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SBS Polymer Modified Base Course Mixtures for Heavy Duty Pavements

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Background

- Usually pm binders are used in wearing course to increase resistance to permanent deformation
- Experiences on e.g. Schiphol/Amsterdam airport have shown that use of pm binders in base courses can be very benificial.

Requirements for SBS Modifications to be used in Base Courses

- High stiffness for a large load-spreading capacity. This implies that a relatively hard base bitumen should be used and hence for modification. The viscosity of the PMB should be looked at carefully when selecting SBS grade and content.
- A hard bitumen generally contains less maltenes; this means that less "solvent" is available. This should also be considered when selecting the SBS grade and content.
- The PMB should give the asphalt mixture a high resistance to cracking and permanent deformation

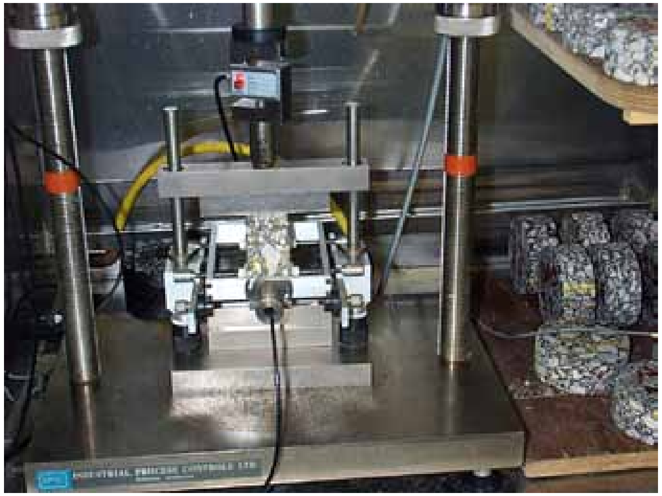
Mixtures Tested

- Stone asphalt concrete base course mixture
- Max grain size 22 mm
- Pen 40 bitumen used in reference mixture
- Binder content 4.6 % by mass
- Void content 5 %
- In pm mixtures same volume of pm binder was replacing reference binder

Test Program

- Stiffness testing using different set ups
- Monotonic tension and compression tests to determine failure envelopes
- Fatigue testing

4p Bending, ITT, Tension and Compression Tests for Stiffness Measurements

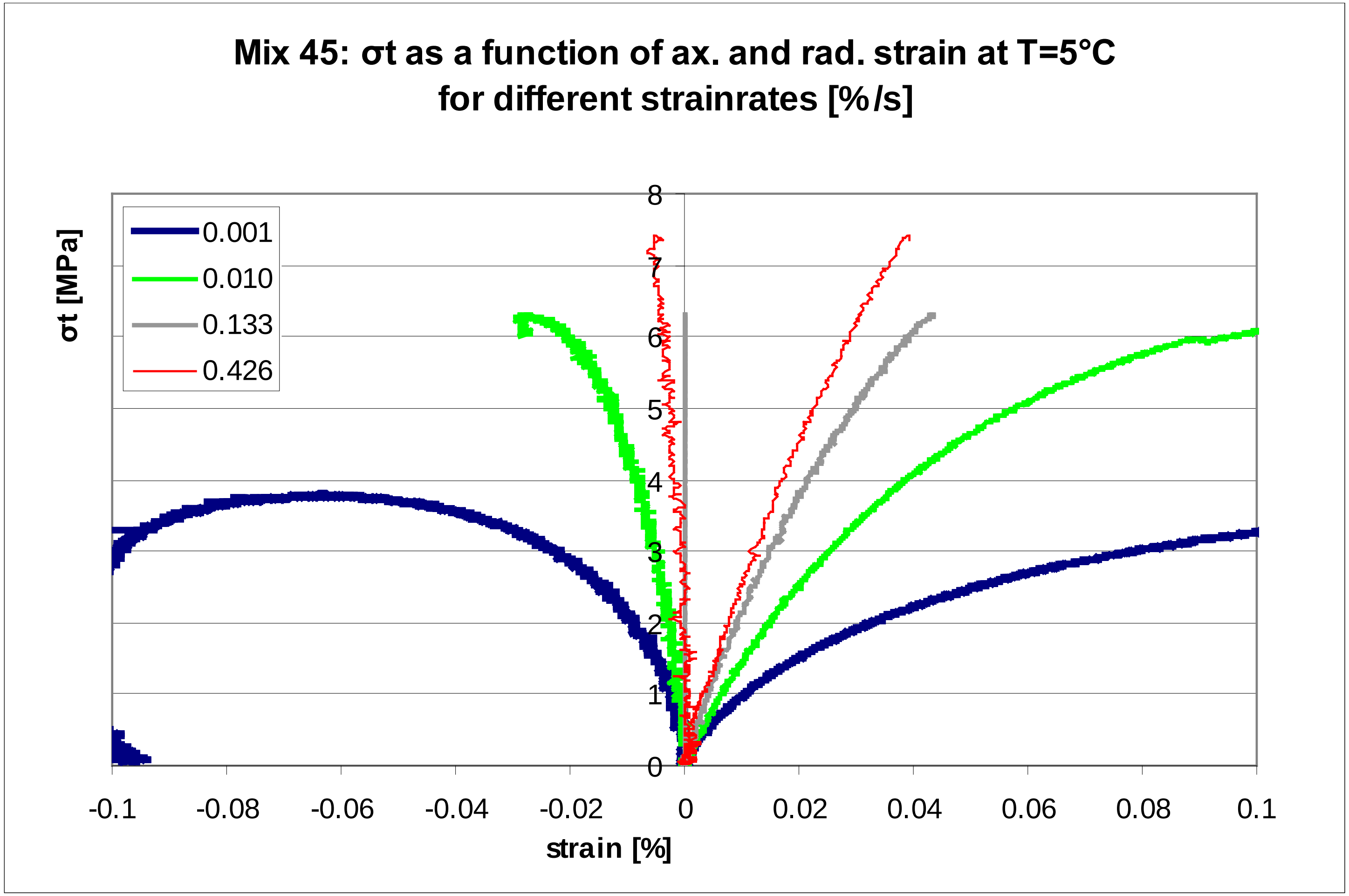


Results Stiffness Tests at 20 ^oC

	4PBT, 8Hz, fatigue (initial)	4PBT, 8Hz, at 50 µstrain	ITT, 8Hz, loadlevel: [1]=800N [2]=1000N	E_t at 1 % / s	E_c at 1 % / s
mixture	[MPa]	[MPa]	[MPa]	[MPa]	[MPa]
599-40 (= 40)	8871		13368[1] 12513[2]	11701	7028
604-41 (= 41)	10124	11018	13991[1] 12630[2]	14468	6161
602-42 (= 42)	10801		11329[2]	12660	7714
45	8154	8502	10378[2]	10046	4029
48	9940	9544			

