Calibration of Mechanistic-Empirical Models Using the California Heavy Vehicle Simulators

P. Ullidtz
Dynatest International, Denmark
J. Harvey & V. Kanekanti
University of California, Davis, California, USA
B.W Tsai & C. Monismith
University of California, Berkeley, California, USA

Mechanistic-Empirical methods are simplifications of reality

- Response models are based on solid mechanics and must be validated for pavement materials
- Performance prediction models derived from laboratory tests must be validated/calibrated to in situ pavements

HVS: a ”large scale” laboratory test

Advantages of HVS testing

- Short test section, carefully constructed
- Intensive materials characterization
- Instrumented to measure response and performance
- Climatic conditions controlled or closely monitored
- All load applications are known exactly
- Testing can be carried out to failure

MDD

Multi Depth Deflectometer

Road Surface Deflectometer (RSD)

27 HVS tests on flexible pavements were used to calibrate the damage models in CalME

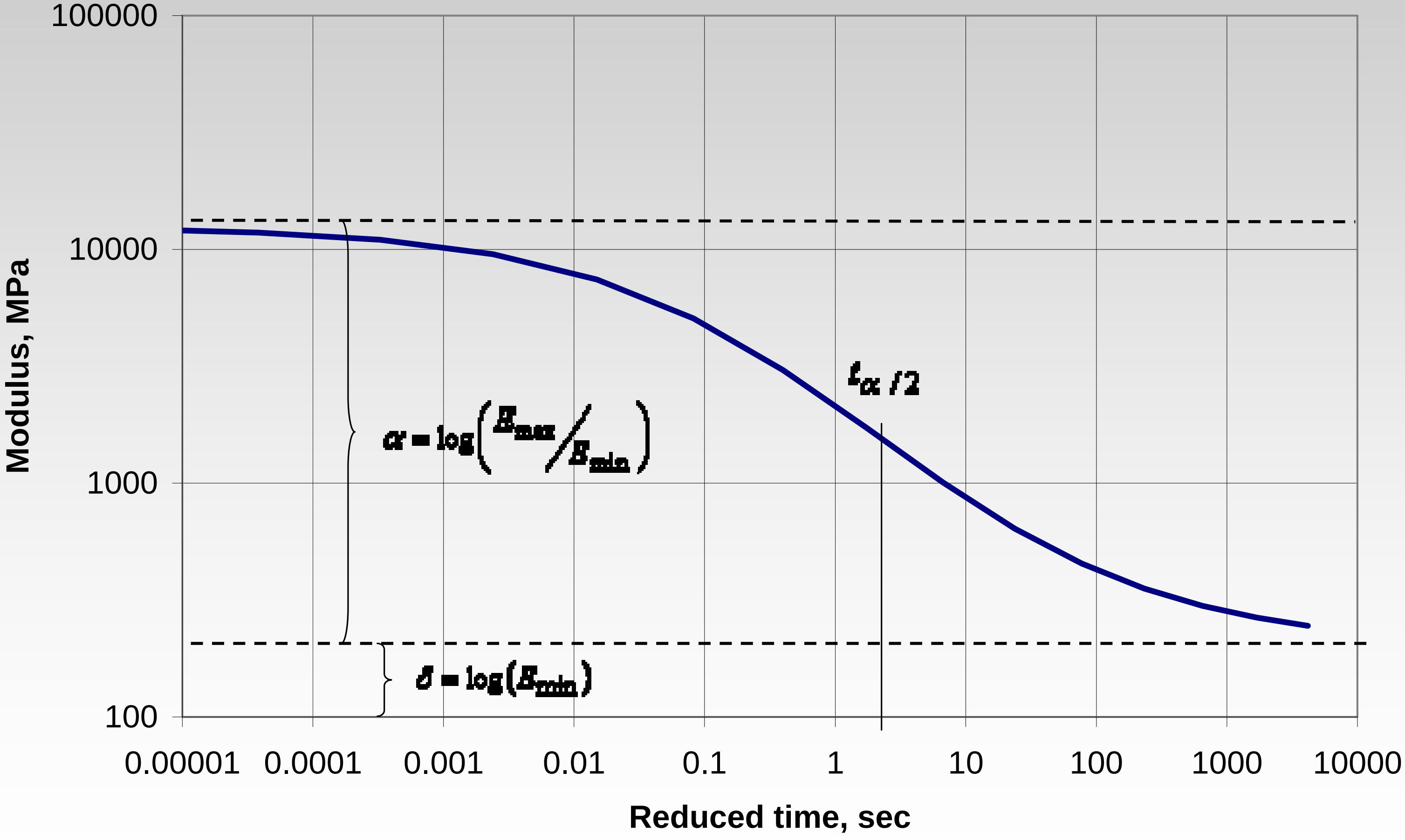
- Caltrans current methods, the R-value method, deflection reduction method for rehabilitation design
- “Classical” ME design (Asphalt Institute method)
- Incremental-recursive method

Models calibrated in CalME

- Asphalt stiffness as a function of reduced time (temperature and loading time)

AC modulus

$$\log(E) = \delta + \frac{\alpha}{1 + \left(t / t_{\alpha/2} \right)^{\gamma}}$$



Models calibrated in CalME

- Asphalt stiffness as a function of reduced time (temperature and loading time)
- Stiffness of unbound materials as a function of confinement and of stress condition

