State-of-the-Art in Pavement Instrumentation and Accurate Measurements

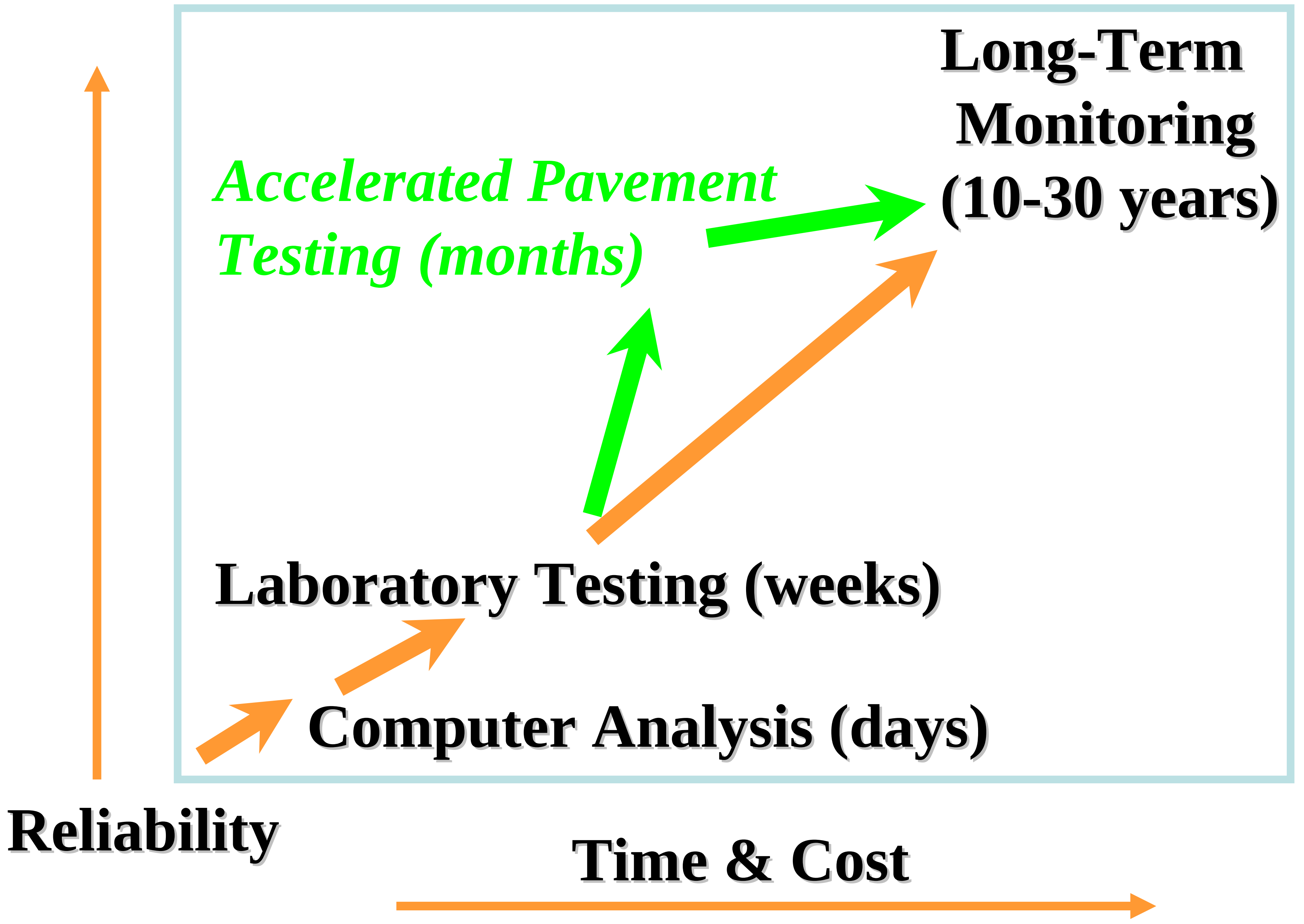
TRB 2008 Workshop on APT

Subject of this Discussion

- Two purposes of APT related to measurement
  - Develop, validate, calibrate mechanistic models of pavement performance (long-term value of the test)
  - Empirical comparison of alternatives in the experiment (immediate purpose)
- Two steps for mechanistic model development requiring measurements
  - Response of pavement to load and climate
  - Damage in pavement as function of response
- Focus of this discussion is on mechanistic models

Three kinds of APT

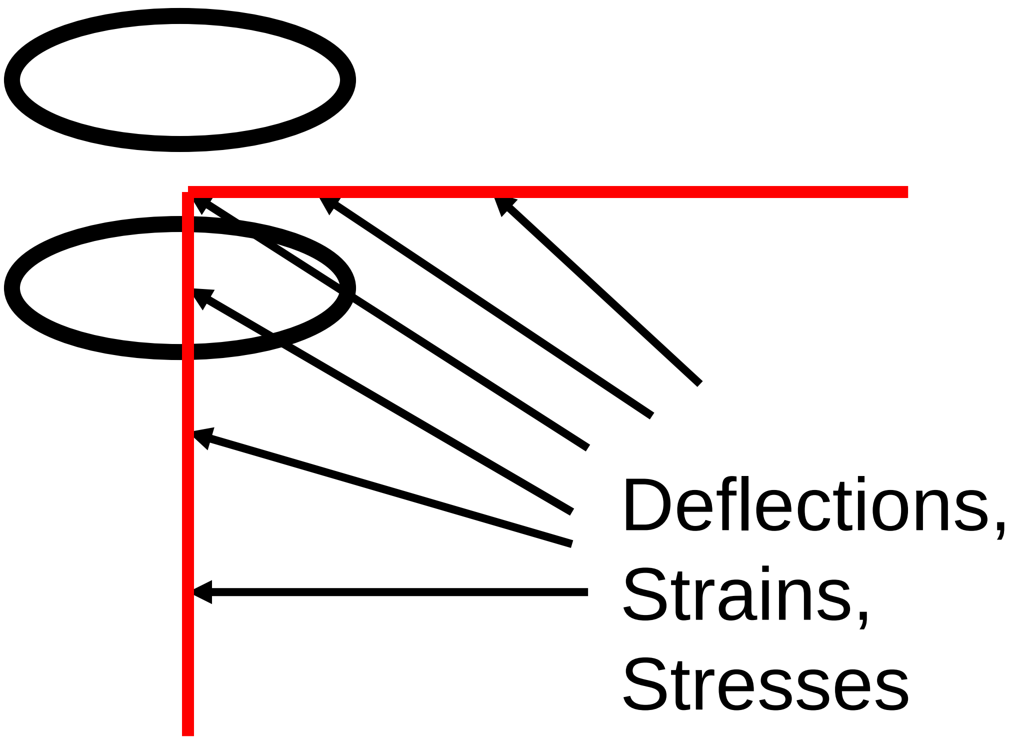
- Fixed devices (HVS, ALF, LinnTrack, PurTrack, MLS)
  - Controlled temperature and moisture
  - Slow wheel
  - Big overloads
  - Short sections
  - Controlled wander
  - Little suspension interaction
- Test tracks
  - Opposite of above
  - Controlled loading
  - Access for field type testing equipment
- Hybrid (LCPC, CEDEX, CAPTIF)
  - Some of each of the above


Long-Term
Monitoring
(10-30 years)
Accelerated Pavement
Testing (months)
Laboratory Testing (weeks)
Computer Analysis (days)
Reliability
Time & Cost

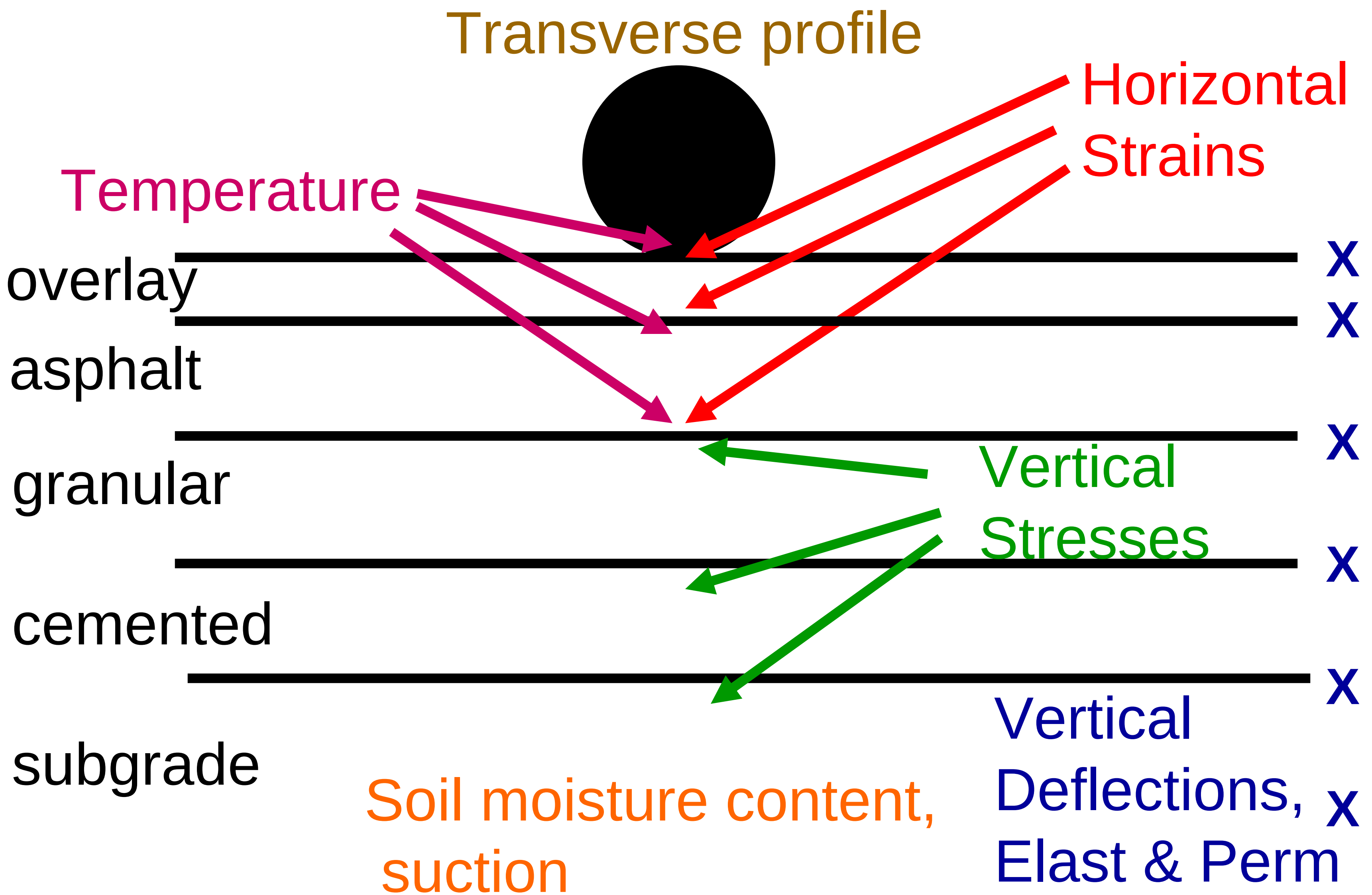
Responses

- What do we want to measure?
  - Stresses, strains and deflections
- Where do we want to measure them?
  - Where the response is believed to be highly correlated (and causally related) with the damage process
- What will we do with these measurements?
  - Materials characterization (combined with lab)
  - Response for each distress

