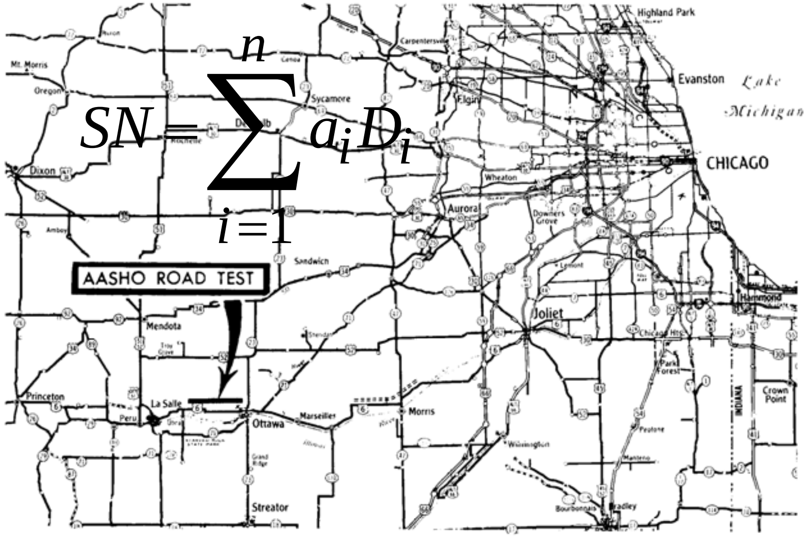
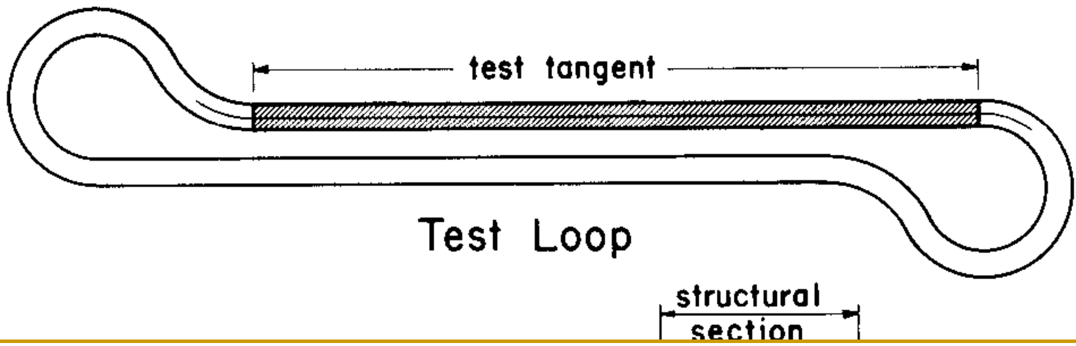
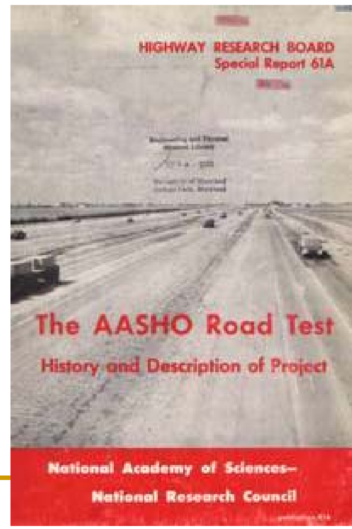
AASHO Road Test (Late 1950's)

$$N_{ESALs} = f\left(p_t, SN, M_r\right)$$

$$SN = \sum_{i=1}^{n} a_i D_i$$







(AASHO 1961)