Unbound layer moduli

Confinement

$$E = Eo \times \left(1 - \left(1 - S / S_{ref}\right) \times Stiffness\ \ factor\right), with$$

$$S = \left(\sum_{1}^{n-1} h_i \times \sqrt[3]{E_i} \right)^3$$

Stress condition

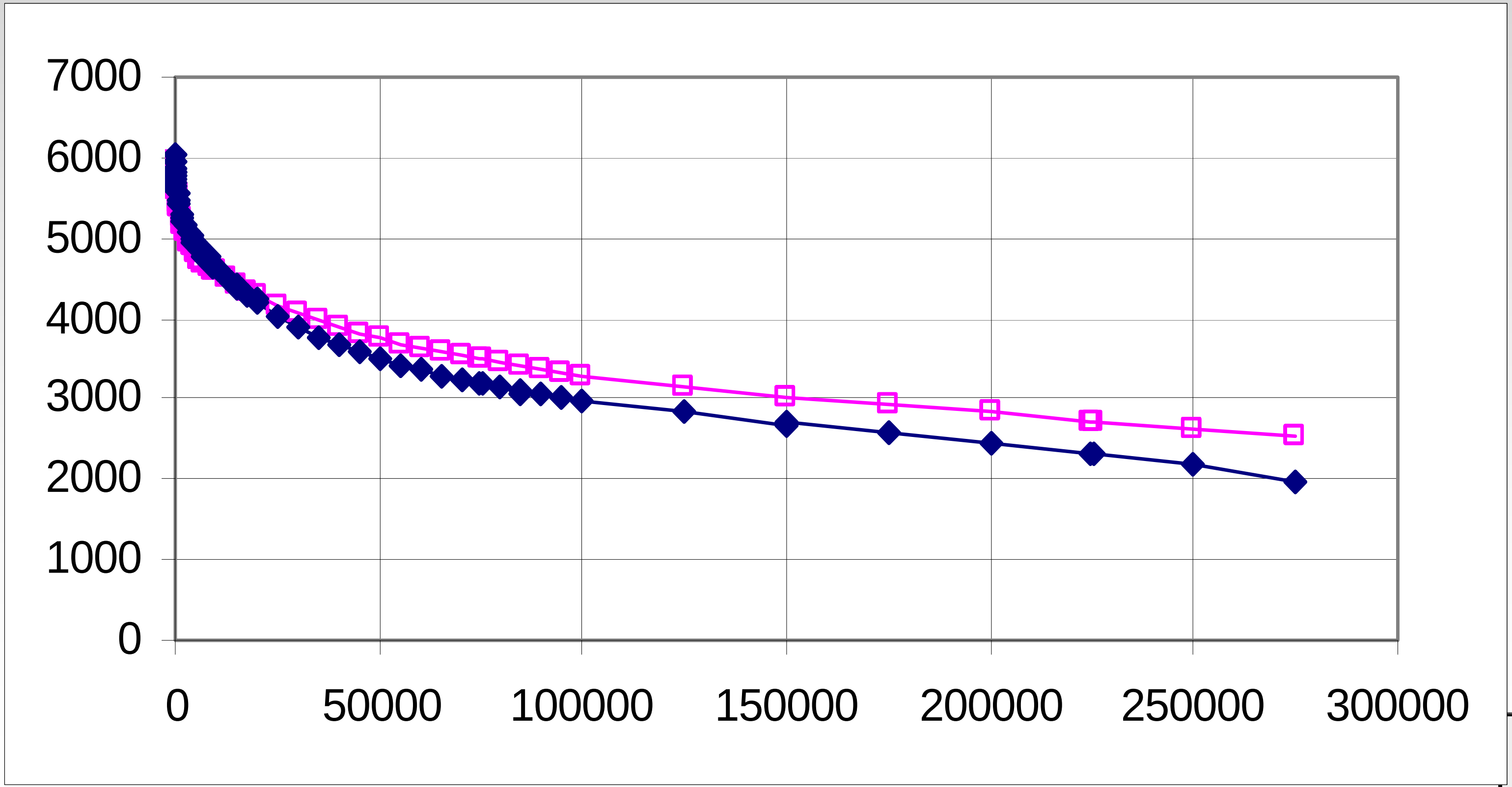
$$E = k_1 \times \left(\frac{stress}{p_a} \right)^{k_2}$$

Models calibrated in CalME

- Asphalt stiffness as a function of reduced time (temperature and loading time)
- Stiffness of unbound materials as a function of confinement and of stress condition
- Reduction in asphalt stiffness caused by damage

$$\log(E) = \delta + \frac{\alpha \times (1-\omega)}{1 + \left(t / t_{\alpha/2} \right)^{\gamma}}$$

$$\omega = A \times MN^{\alpha} \times \left(\frac{\mu\varepsilon}{200\ \mu strain} \right)^{\beta} \times \left(\frac{E}{3000\ MPa} \right)^{\gamma} \times \exp(\delta \times t)$$