Tension Test

Tension Test Results at 5 ºC

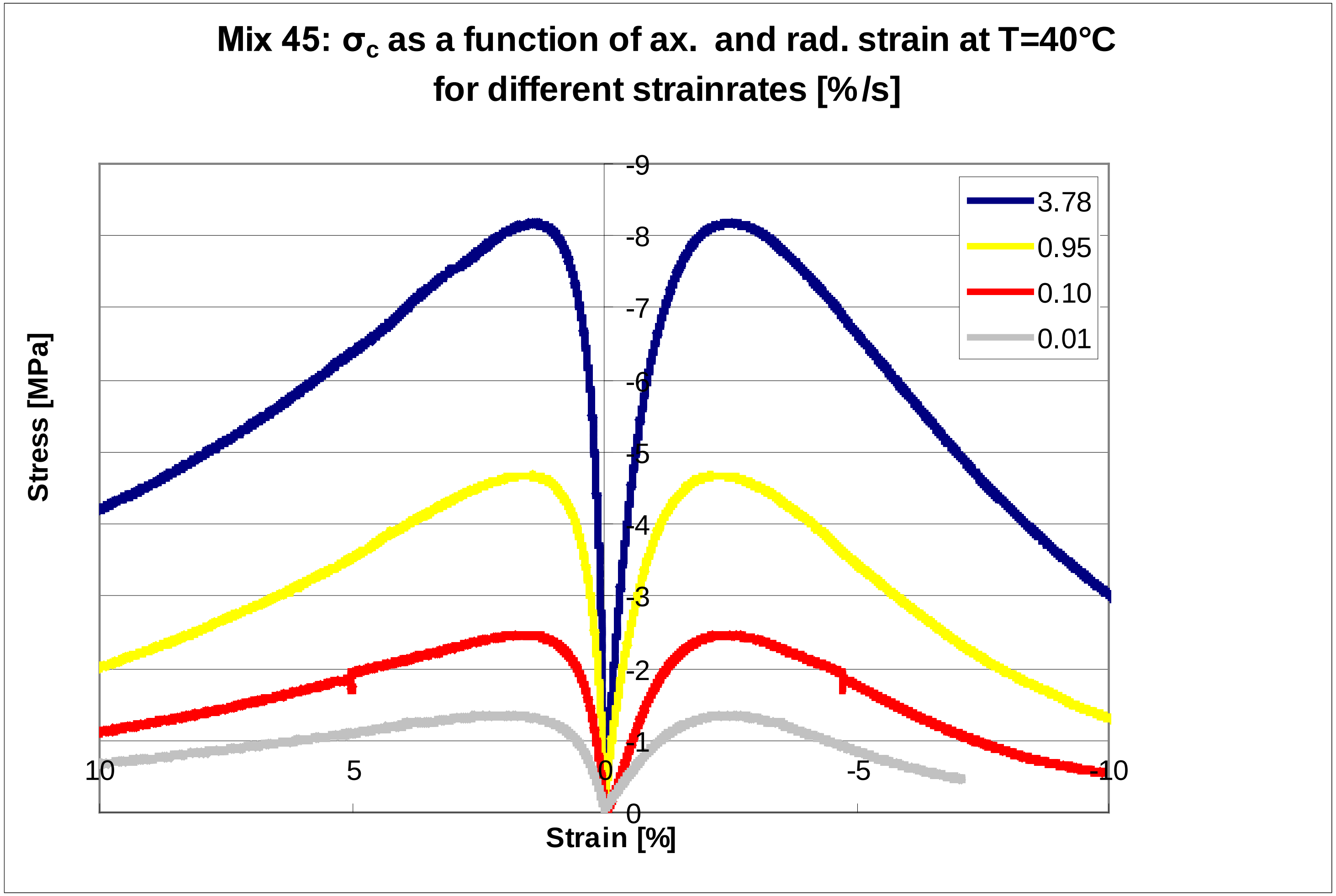


Tensile Strength in relation to Strain Rate and Temperature

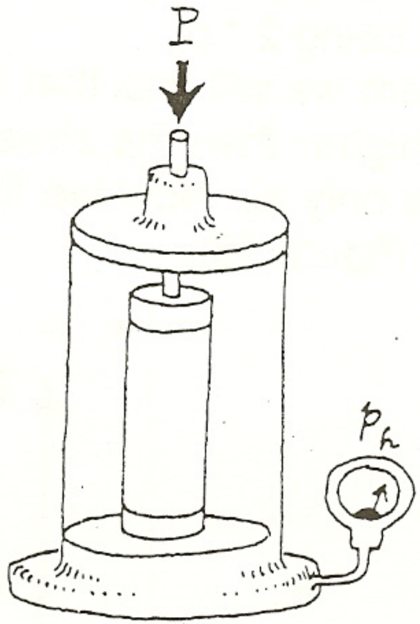
$$f_t = a\left[1 - \frac{1}{1 + \left[\dot{\varepsilon}\, e^{\left(b + \frac{c}{T}\right)}\right]^{d}}\right]$$

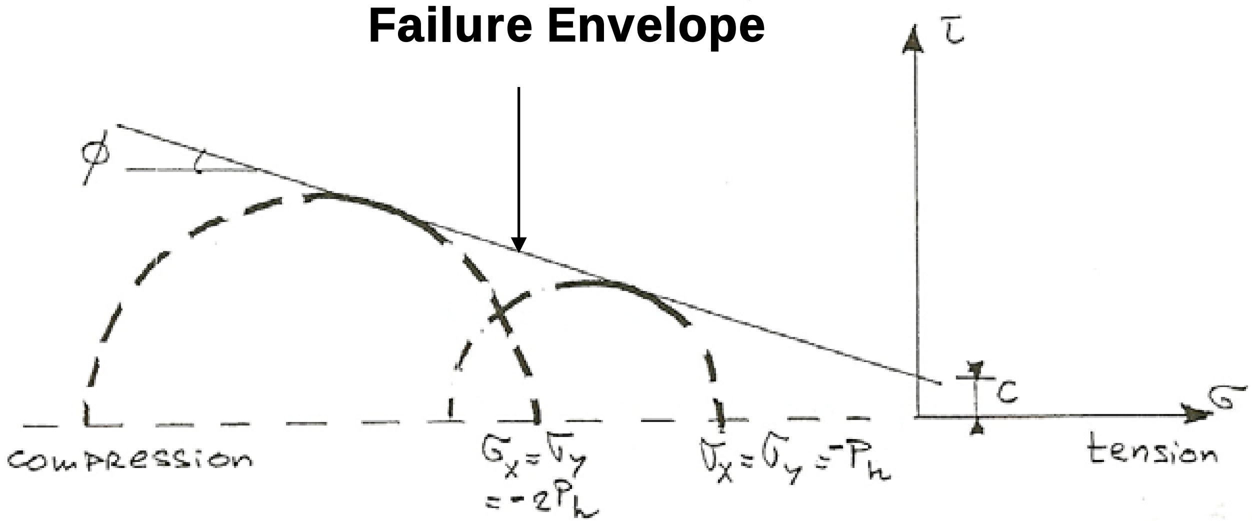
Compression Test

Compression Test Results at 40 ºC



Triaxial Test, Cohesion "C" and Angle of Internal Friction "f "