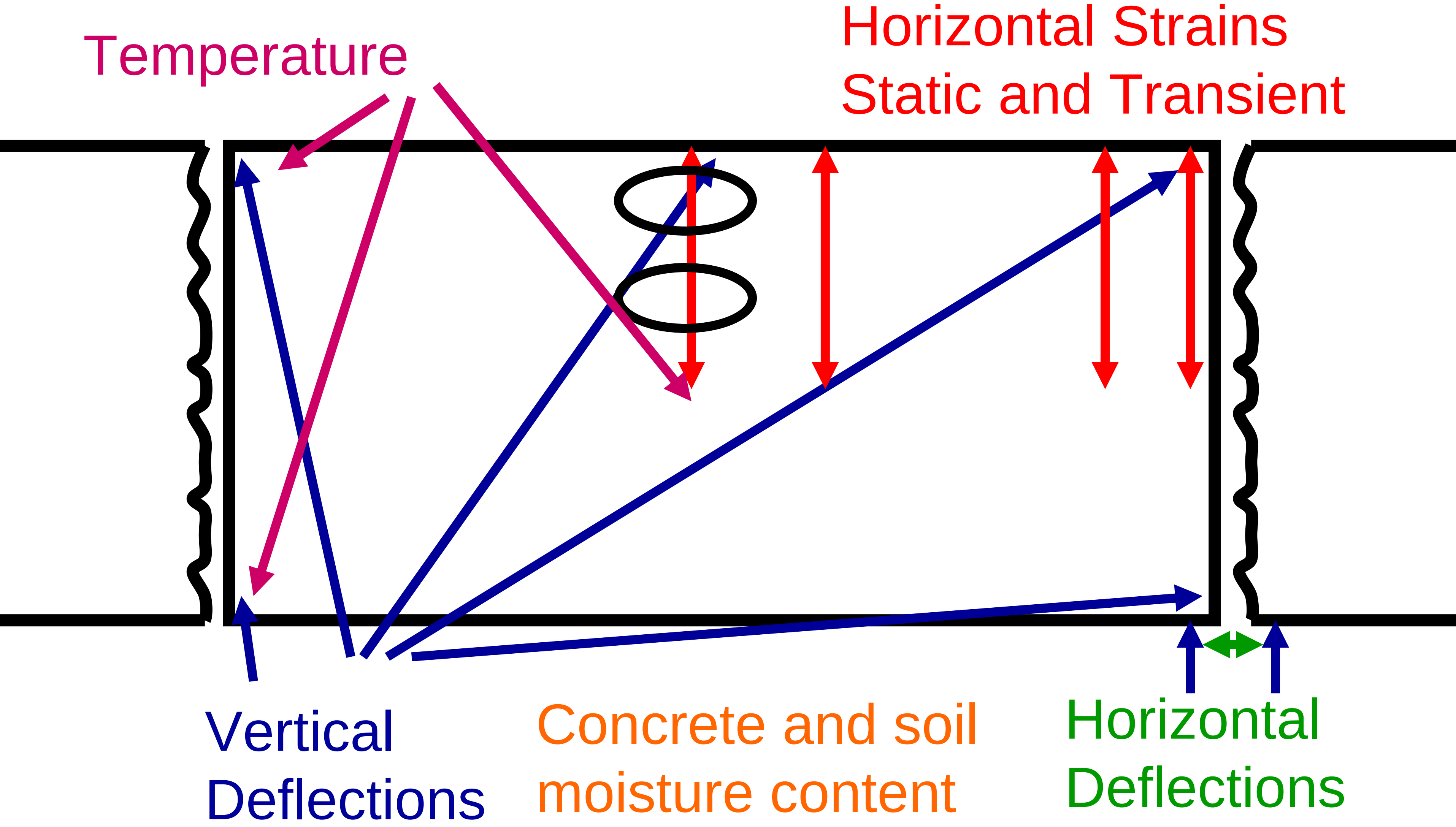
Typical measurements in asphalt pavements: plan- view



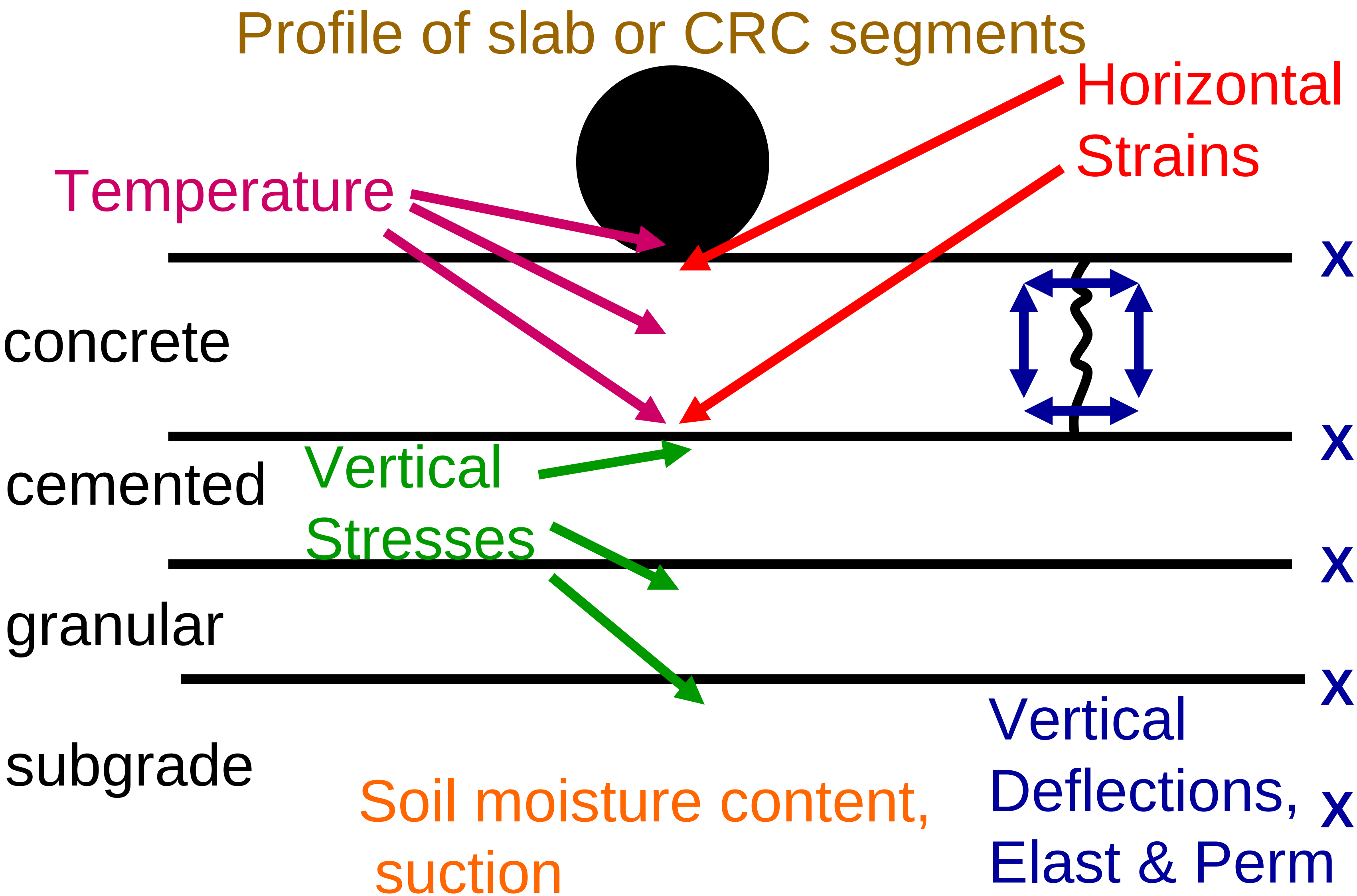
Typical measurements in asphalt pavements: X-section



Typical measurements in concrete pavements: plan view



Typical measurements in concrete pavements: X-section



Typical Measurements in Composite Pavements

- Asphalt layers: same as in asphalt pavement
- Concrete and layers below: same as in concrete pavement

Pavement condition and loading

- Temperature
  - Thermocouples
  - Buttons XXX
- Moisture
  - Small buttons
- Wheel load
  - Weigh in Motion
- Contact stress
  - Stress in Motion

Indirect use of measurements for the mechanistic model

- Process:
  - Characterize materials in laboratory
  - Calculate critical response ($\sigma,\varepsilon,\delta$)
  - Correlate observed performance with calculated response
- Example:
  - Use triaxial lab result for stiffness of soils
  - Calculate asphalt master curve from parametric equation
  - Calculate initial strains
  - Compare calculated strains with observed cracking