Texas has sought to improve MEPDG

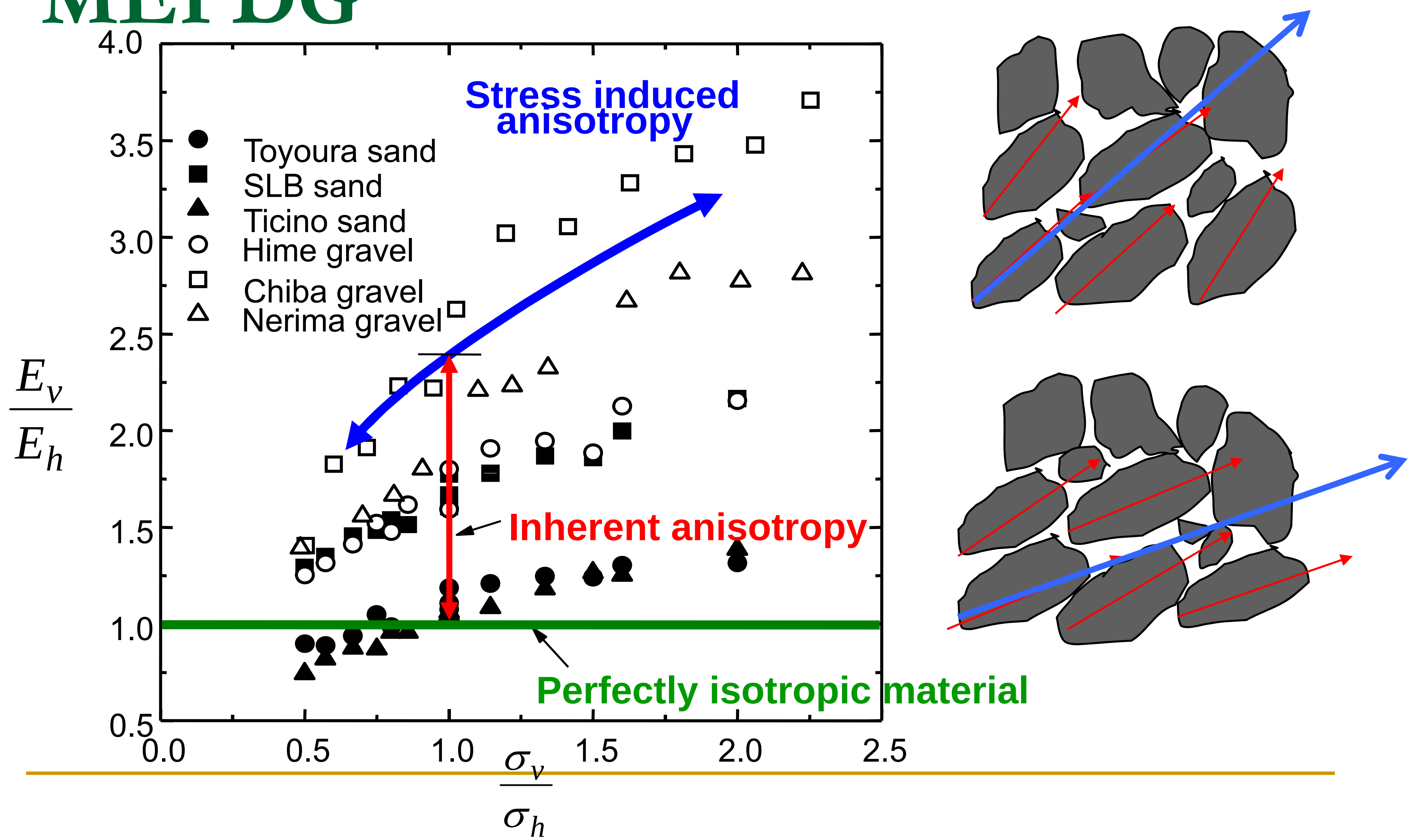
- TxDOT
  - Improving the fatigue model
  - Improve the rutting model - replace

$$\log\left(\frac{\varepsilon_p}{\varepsilon_r}\right) = a_o + a_1 \log(N) + a_2 \log(T)$$