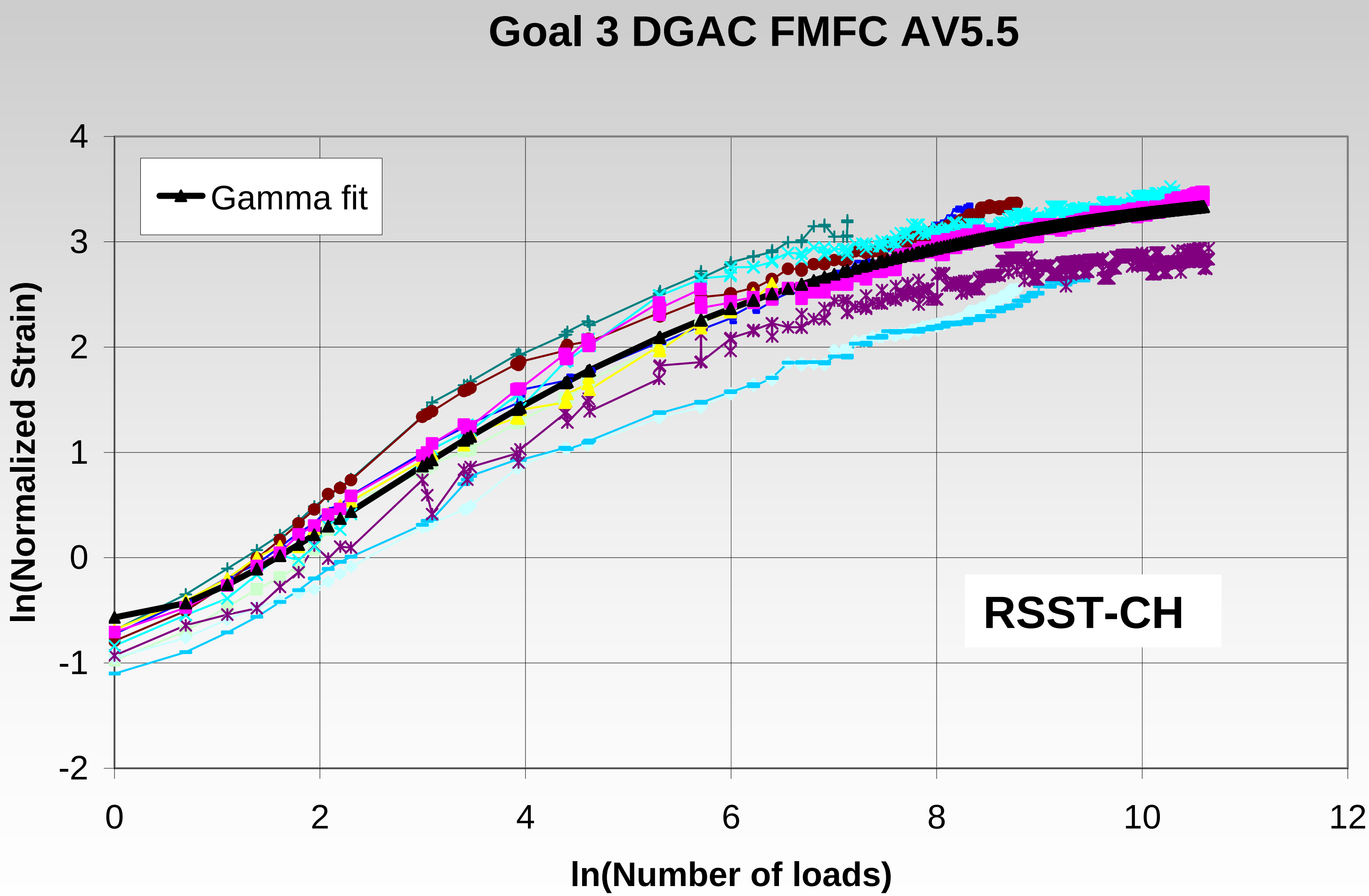


Models calibrated in CalME

- Asphalt stiffness as a function of reduced time (temperature and loading time)
- Stiffness of unbound materials as a function of confinement and of stress condition
- Reduction in asphalt stiffness caused by damage
- Permanent deformation of asphalt layers

Permanent deformation of AC

$$\gamma_p = \exp\left(A + \alpha \times \left[1 - \exp\left(\frac{-\ln(N)}{\gamma}\right) \times \left(1 + \frac{\ln(N)}{\gamma}\right)\right]\right) \times \exp\left(\beta \times \frac{\tau}{0.1\,MPa}\right) \times \gamma_e$$



Models calibrated in CalME

- Asphalt stiffness as a function of reduced time (temperature and loading time)
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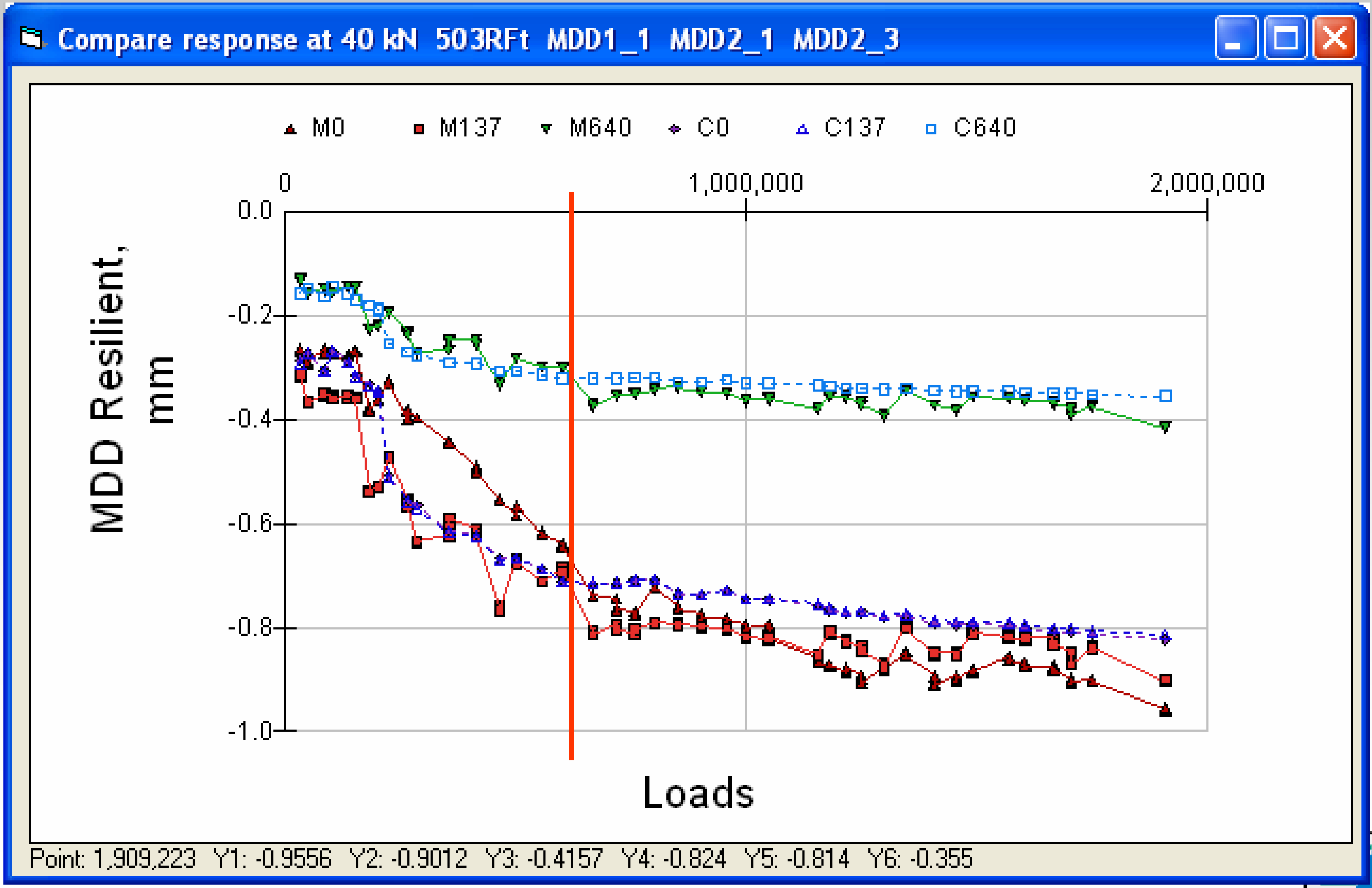
- Permanent deformation of unbound layers