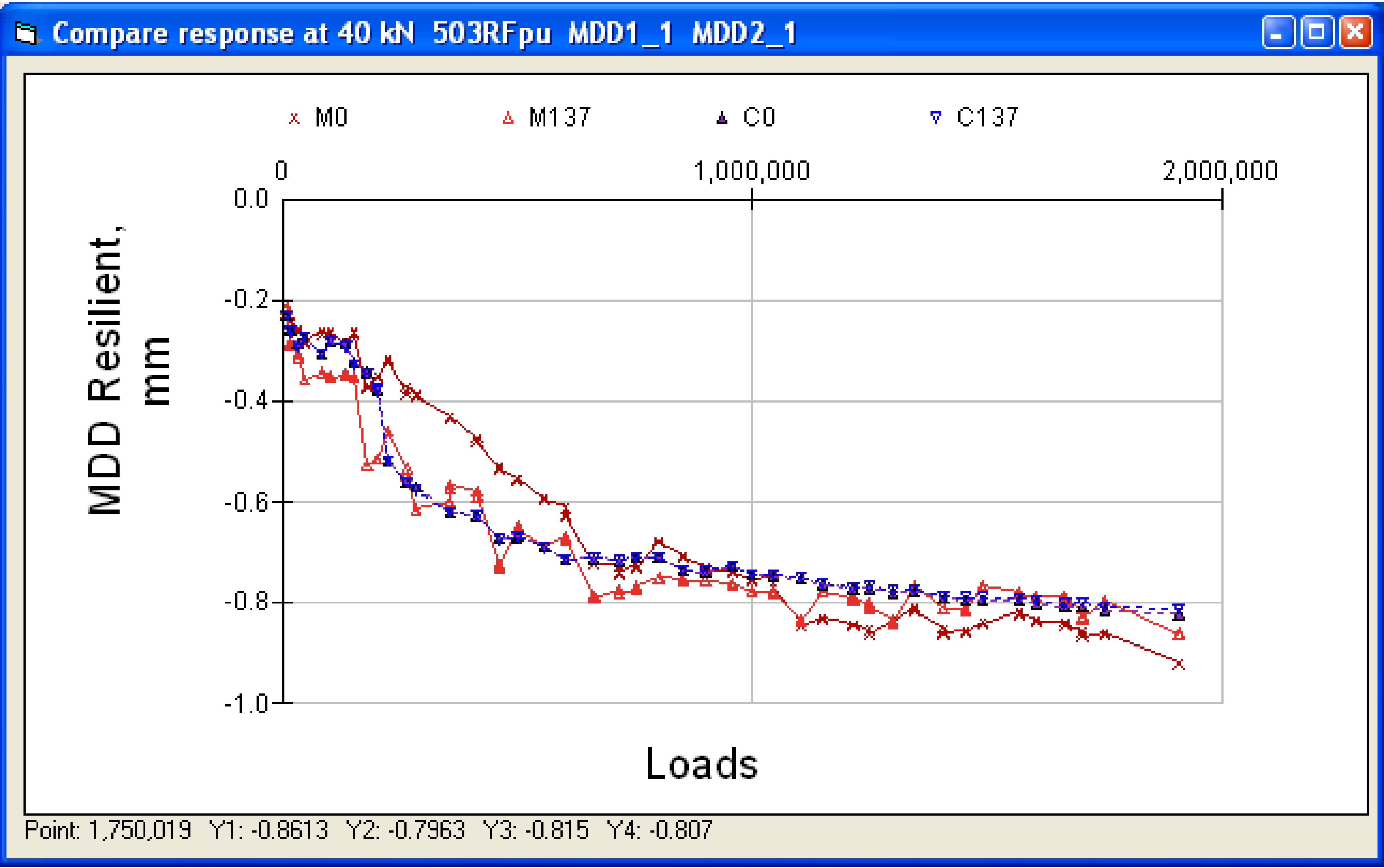
Direct use of measurements for the mechanistic model

- Process:
  - Characterize materials in field and lab
  - Reconcile field and lab characterization based on different boundary conditions, stress states
  - Characterize damage relation with critical response in lab
  - Calculate critical response (σ,ε,δ)
    - Compare to measured response if possible
    - Compare calculated and actual response initially and throughout APT test
    - Requires updating damage during simulation
  - Correlate observed performance with calculated damage
- Example in the next figures

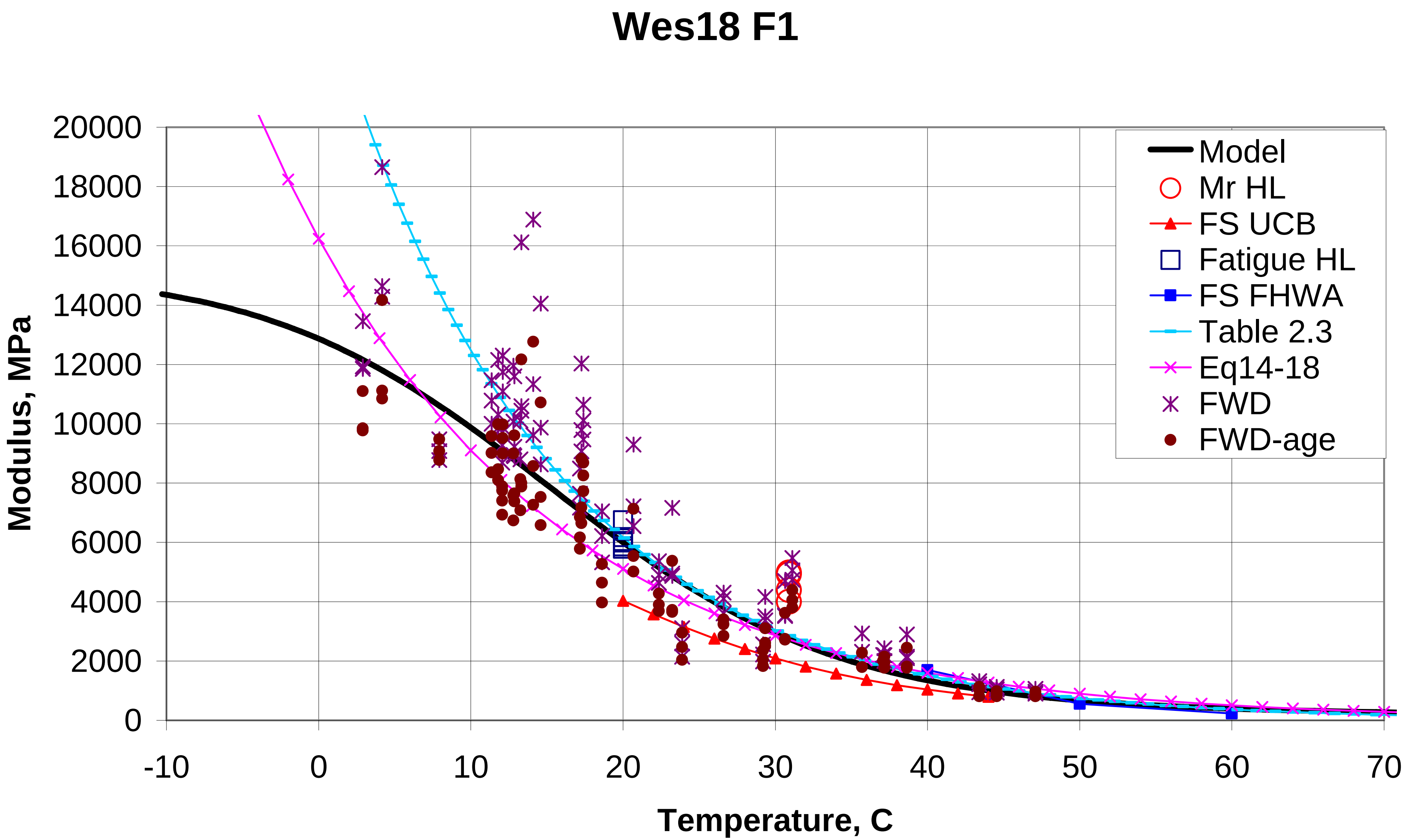
Example: Use of FWD, MDD, RSD and lab tests with APT

- Calibration of initial stiffnesses
  - Master curve for asphalt layers
  - Stiffness responses of granular and subgrade layers
- Identification of the funny stuff
  - Do you know the bonding?
  - Self-cementing materials and temporary recovery
- Calibration of the damage process

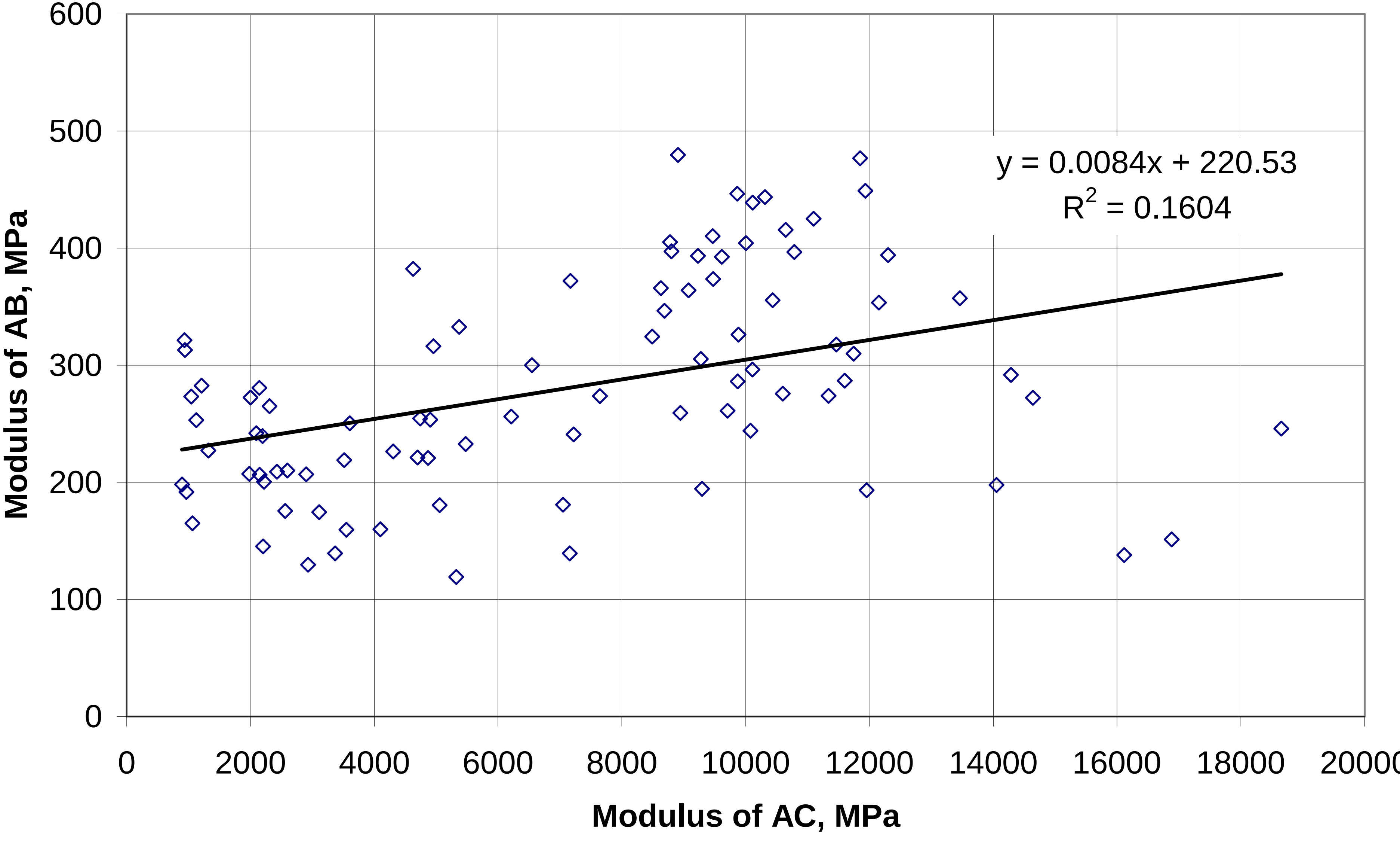
Comparison of actual and calculated vertical deflections (HVS)