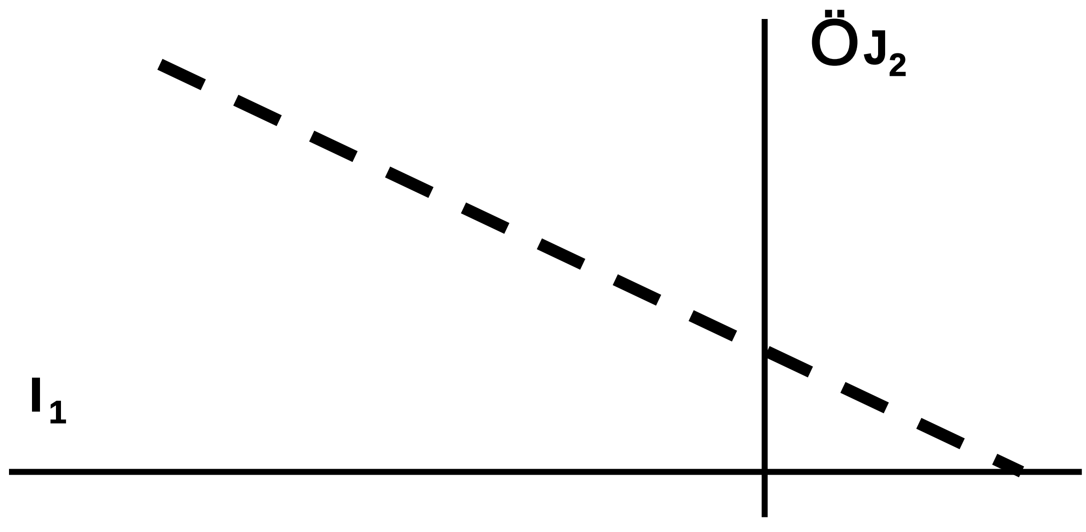
General Case

- Failure envelope can also be generated by means of tension and compression tests.
- In generalized case, s is replaced by bulk stress I_1 and t is replaced by deviator stress parameter J_2

Parameters used in the Failure Envelope Graphs

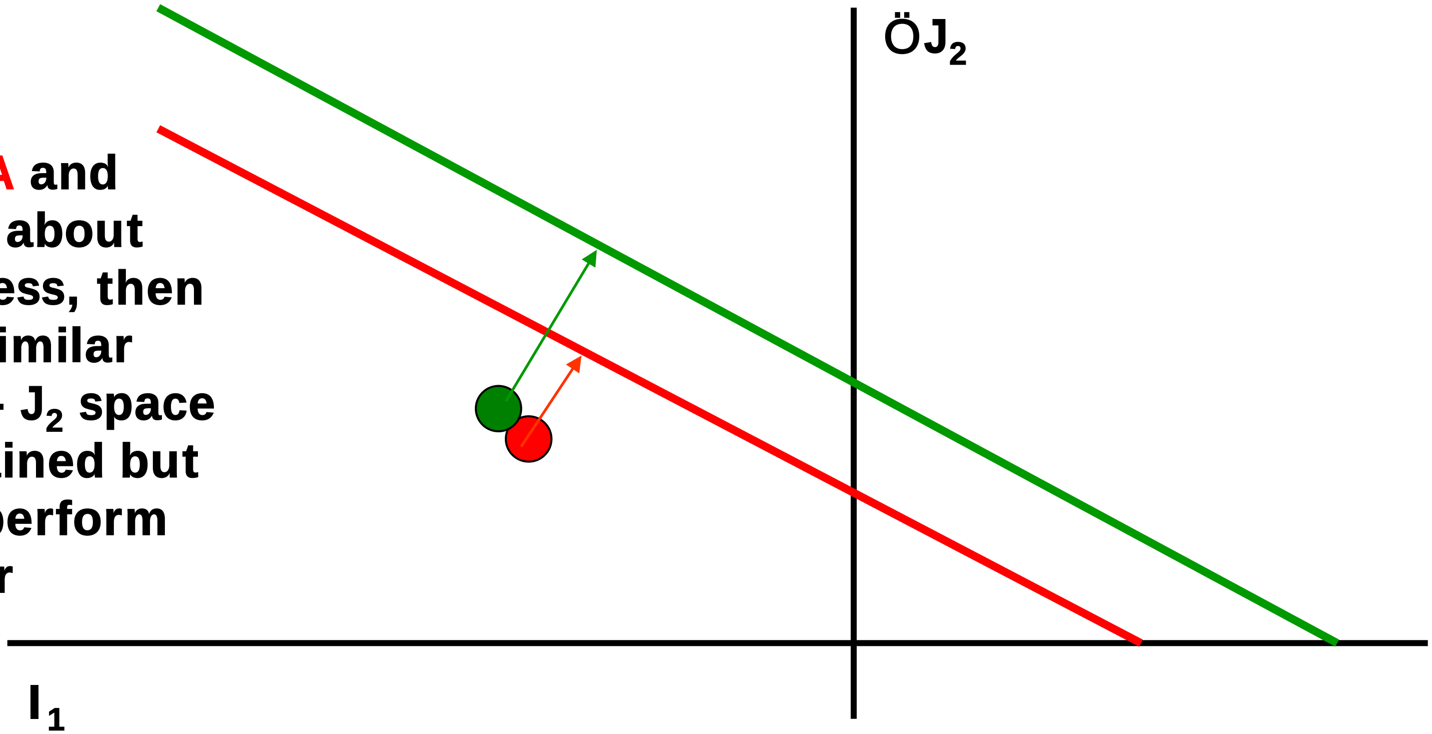
$$I_1 = \sigma_1 + \sigma_2 + \sigma_3$$

$$J_2 = \frac{1}{2}(\sigma_1^2 + \sigma_2^2 + \sigma_3^2) = \frac{1}{6}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2\right]$$