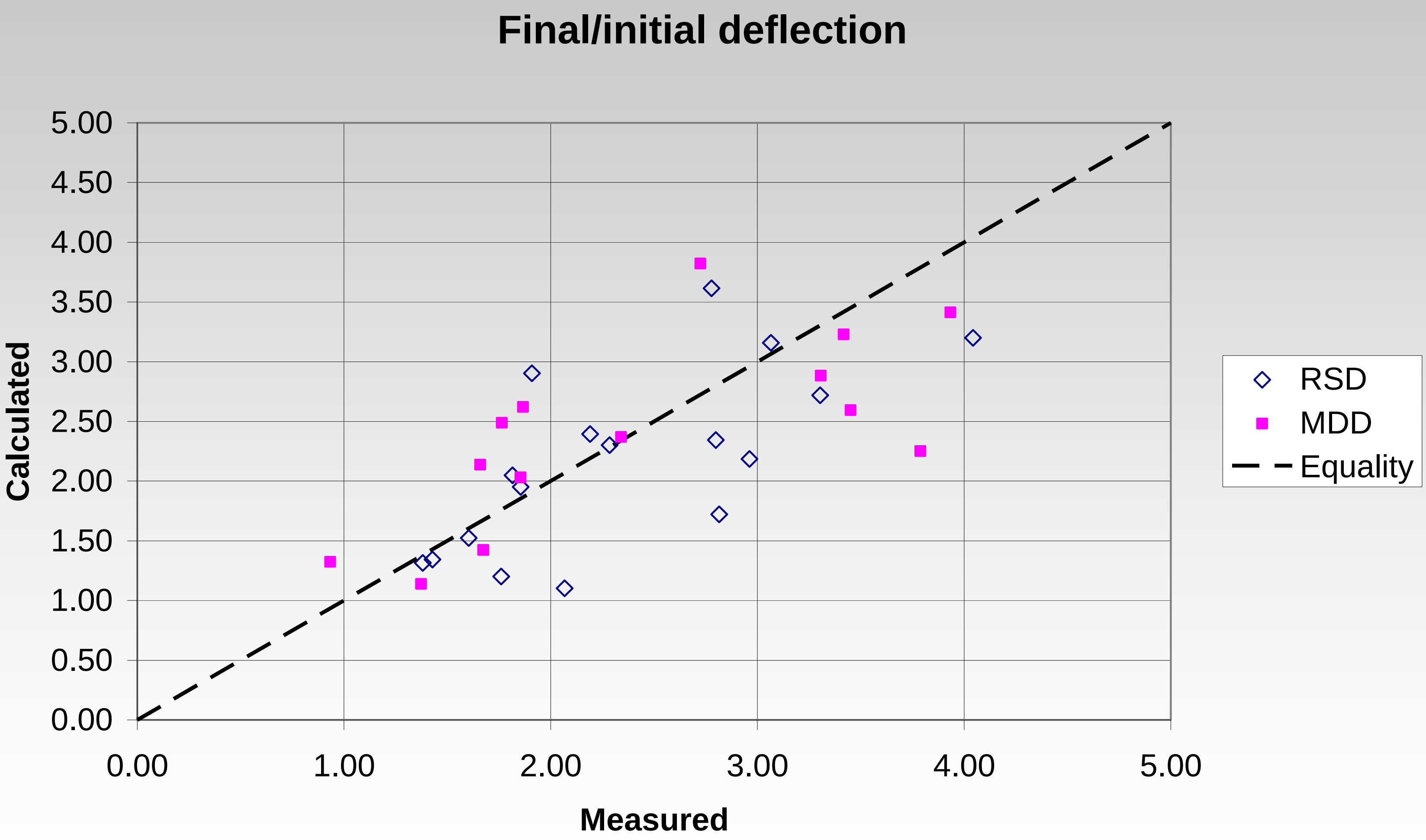
Permanent deformation of unbound layers

$$dp\ mm = A \times MN^{\alpha} \times \left(\frac{\mu\varepsilon}{1000\ \mu strain} \right)^{\beta} \times \left(\frac{E}{40\ MPa} \right)^{\gamma}$$