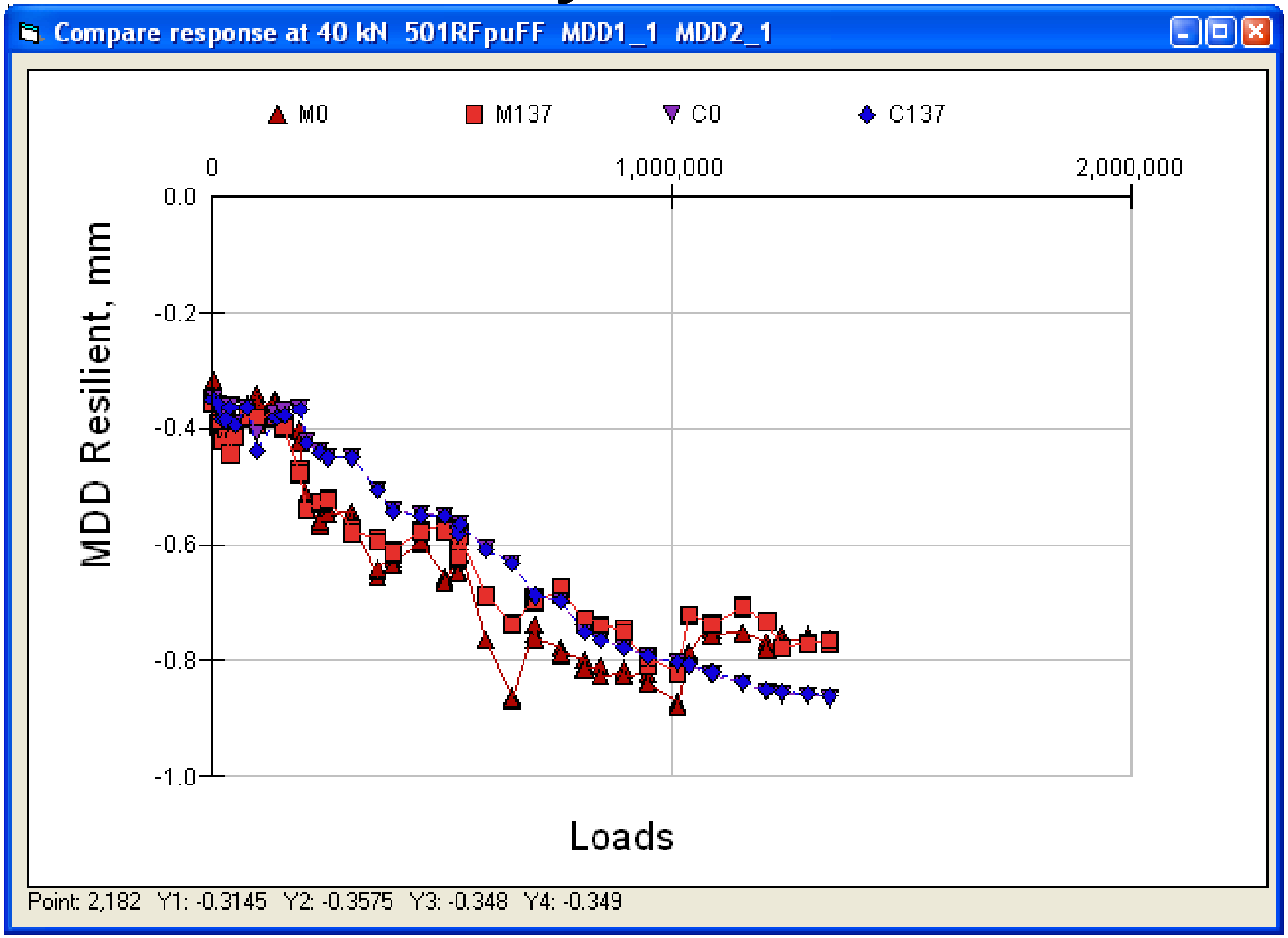
Comparison of laboratory and field generated stiffnesses: asphalt