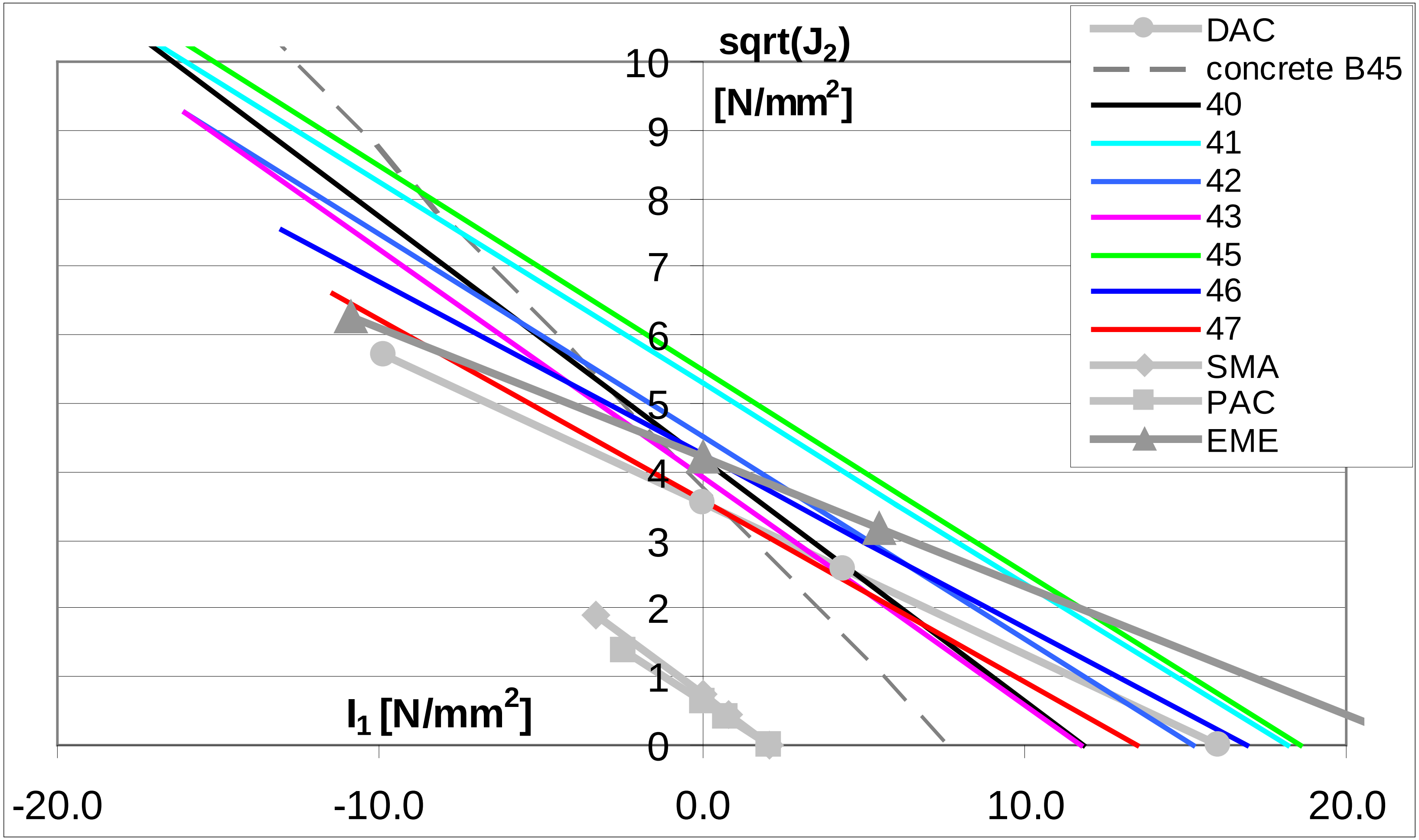
Importance of Failure Envelope

When mat A and mat B have about same stiffness, then an almost similar point in $I_1 - J_2$ space will be obtained but mat B will perform much better