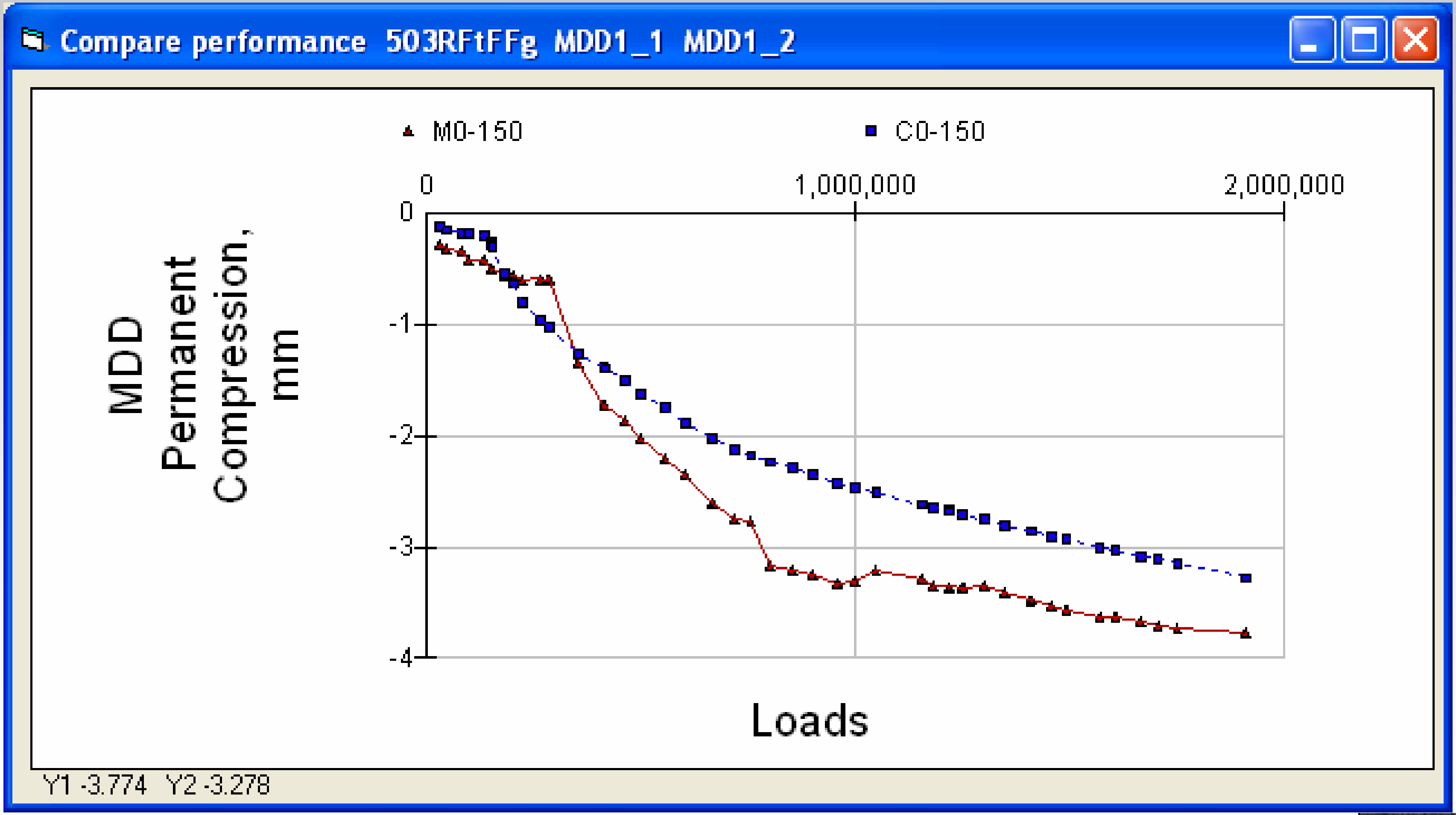
Step 1: Pavement response



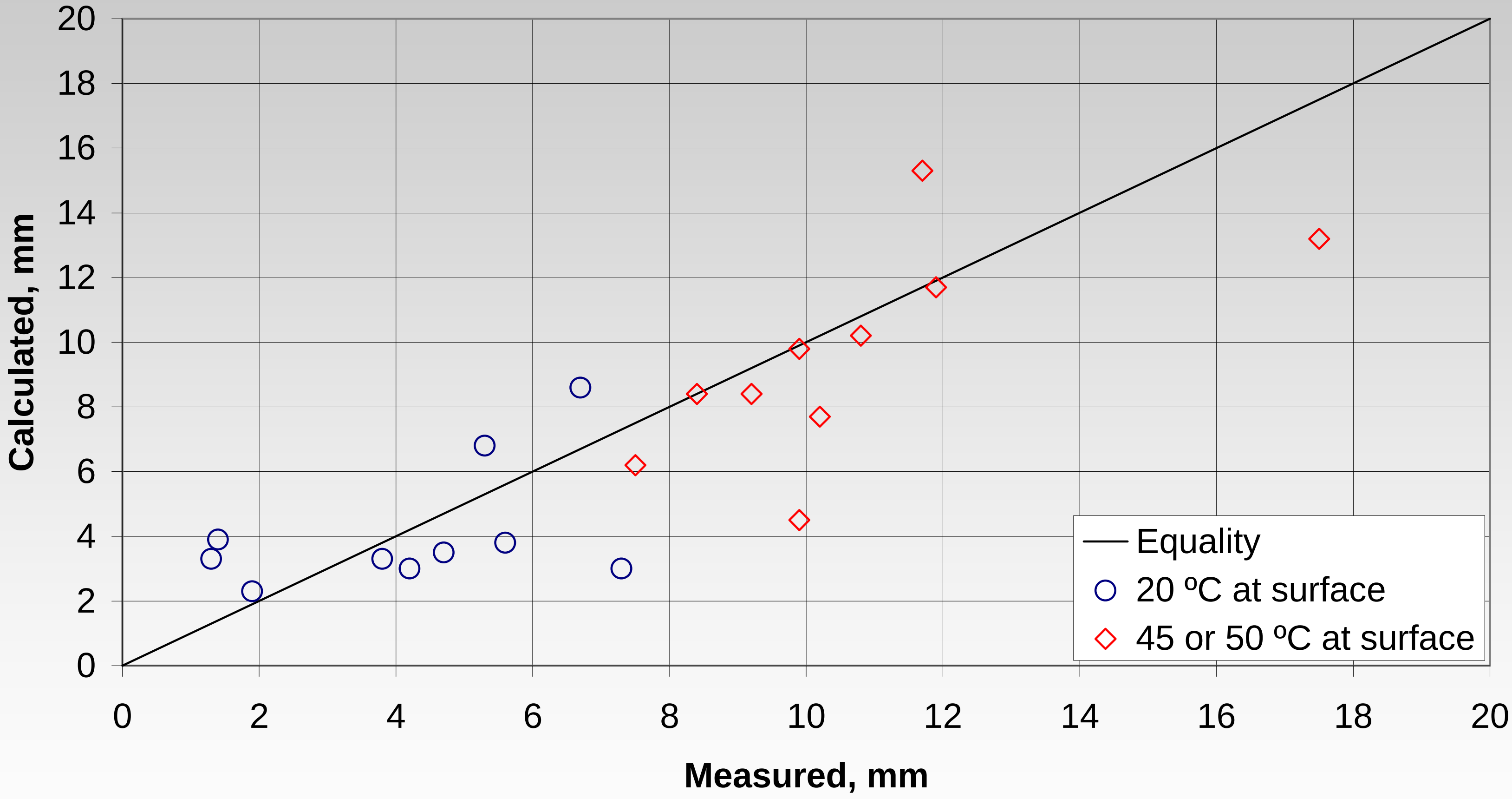