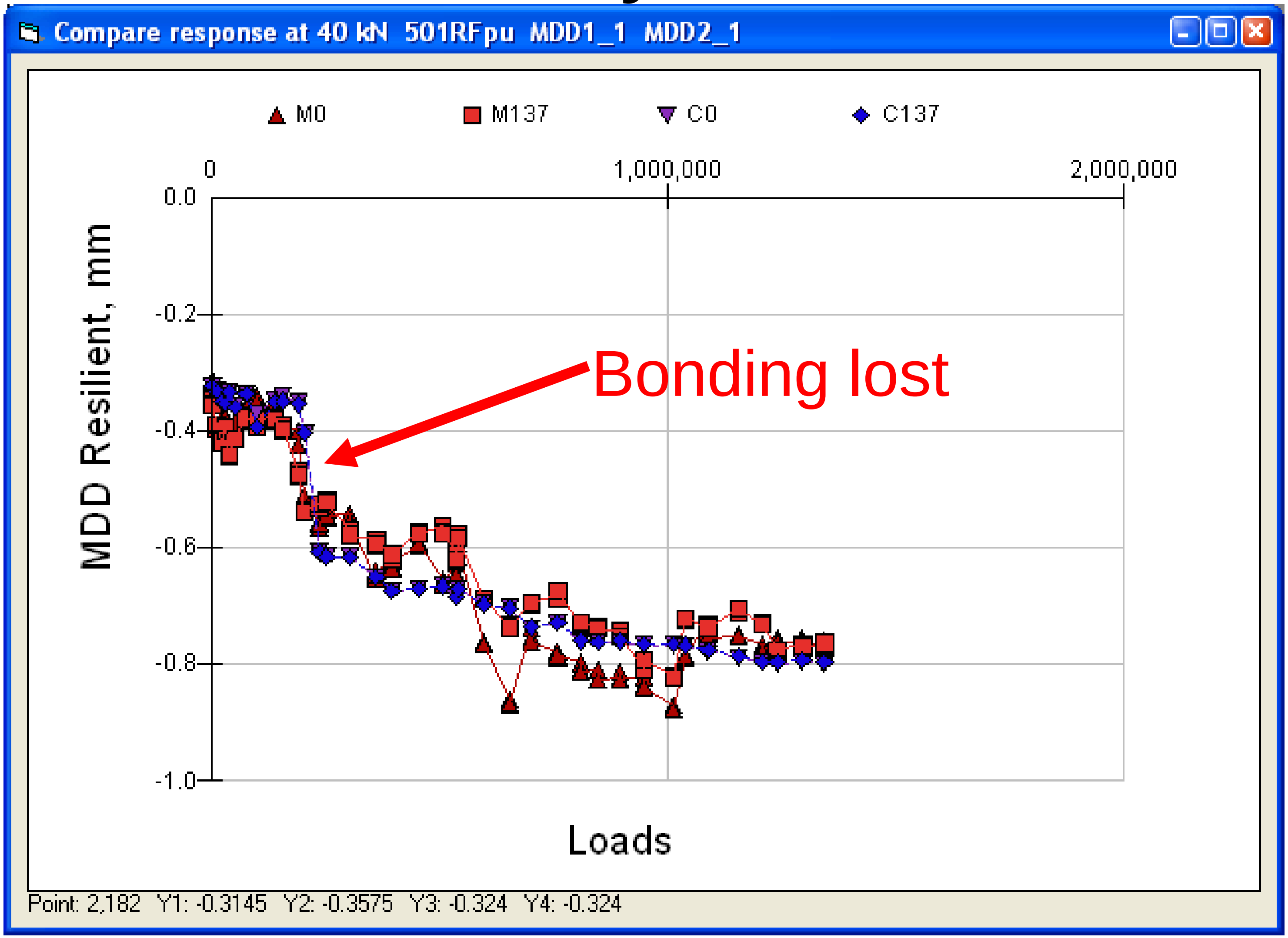
Relations between moduli



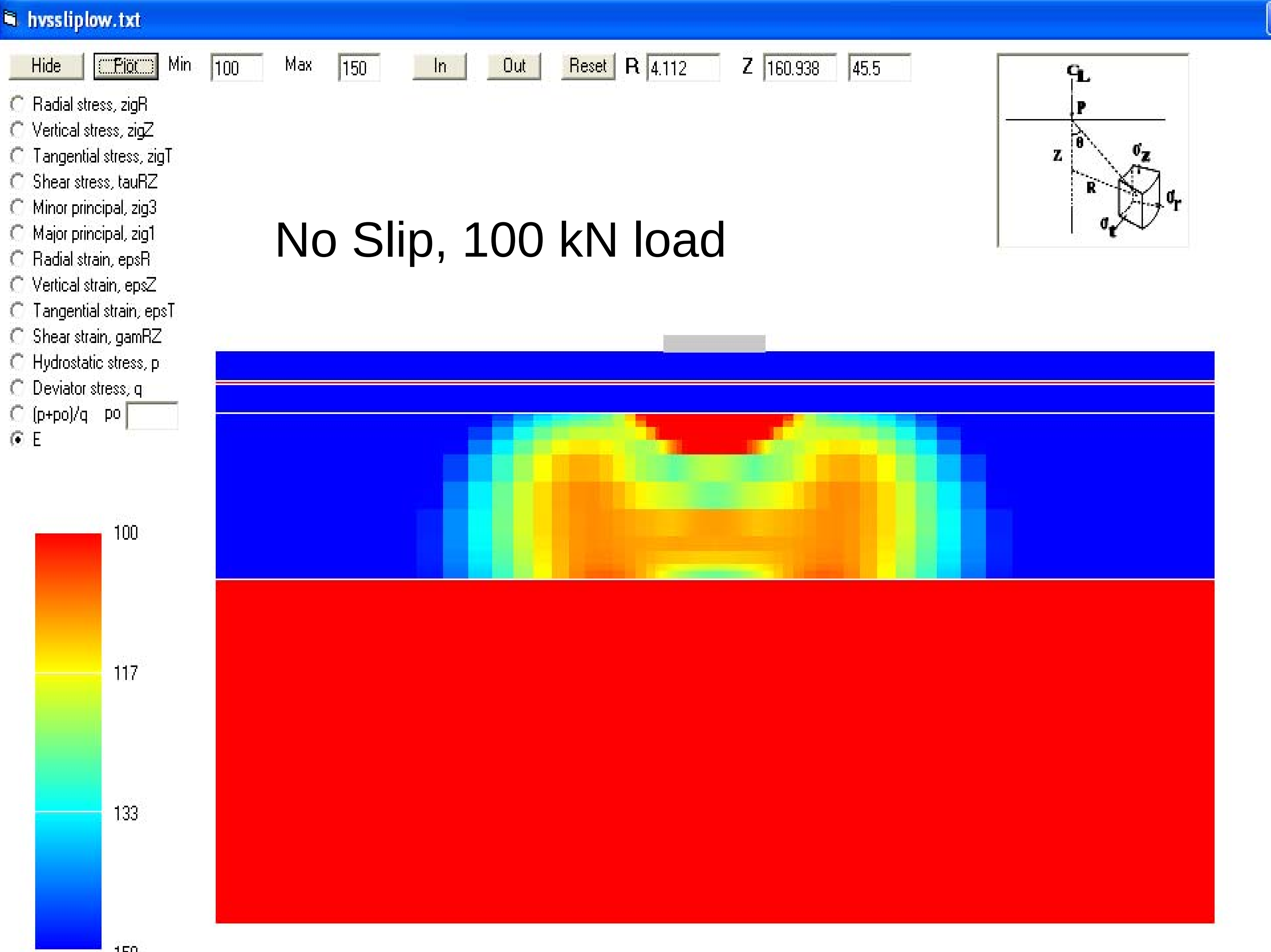
Good bonding between asphalt layers



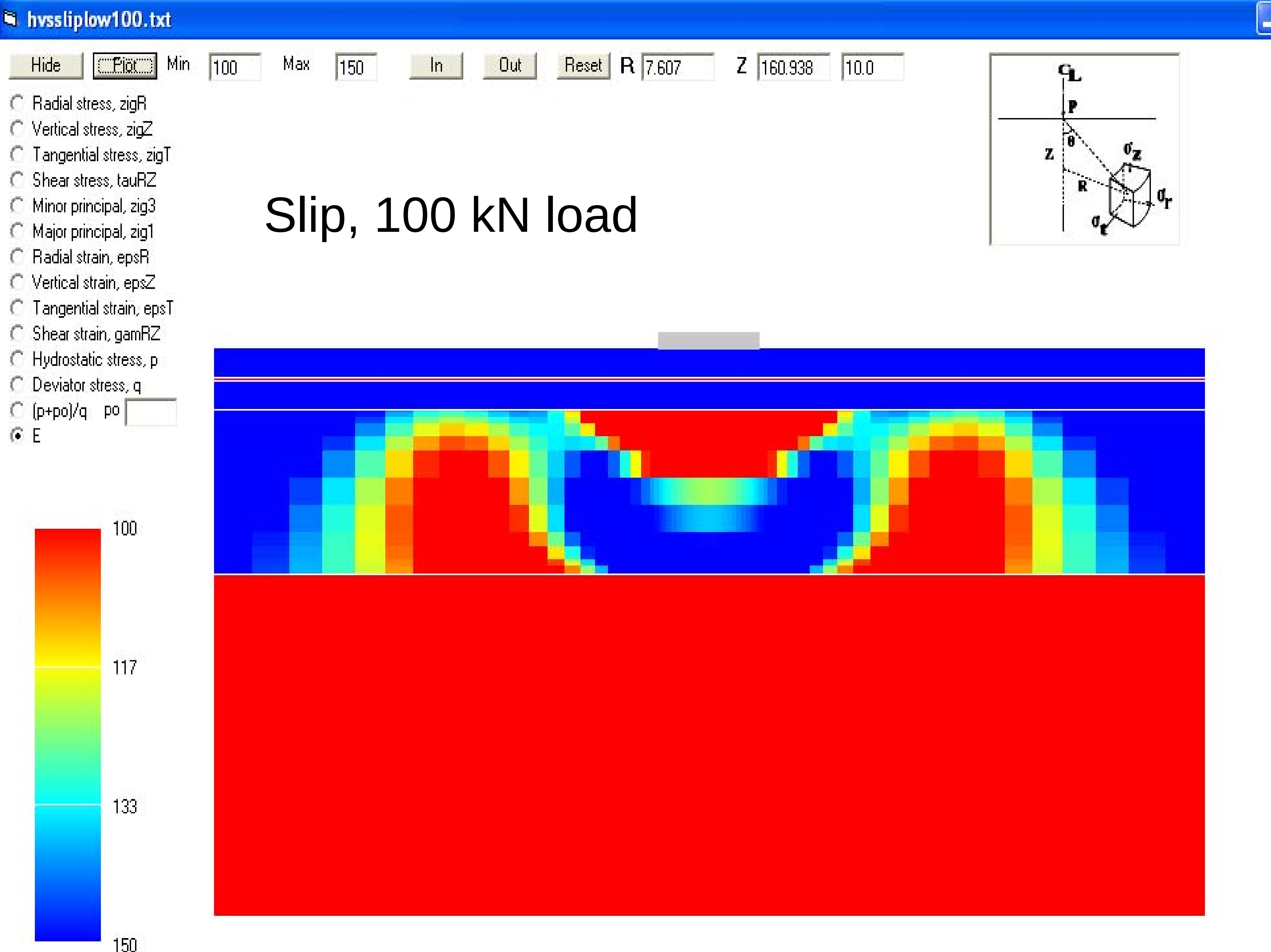
Loss of bonding between asphalt layers