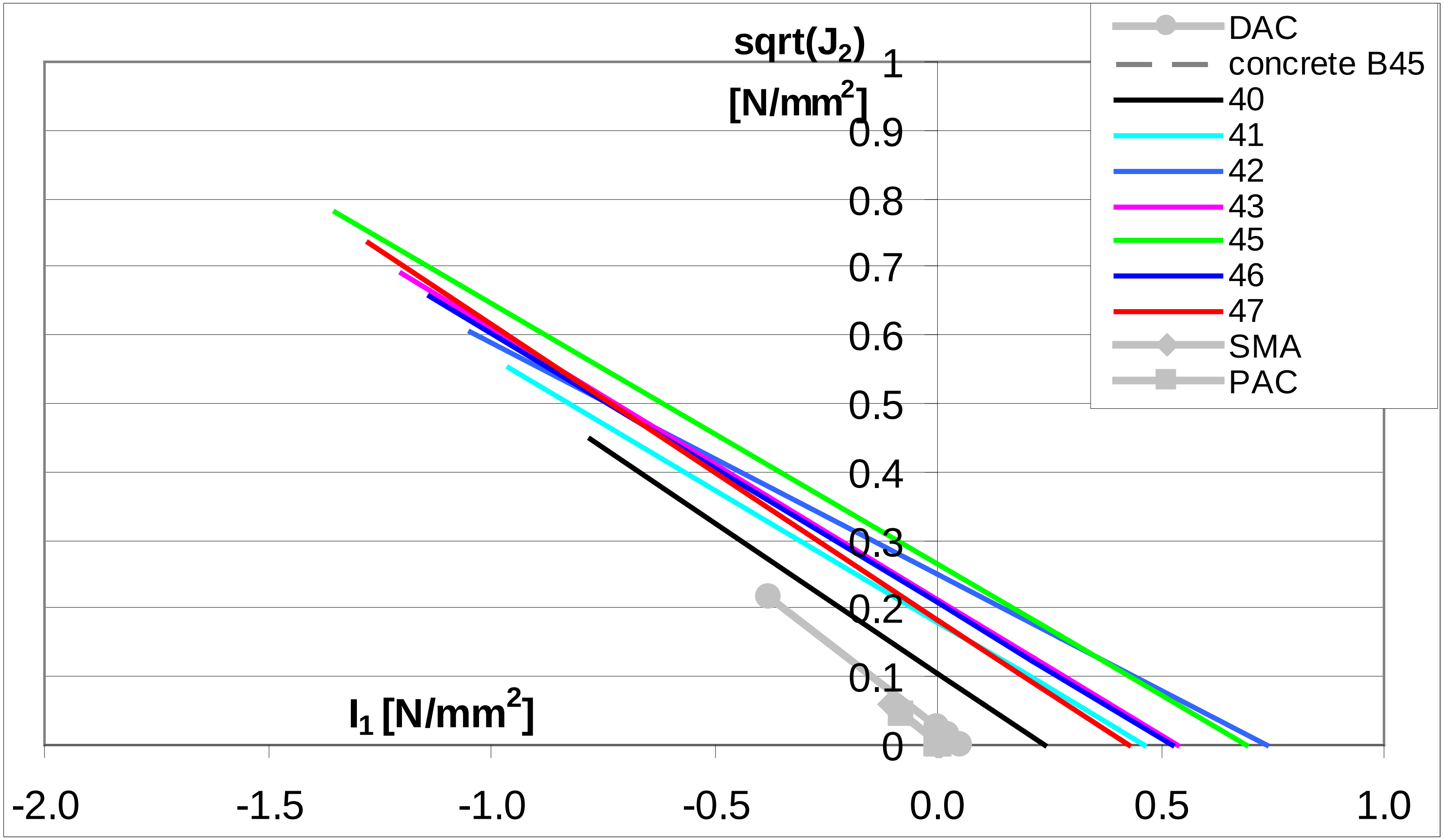


Mixtures did not differ too much in terms of stiffness

Failure Envelopes at 5 ºC and Strain Rate of 0.01 % / s



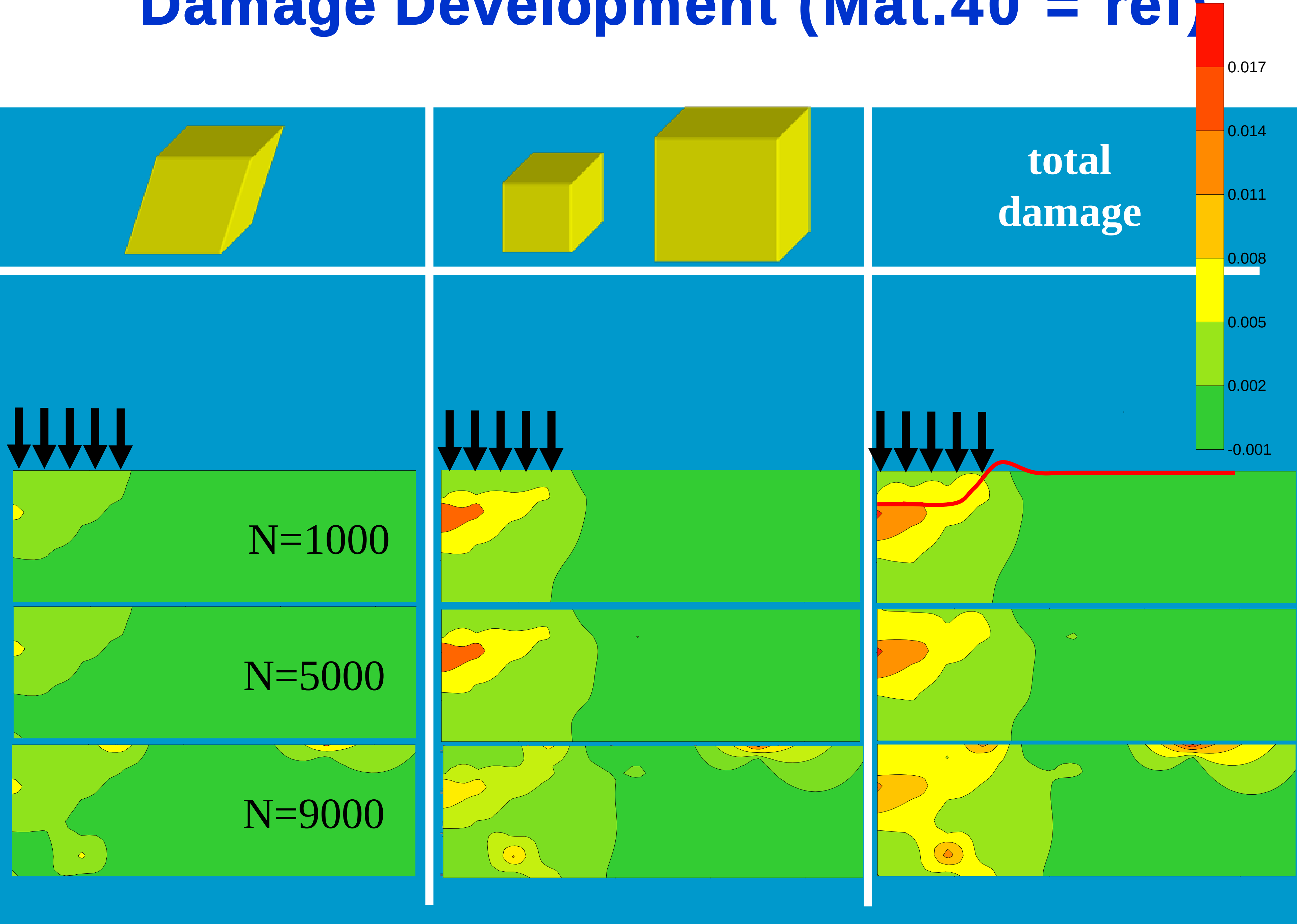
Failure Envelopes at 40 ºC and Strain Rate 0.01 % / s