Change in response during testing



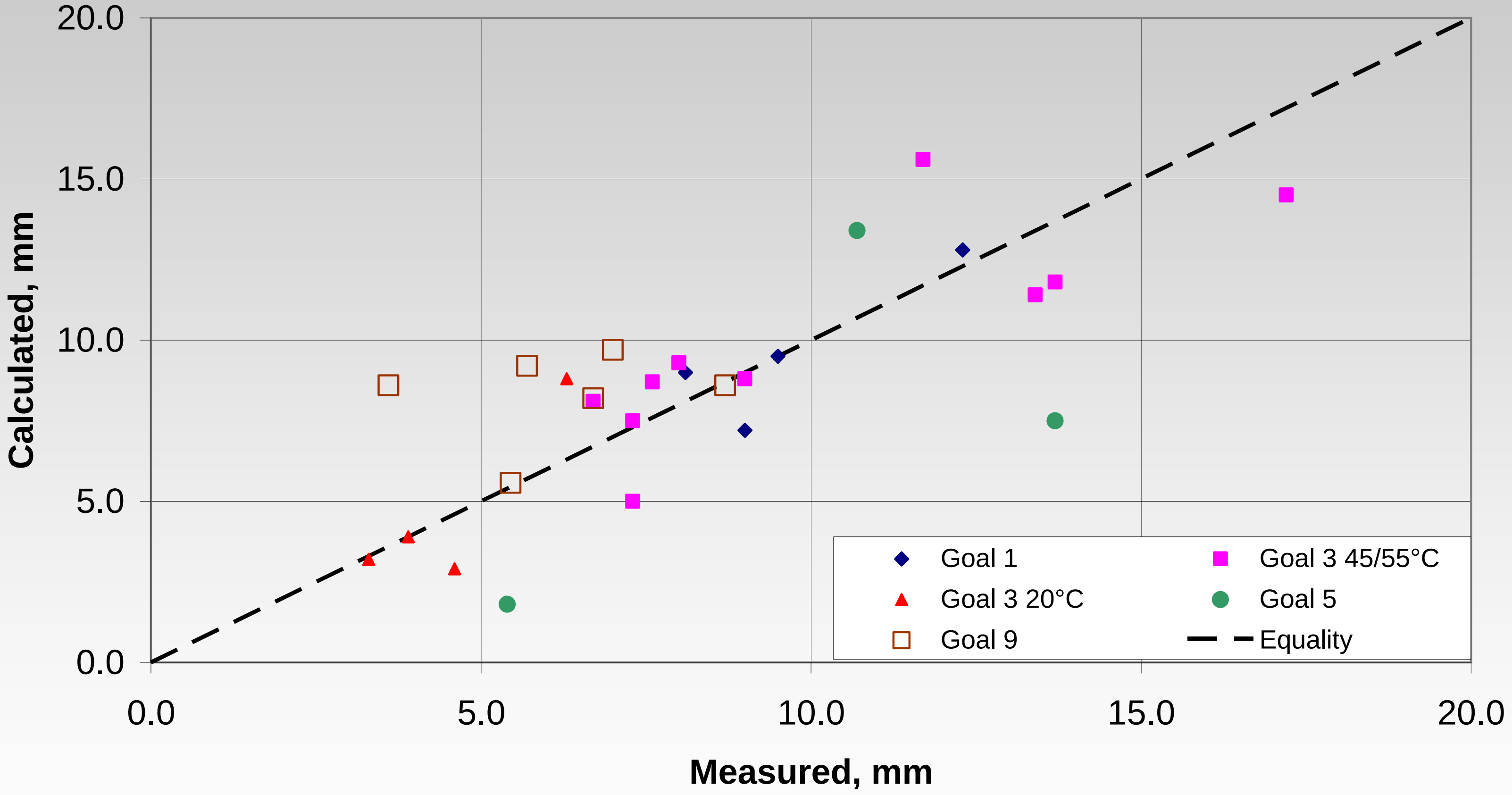