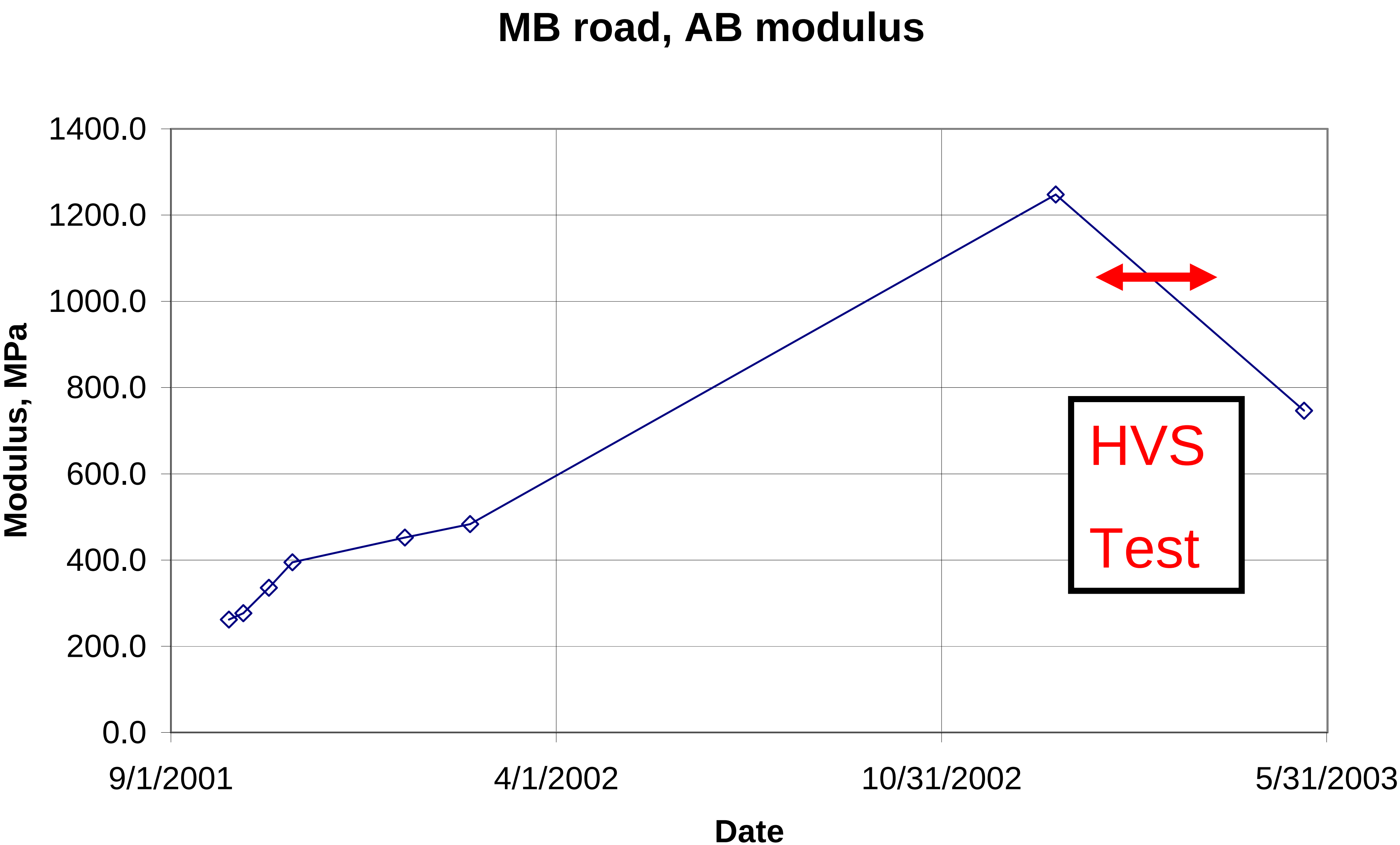
No Slip, 100 kN load



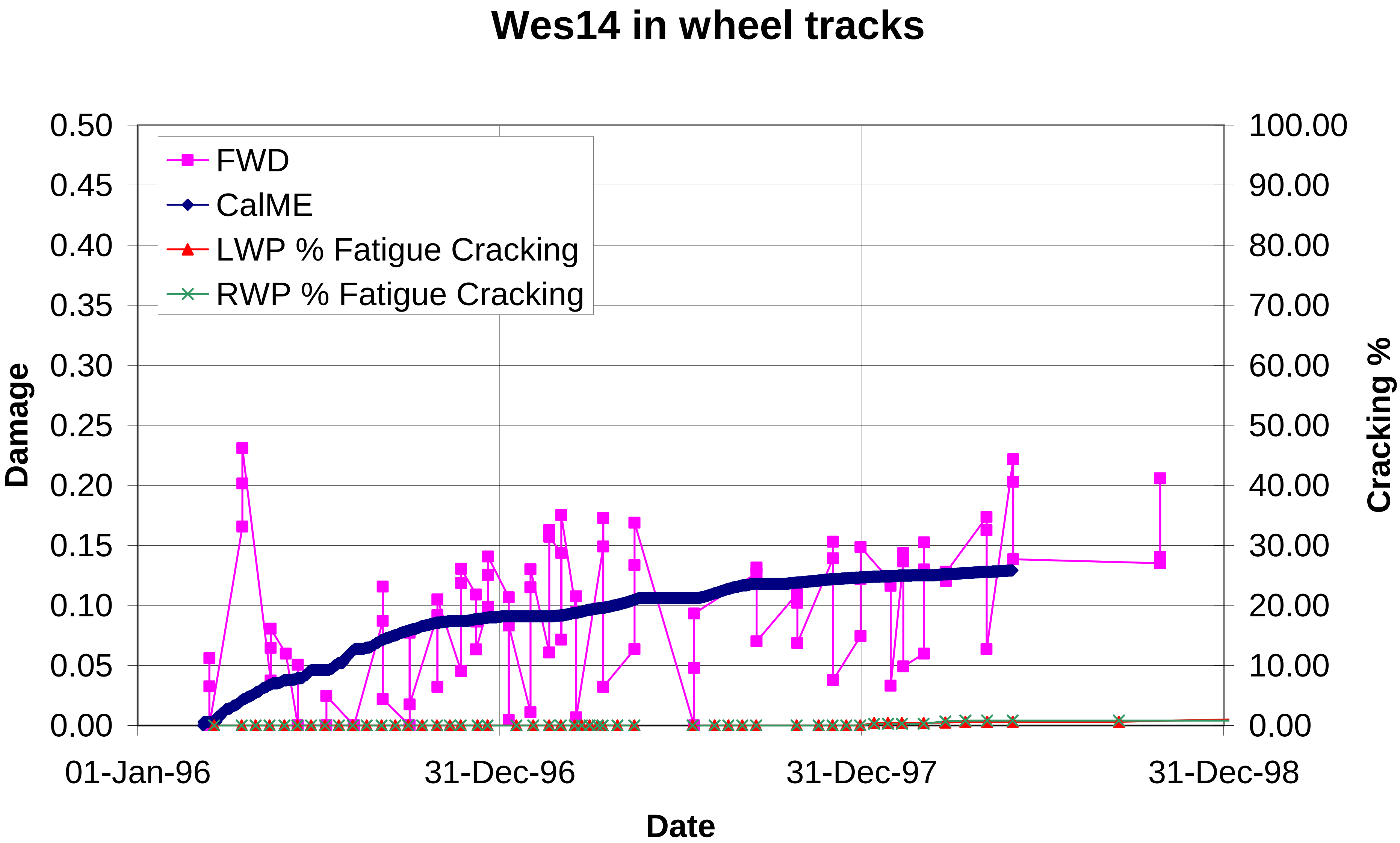
Slip, 100 kN load



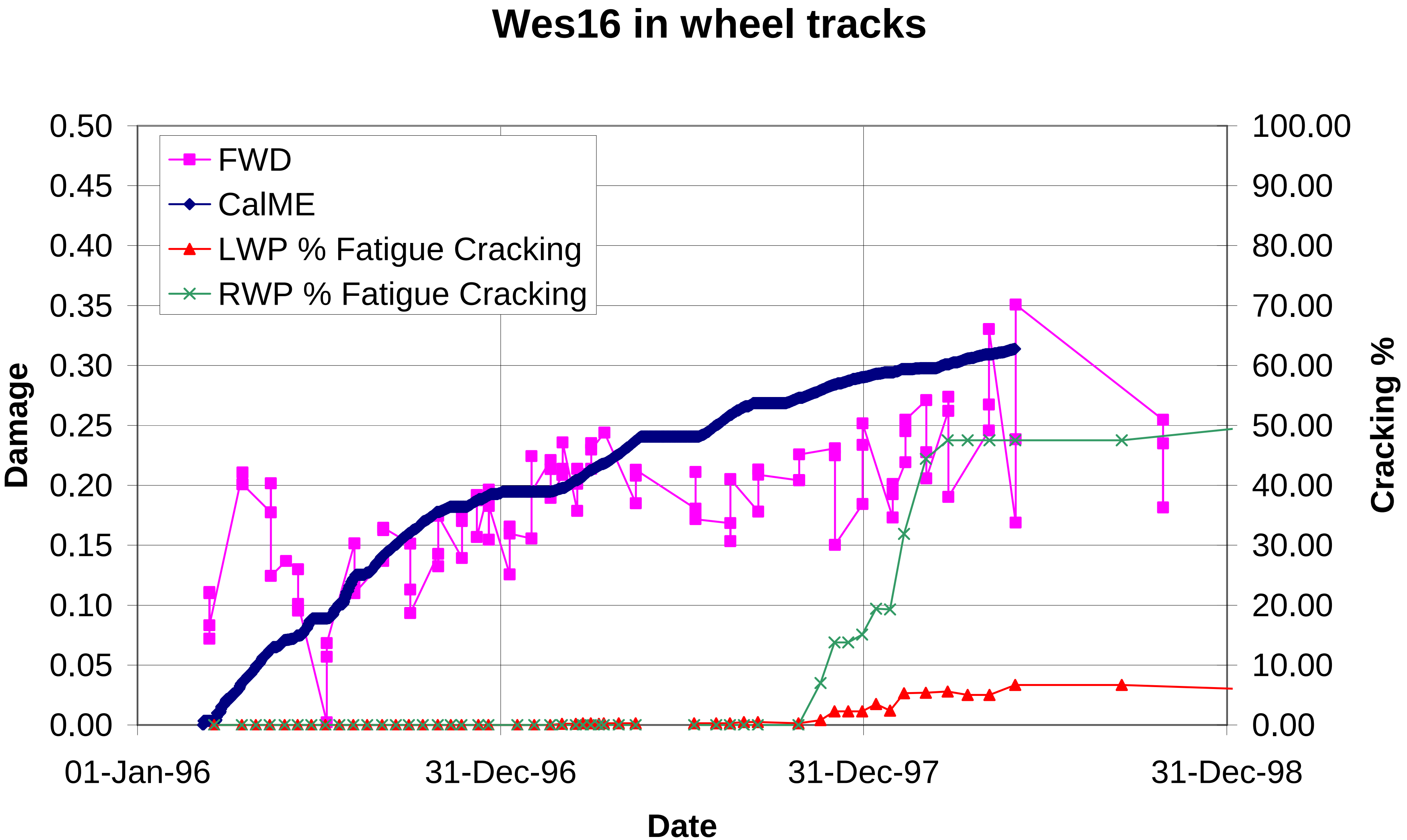
Light cementation in aggregate base containing recycled concrete