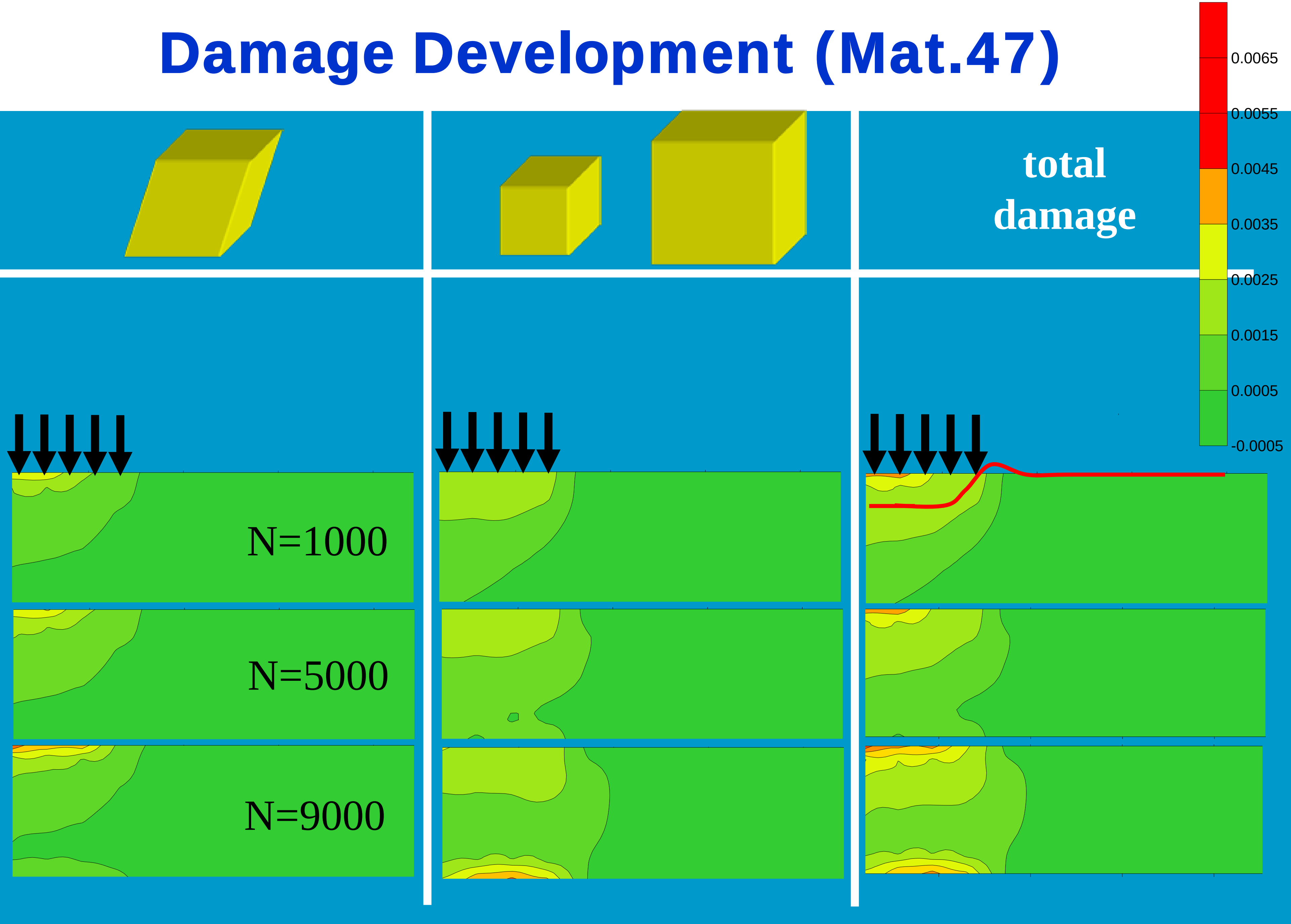
Analyses

- Results were used as input for advanced elasto-visco-plastic models
- Models were incorporated in FEM code
- 9000 load repetitions were simulated
- 2 days computation time

Damage Development (Mat.40 = ref)

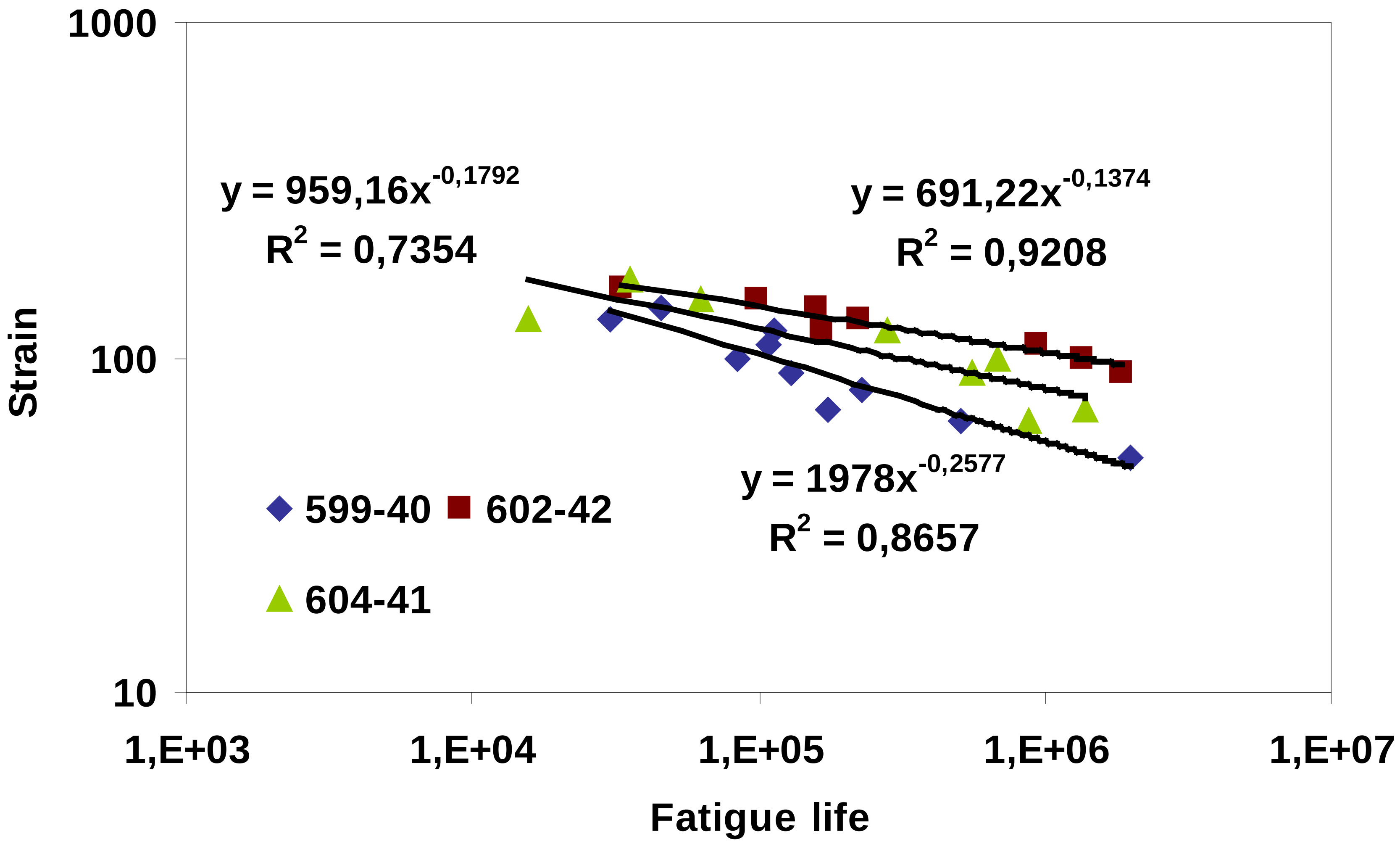


Damage Development (Mat.47)



