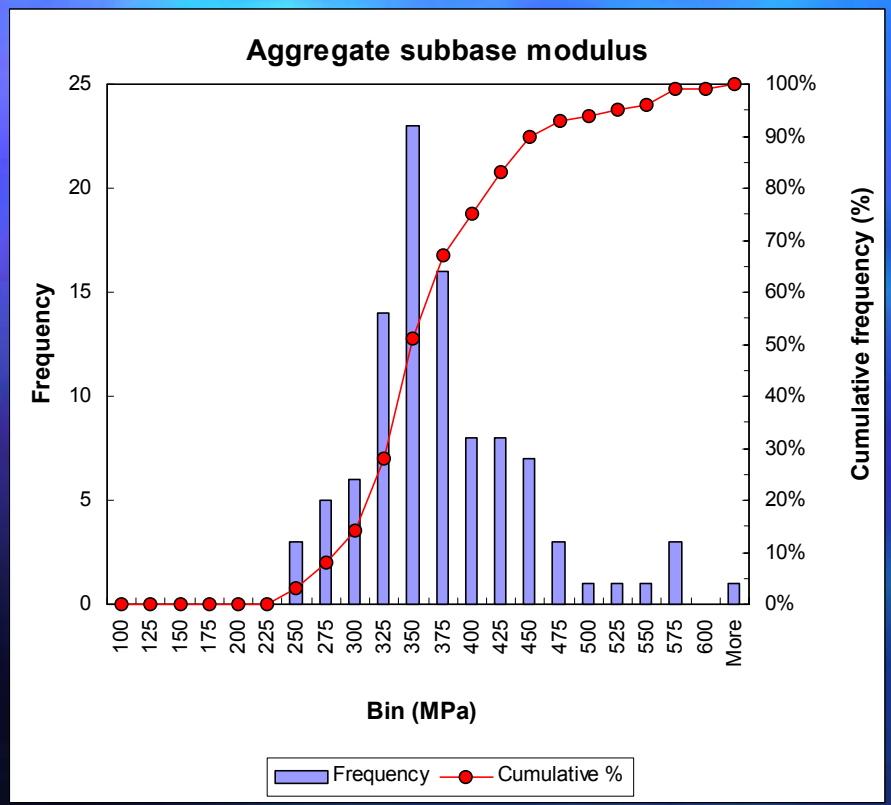


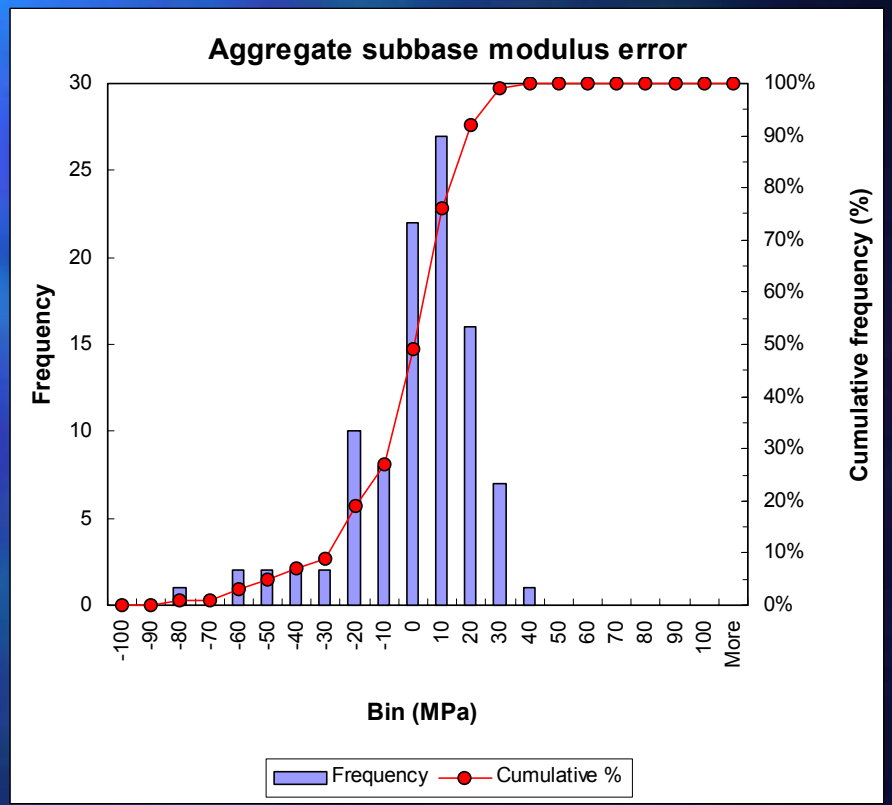
Down-the-line error: Aggregate base resilient modulus