Permanent deformation of AC



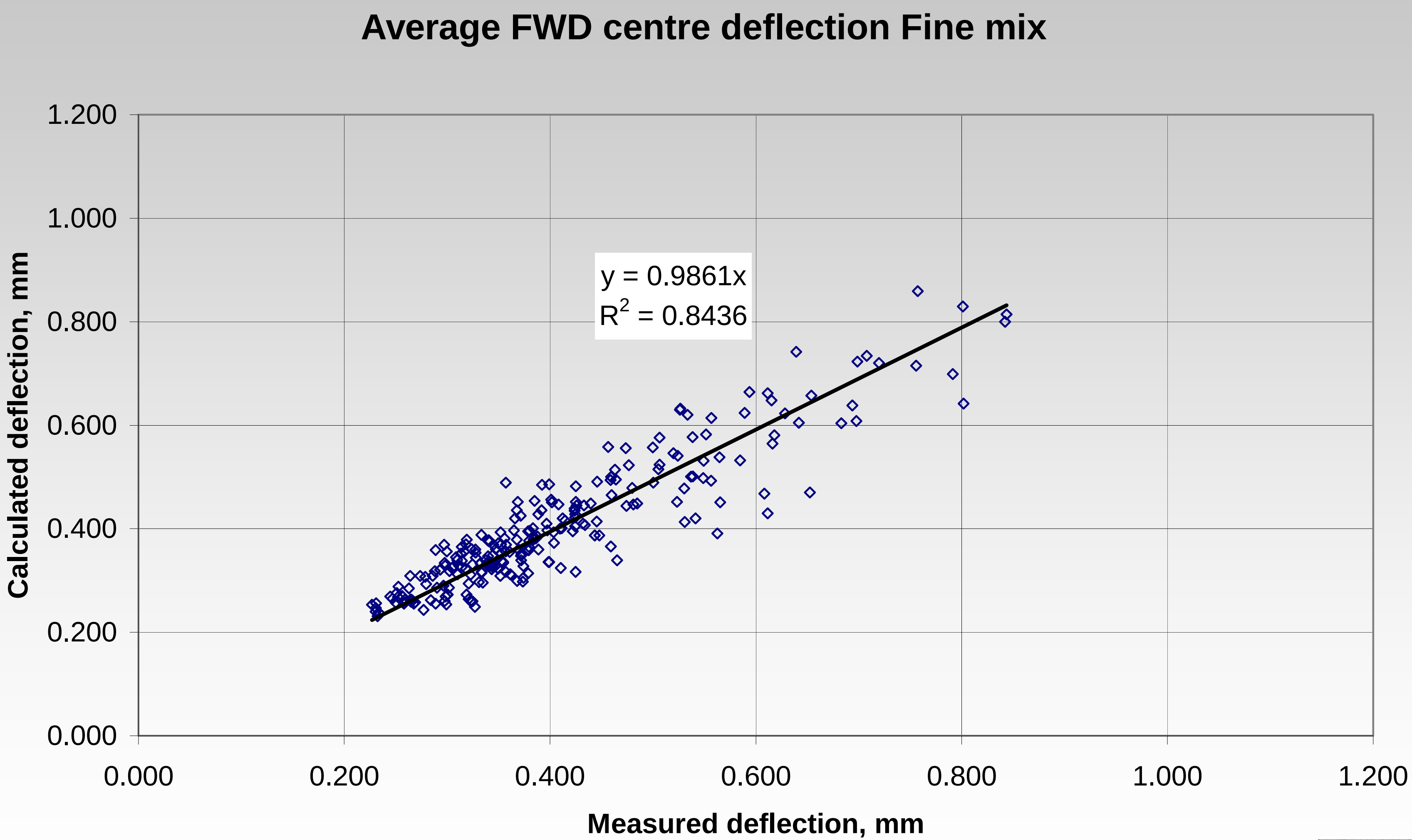
Permanent deformation in AC (pro rated)