4 Point Bending Fatigue Test

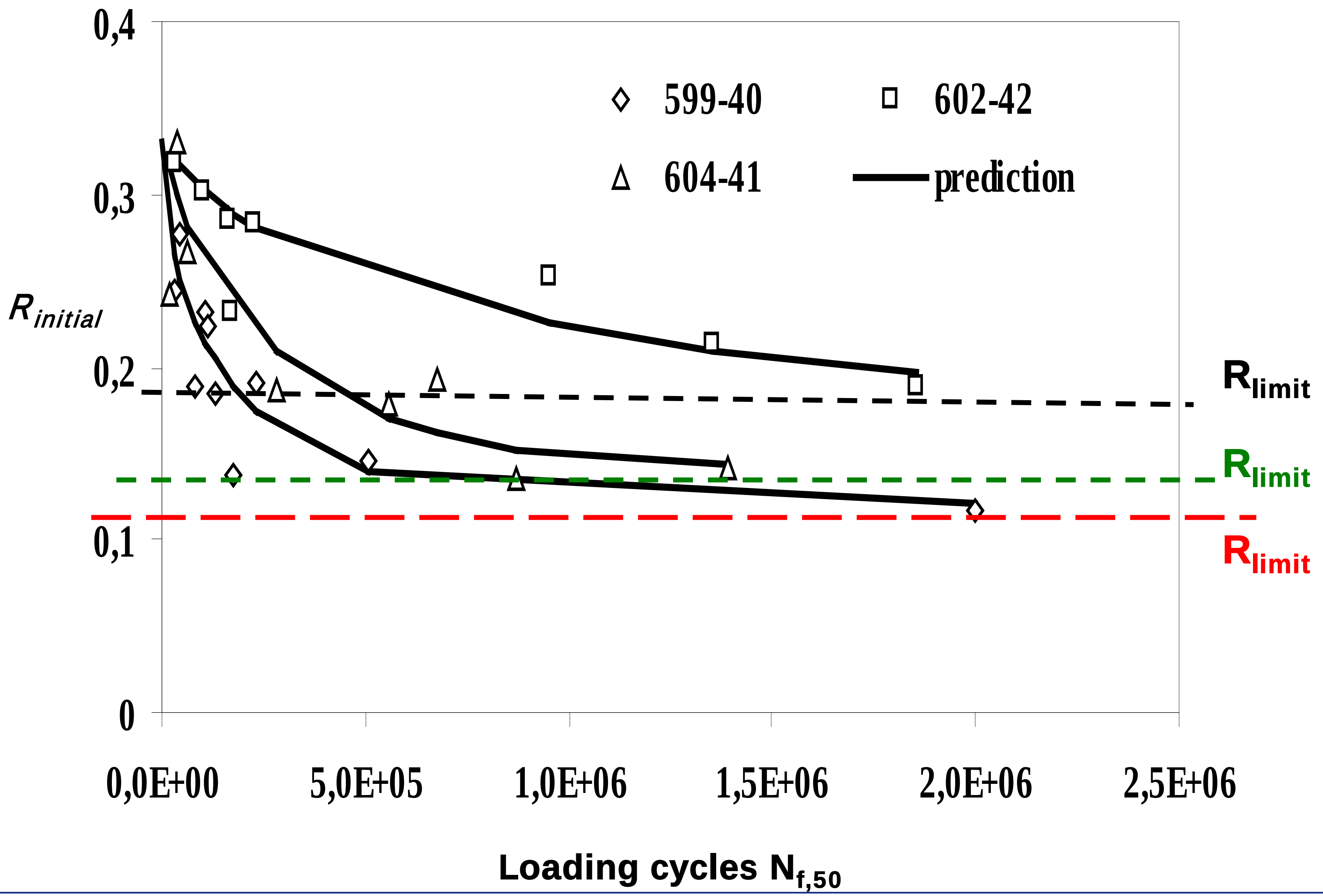
Fatigue Test Results at 20 ºC and 8 Hz



Procedure to get Limit Strain Value = Endurance Limit

- From frequency and strain level used in fatigue test, strain rate can be calculated
- From strain rate and temperature, tensile strength can be calculated
- Applied stress during fatigue test is know
- Stress ratio $R = s_t / f_t$ can be calculated
- Fatigue results can be expressed as $N_{f,50}$ vs R
- R_{limit} can be determined