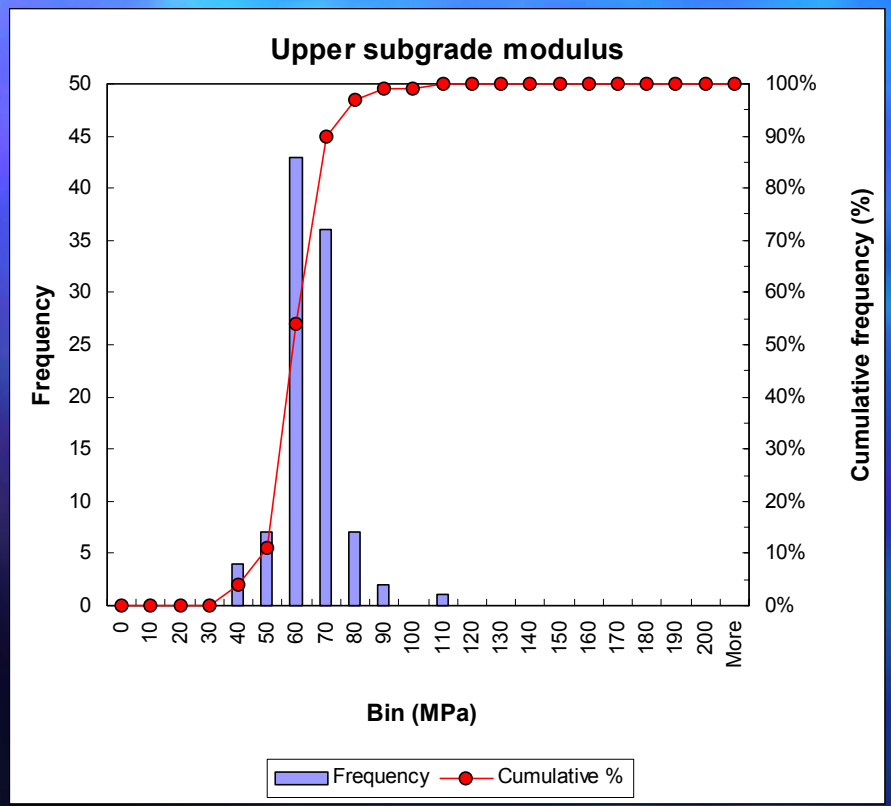


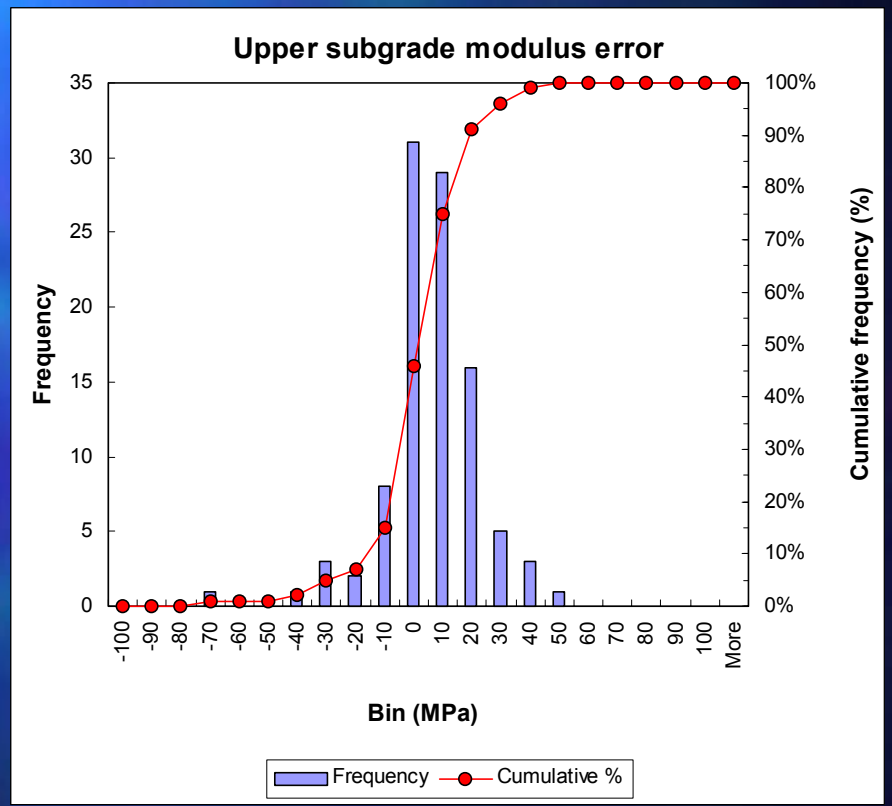
Down-the-line error: Aggregate subbase resilient modulus