Permanent deformation at pavement surface

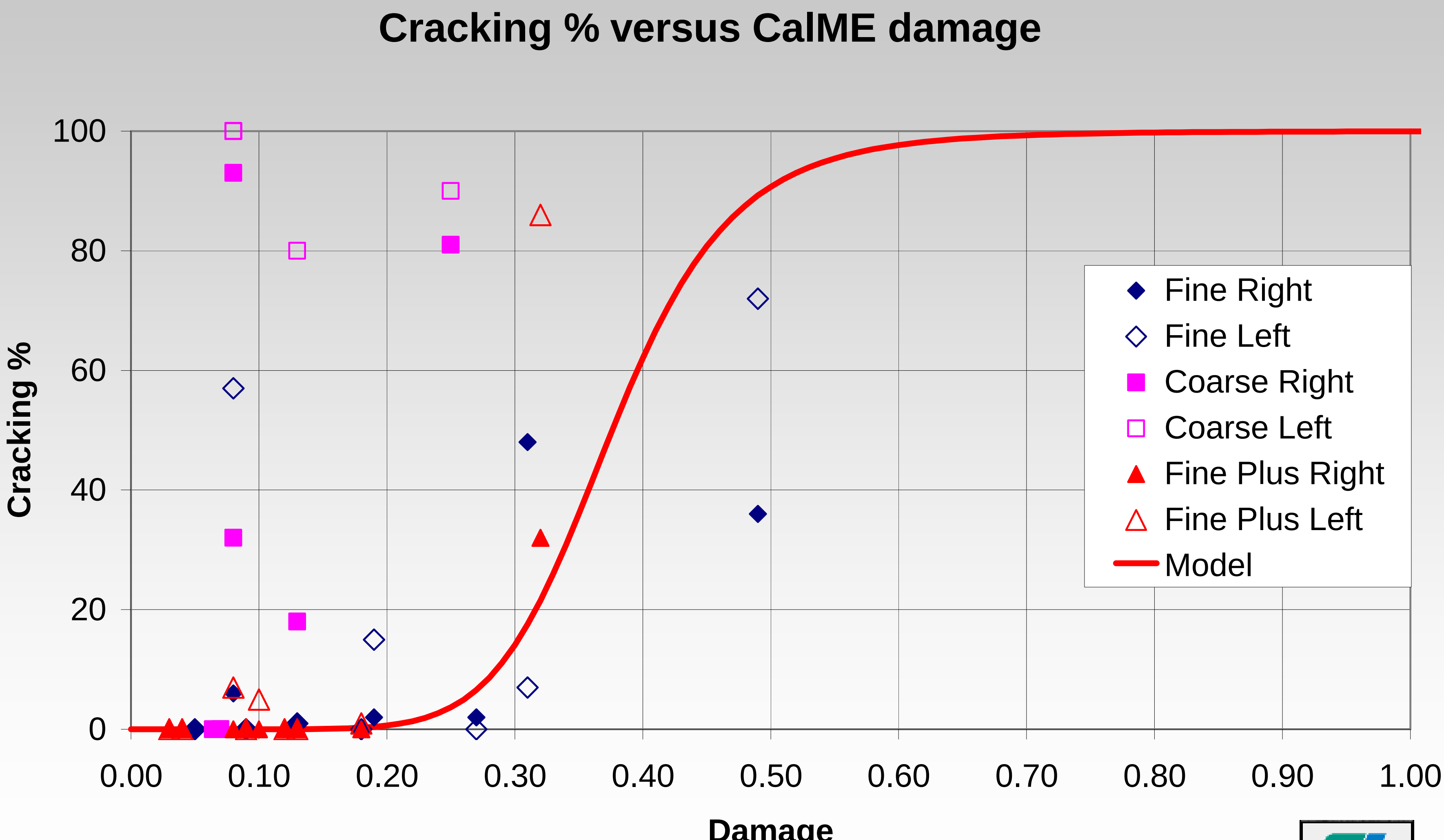


WesTrack: FWD deflections

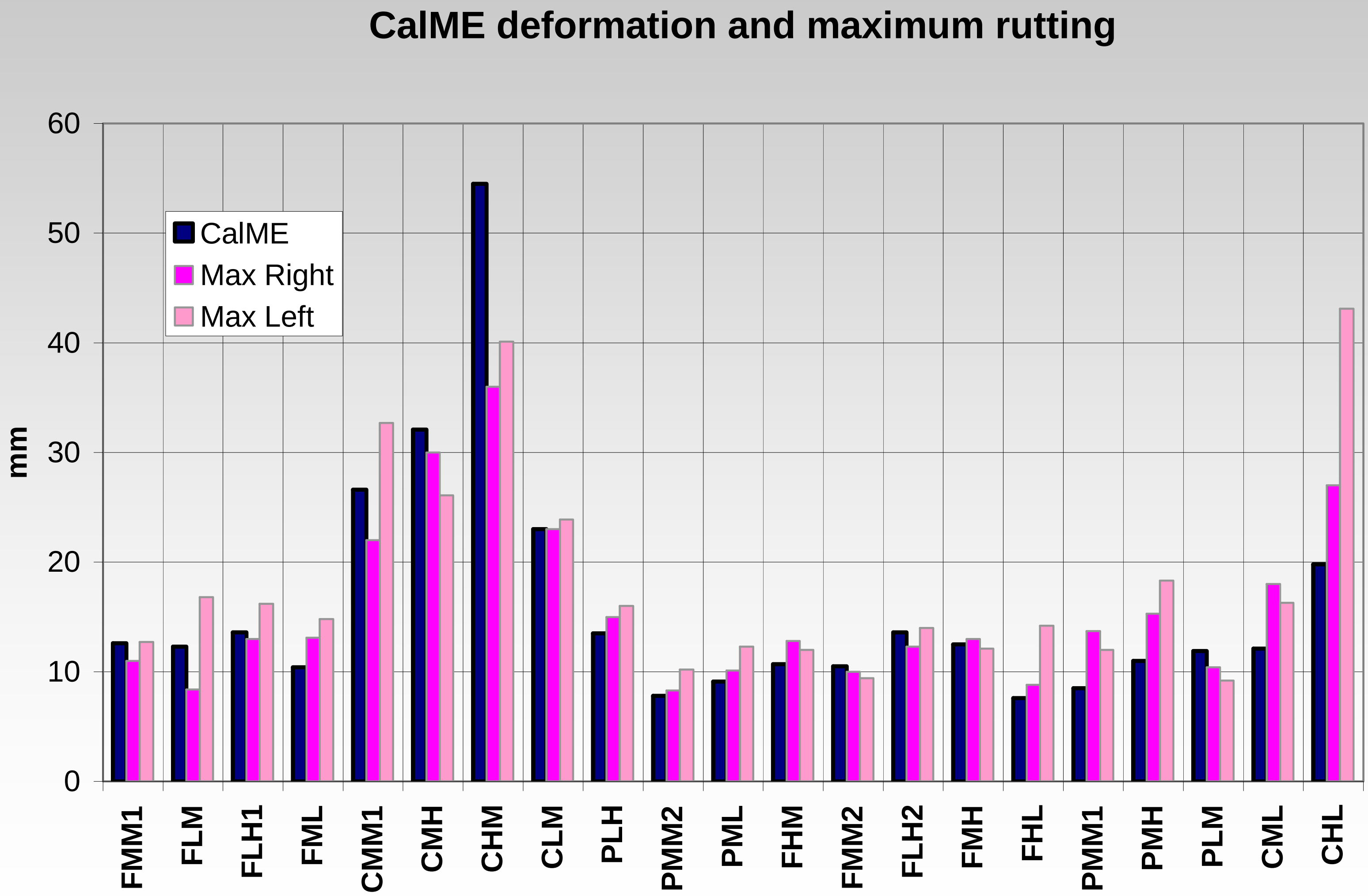


26 original test sections

WesTrack: Cracking



WesTrack: Permanent deformation



Conclusion

- A large change in pavement response was observed during the HVS tests
- Most of the large increase in deflection happened before any cracking was observed
- The increase in deflection was due to a decrease in the moduli of all layers
- Both response and performance were reasonably well predicted by CalME
- The next step is calibration against in situ pavement sections

Thank you