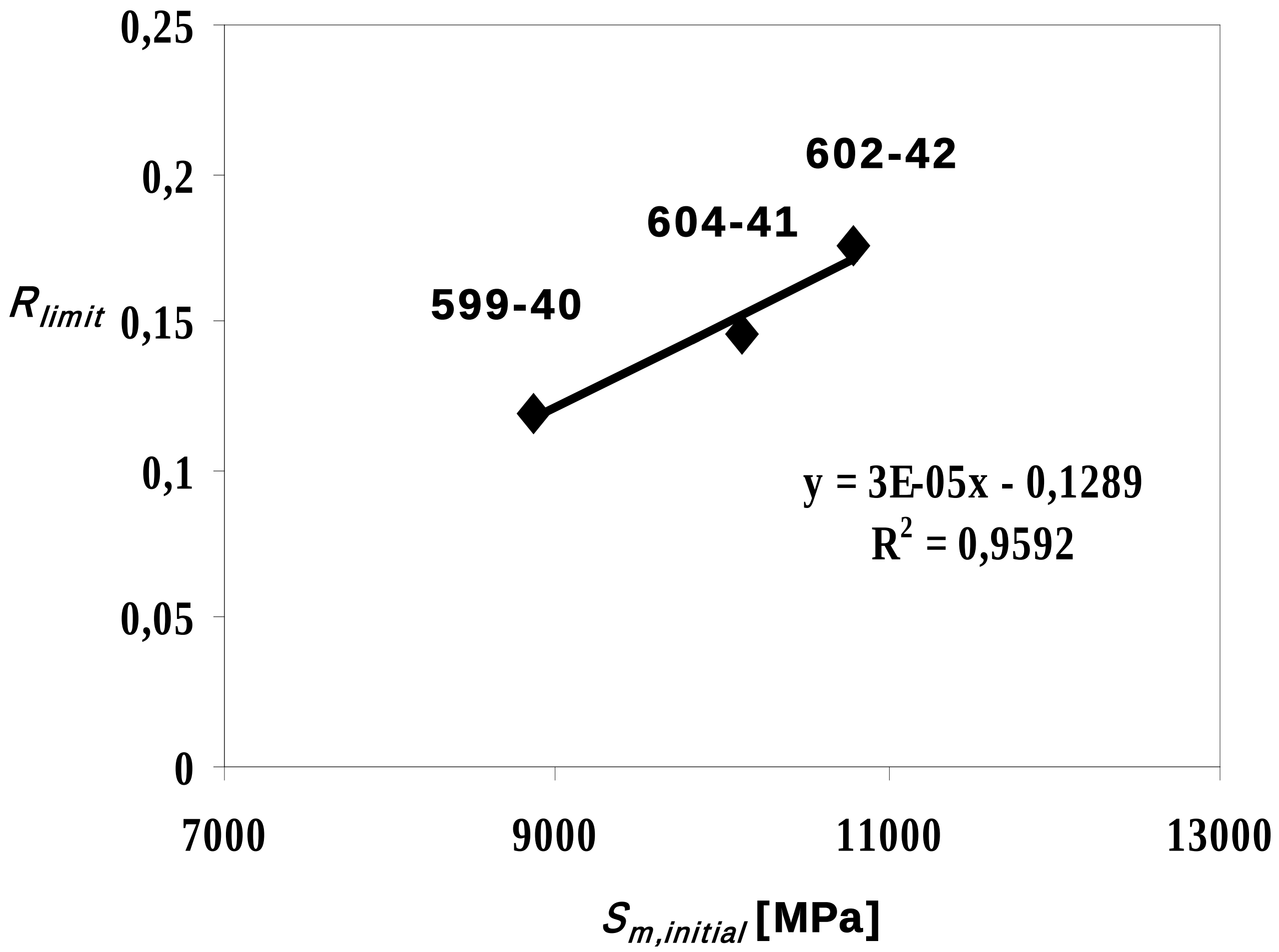
Fatigue Life in terms Stress Ratio



Limit Tensile Strain

$$\varepsilon_{limit} = \frac{R_{limit}}{S_{m,initial}} \cdot a \left[1 - \frac{1}{1 + \left[4 \cdot f \cdot \varepsilon_{init} \cdot 100 \cdot e^{\left(b + \frac{c}{T}\right)} \right]^{d}} \right]$$

Relationship between R_{limit} and Mix Stiffness



Endurance Limits at 8 Hz and 20 ^{o}C

Mixture	$S_{m,initial}$ (GPa)	ε_{limit} (10^{-6} m/m)
599-40	8.9	50
602-42	10.8	80
604-41	10.1	75

Analyzed Pavement Structures

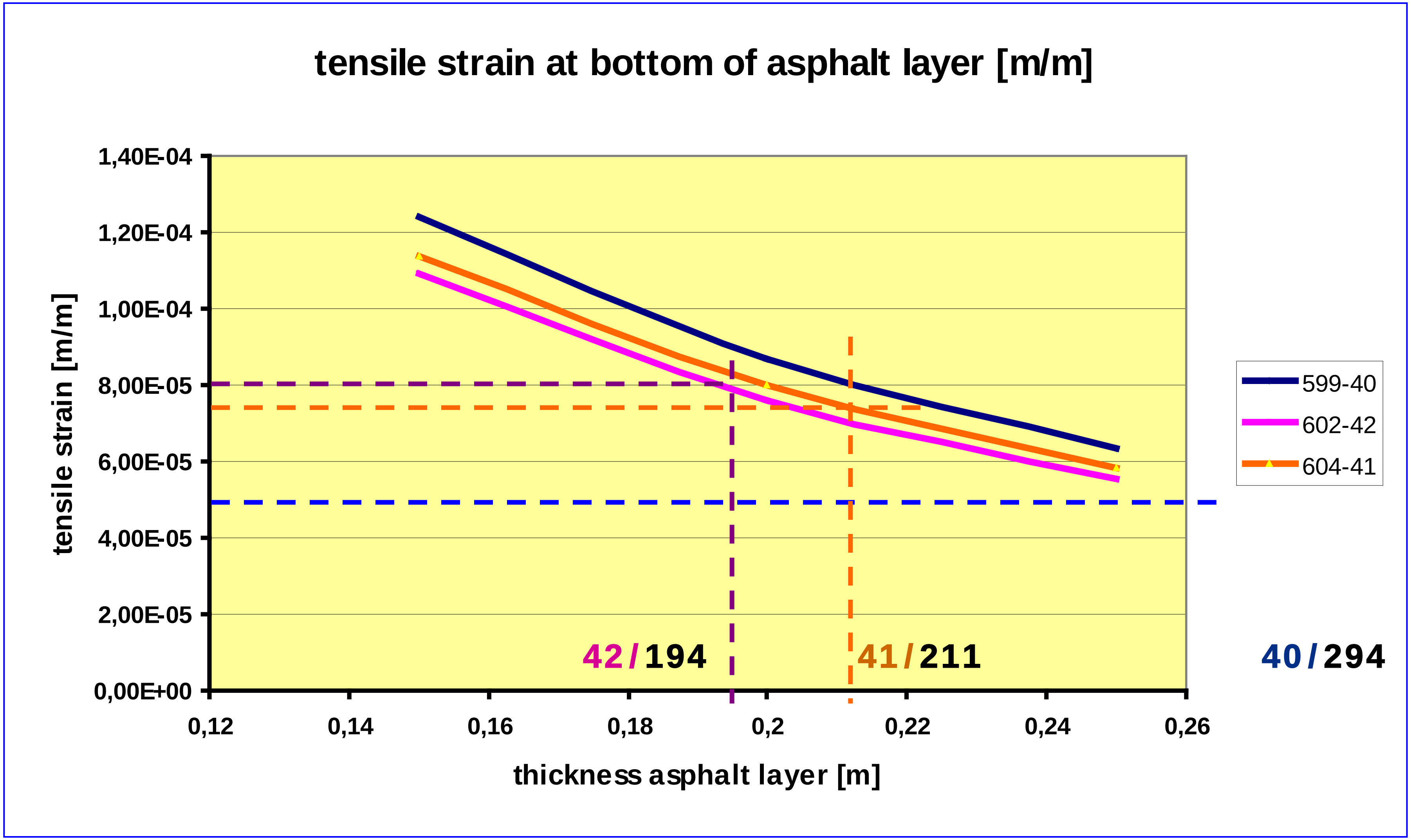
F = 50 kN; r = 150 mm

Variable thickness; Stiffness of mixtures 40, 41 and 42; m= 0.35

E = 300 MPa; h = 300 mm; m= 0.35

E = 100 MPa; m= 0.35

Required Asphalt Thickness



Conclusions

- Mixtures with excellent mechanistic properties can be produced using specially designed polymers.
- The fatigue behaviour of asphalt mixtures can be described by means of an endurance limit.
- The endurance limit can be estimated using a series of tension tests performed at different strain rates and temperatures and mix stiffness tests. Extensive fatigue testing seems not necessary.
- Modifying asphalt mixtures with specially designed polymers can result in a significant reduction of the asphalt layer thickness.


Thank you for your attention