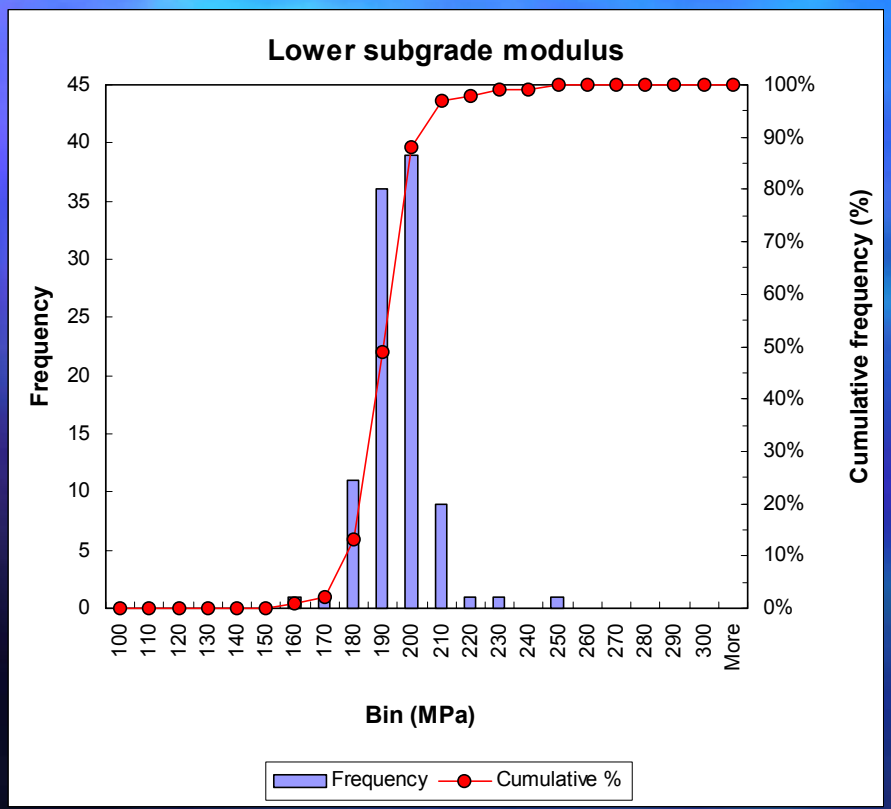


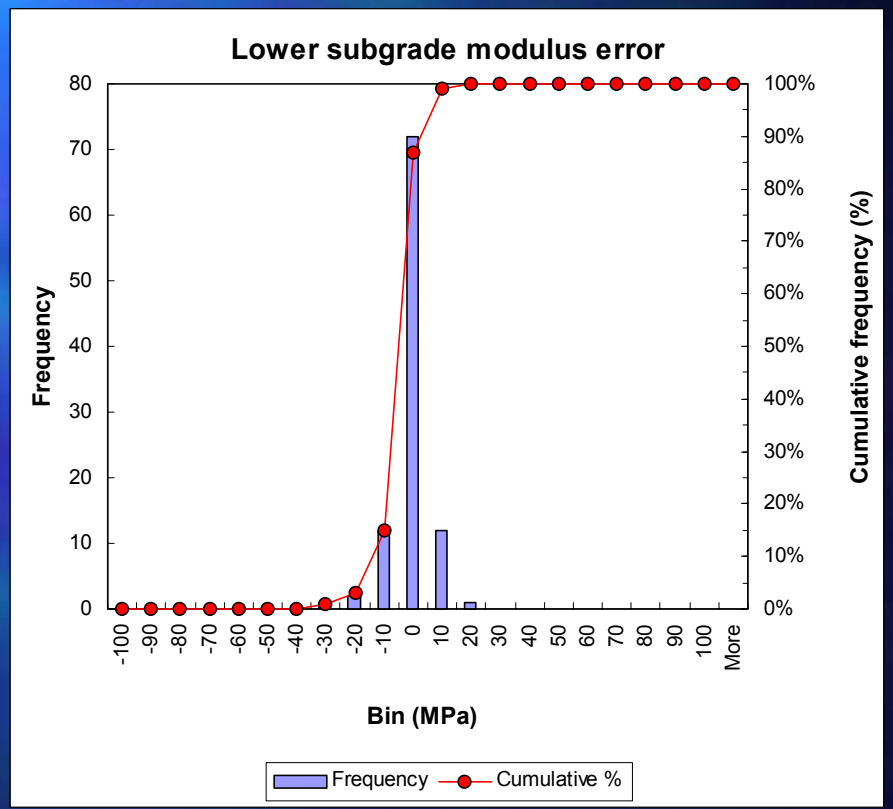
Down-the-line error: Upper subgrade resilient modulus





Down-the-line error: Lower subgrade resilient modulus





To summarize

- Different materials respond (now and in time) differently to external loading
  - Require different response measurements
- Focus on mechanical/structural behaviour
  - Cause and response (pavement/layer response to external loading)
    - Resilient (elastic) and distress (plastic/fatigue) response
  - Aim to calibrate input parameters and response models for rational Mechanistic-Empirical (ME) design methods