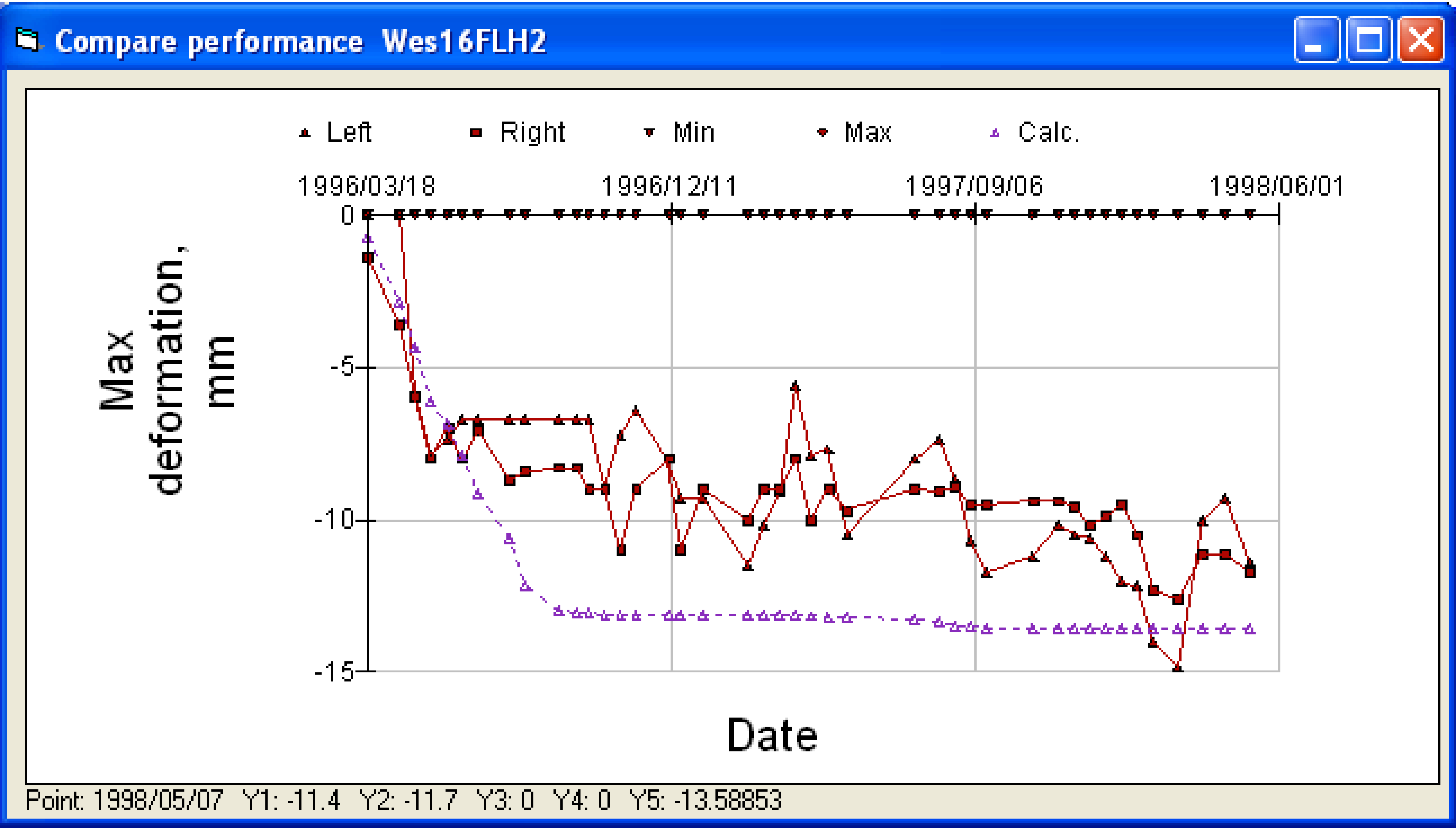
Damage parameters: moduli



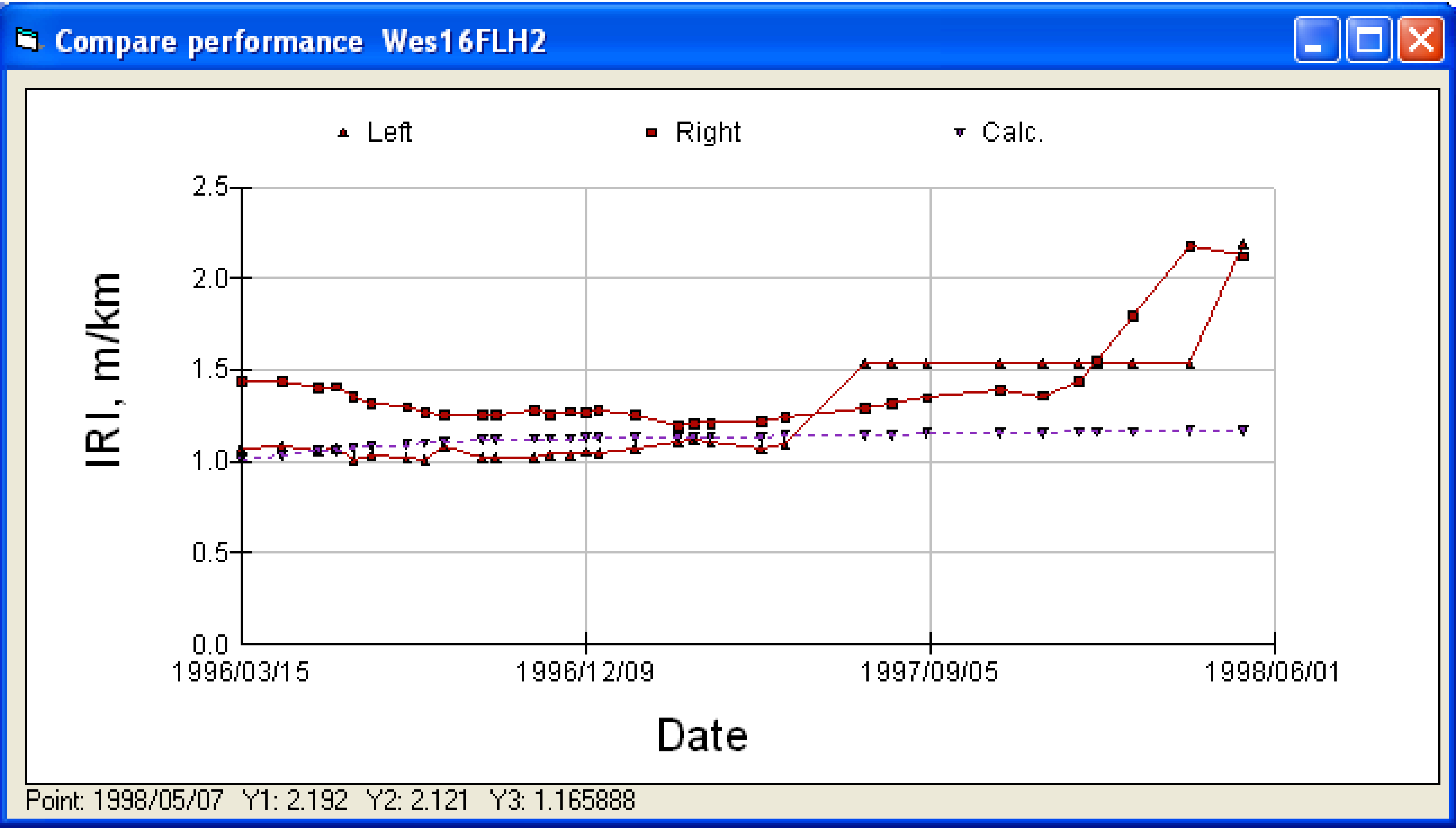
Damage parameters: cracking



Damage parameters: permanent deformation



Damage parameters: roughness



What would we like to measure that we can’t

- Wireless where possible!!
- Asphalt pavement
  - Shear stresses and strains
  - Strains in thin overlays
  - Lateral stress in soils layers at locations under and away from load
  - FWD type deflection basins or direct stiffness measurement under a fixed device
  - Soil suction under the load
  - Bonding between asphalt layers
  - Crack initiation (top or bottom)

What would we like to measure that are currently difficult

- Concrete pavement
  - Bonding between base and slab
  - Lift-off of slab from base under climate, shrinkage, traffic
  - Dowel bearing stress under load (climate and traffic)
  - Crack opening at bottom of CRC
- Asphalt on concrete
  - Strains in overlay above cracks and joints
  - Bonding between asphalt and concrete, especially above cracks/joints

Conclusions

- Instrumentation should be planned to provide 1st level comparison (what the DOT wants right now) and mechanical response and empirical correlation of response to performance
- Response changes during the test. Two choices:
  - Ignore it and calibrate against initial condition
  - Model the damage and distress processes

Conclusions

- Link between laboratory characterization and APT. Future use of models for design and analysis will rely on laboratory characterization. Two choices in APT:
  - Ignore the differences
  - Understand the differences
- Link between APT and field results. How to do it:
  - Link APT and field instrument measurement
  - Use results from both test tracks (less controlled) and fixed devices (more controlled)

How to find out what is being used?

- Most programs have information regarding instrumentation used and results in their research reports.
- Instrumentation and comparison with modeling papers in Proceedings of International Conferences on Accelerated Pavement Testing
- Some gathering of information across programs has also been done, example:
  - HVS International Alliance: http://www.gautrans-hvs.co.za/hvsia/hvsia_instrument_matrix.htm

Figure of master curve all data

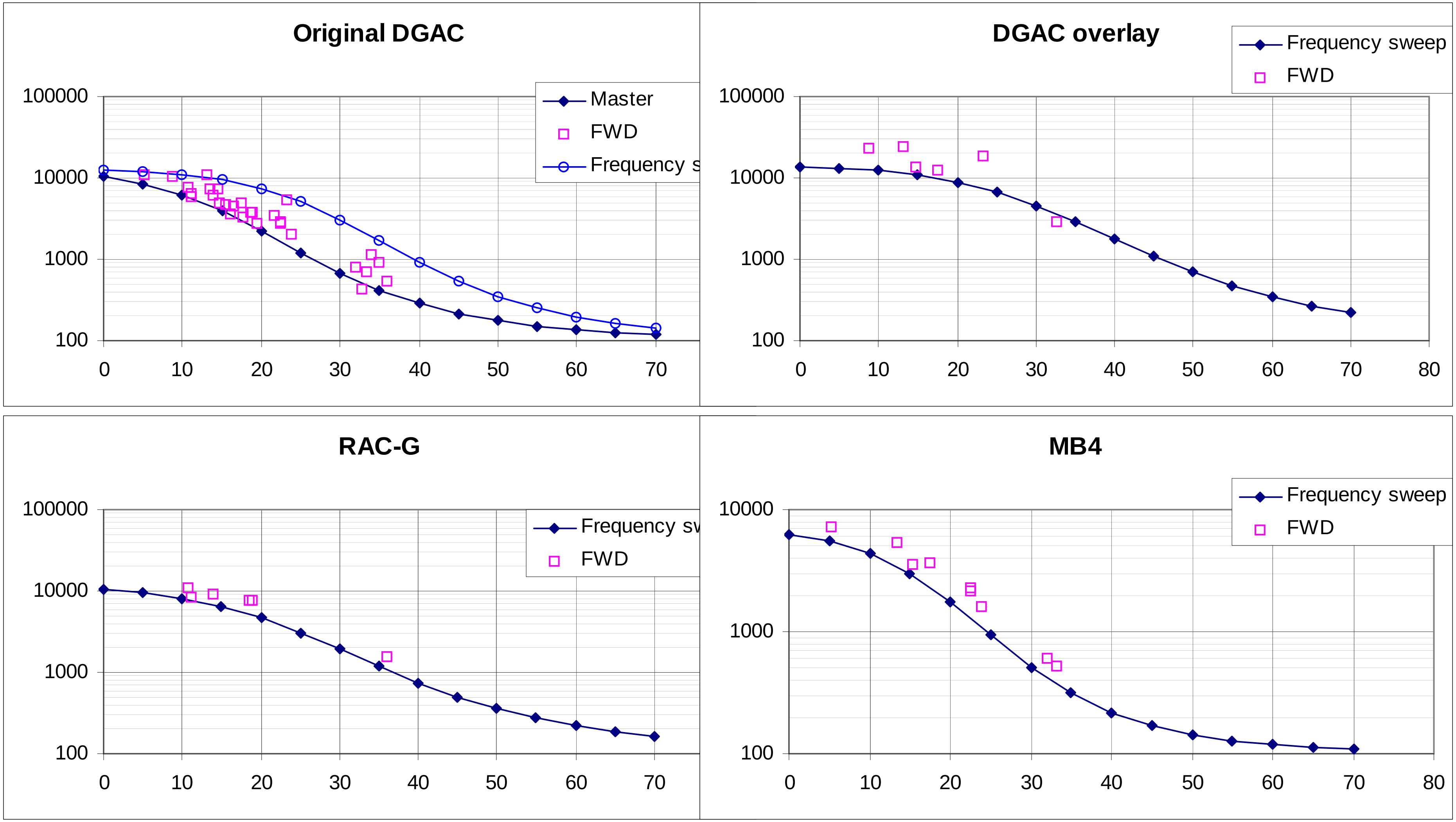


Figure of granular response

Moduli as function of stiffness of layers above

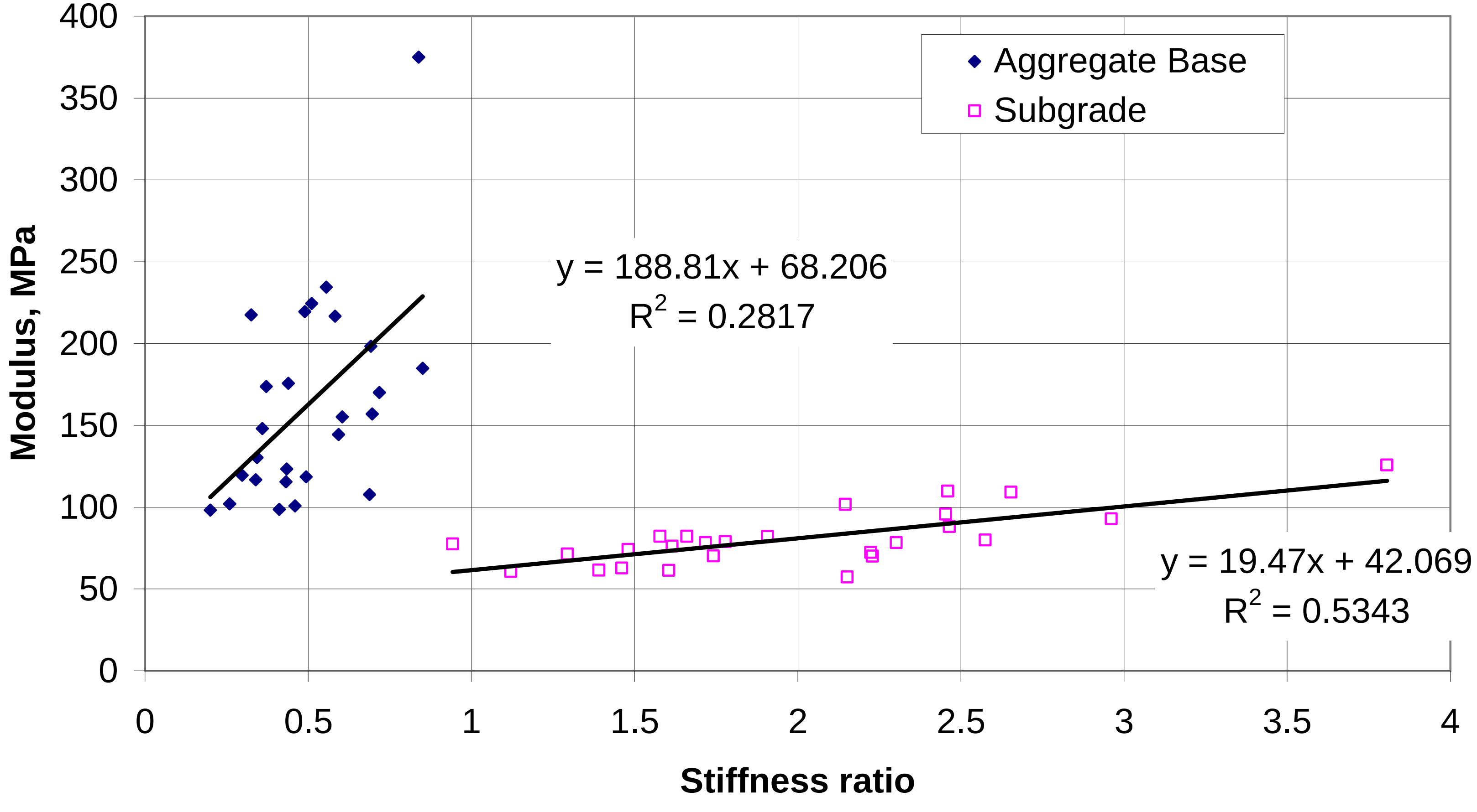
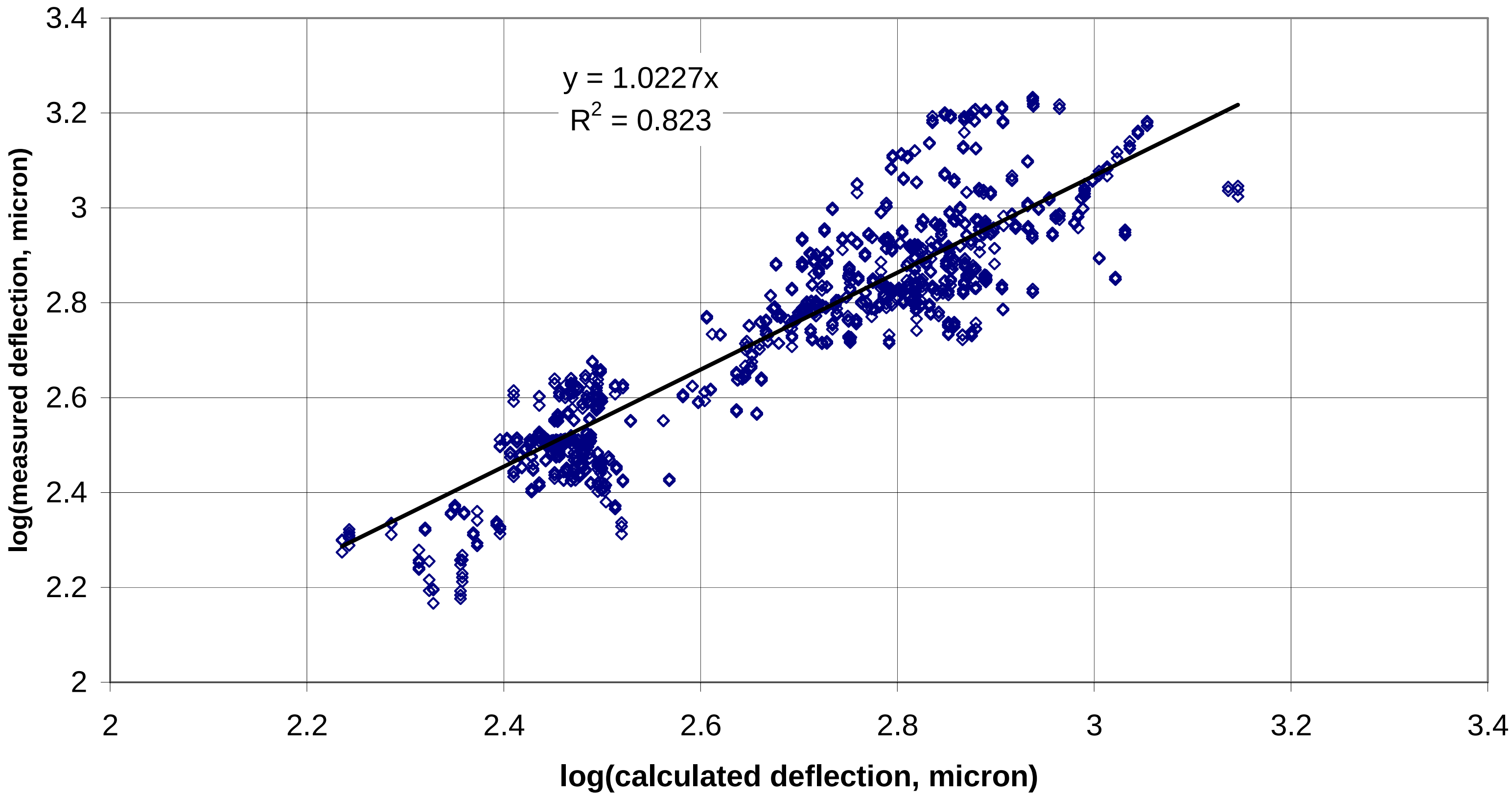


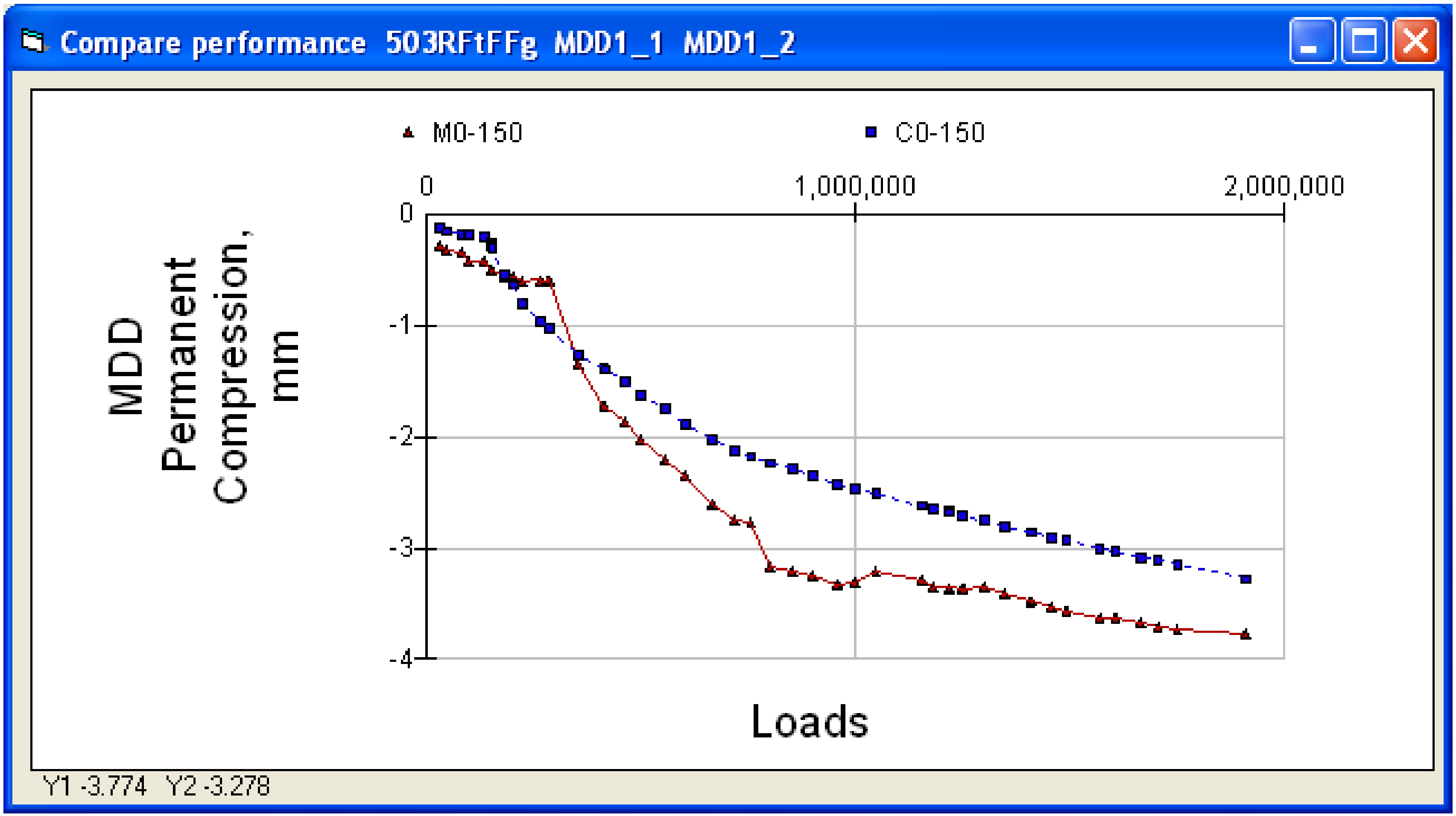
Figure of light cementation

Section		Moduli before HVS (MPa)				Moduli after HVS (MPa)			
No	Overlay	$E_{ovl}(20)$	$E_{ac}(20)$	E_{ab}	E_{sg}	$E_{ovl}(20)$	$E_{ac}(20)$	E_{ab}	E_{sg}
586RF	MB15-G	4,109	3,901	3,736	308	1,924	4,060	1,019	270
587RF	RAC-G	5,361	2,300	1,792	280	1,887	1,258	115	129
588RFa	AR4000-D	9,567	6,662	956	223	3,483	2,761	342	66
588RFb	AR4000-D	8,760	6,296	620	199	1,660	1,365	178	63
589RF	MB4-G	2,894	4,086	606	196	1,230	1,721	167	117
590RF	MB4-G	2,147	2,774	522	180	2,655	3,213	128	86
591RF	MAC15-G	6,280	3,581	1,750	211	3,410	2,703	199	50

Figure calculated and actual deflection



Calculated and actual deformation, AC



Calculated and actual deformation, total