with VESYS-type model

$$\varepsilon_p = \varepsilon_r \, \mu N^{-\alpha}$$

Texas has sought to improve MEPDG

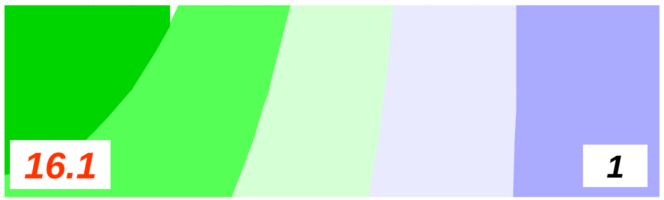


Pavement Response Analysis

Vertical Stress in Base Layer

Linear Isotropic

Nonlinear Anisotropic



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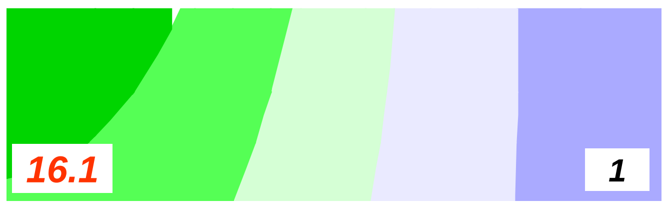
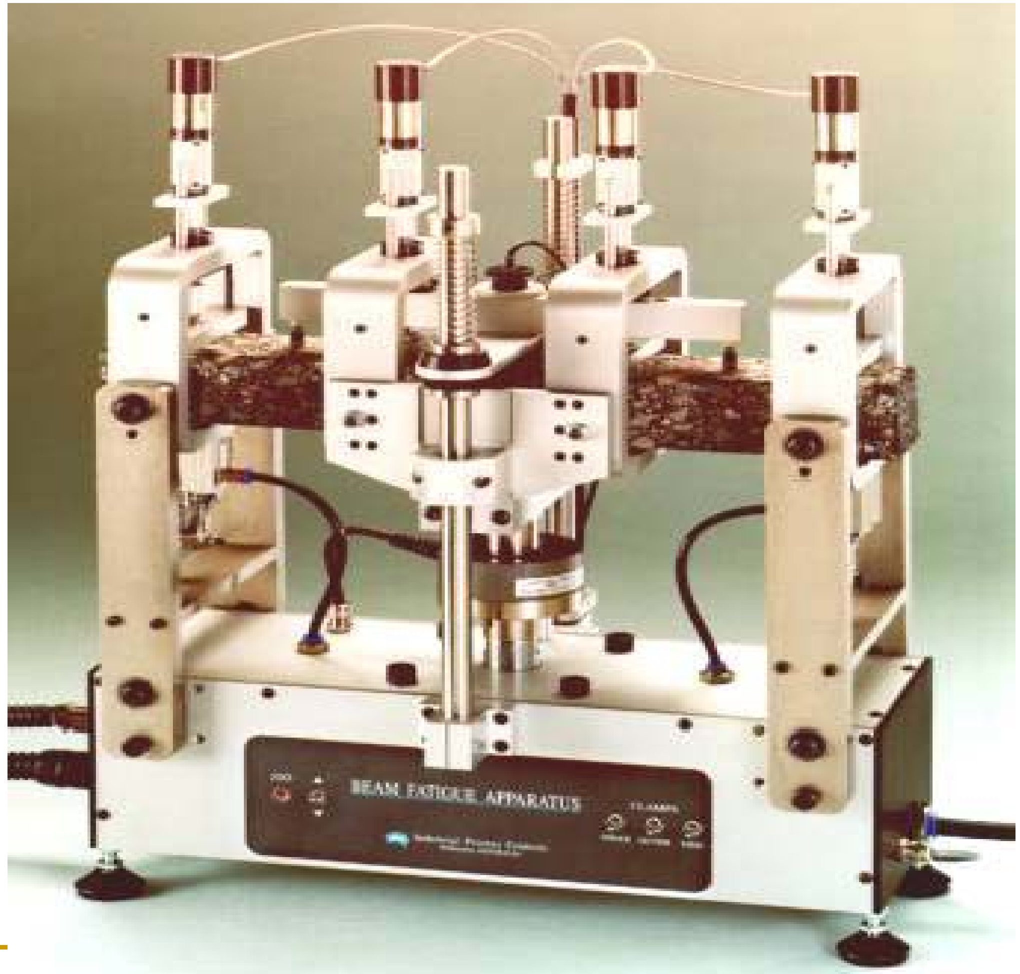


Fatigue Beam Testing

N_f – Flexural Beam Apparatus

- ***Constant Stress***
- ***Constant Strain***



Shell Fatigue Equations: Controlled-Stress v. Controlled-Strain

- General form of fatigue equation

$$N_f = A_f K_1 \left(\frac{1}{\varepsilon_t} \right)^{k_2} \left(\frac{1}{E^*} \right)^{k_3}$$

Fatigue Equations from Shell Database

Controlled strain (≤ 2-in.)

$$\alpha = \frac{Const.Strain\ \alpha_i}{Const.Stress\ \alpha_i}$$

$$N_f = A_f \left[0.17\,PI - 0.0085 PI\left(V_b\right) + 0.454\,V_b - 0.112 \right]^5 \varepsilon_t^{-5} E^{-1.8}$$

$K_{\varepsilon 1}$

Controlled stress (≥ 8-in.)

$K_{\sigma 1}$

$$N_f = A_f \left[0.0252 PI - 0.00126 PI\left(V_b\right) + 0.00673\,V_b - 0.0167 \right]^5 \varepsilon_t^{-5} E^{-1.4}$$

Fatigue Equations from Shell Database

Controlled strain (≤ 2-in.)

$$N_f = 13{,}909 A_f K_{1\sigma} \left(\frac{1}{\varepsilon_t}\right)^5 E^{*-1.8}$$

Controlled stress (≥ 8-in.)

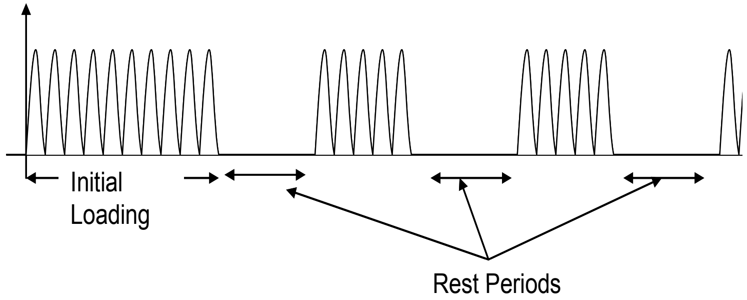
$$N_f = A_f K_{1\sigma} \left(\frac{1}{\varepsilon_t}\right)^5 E^{*-1.4}$$

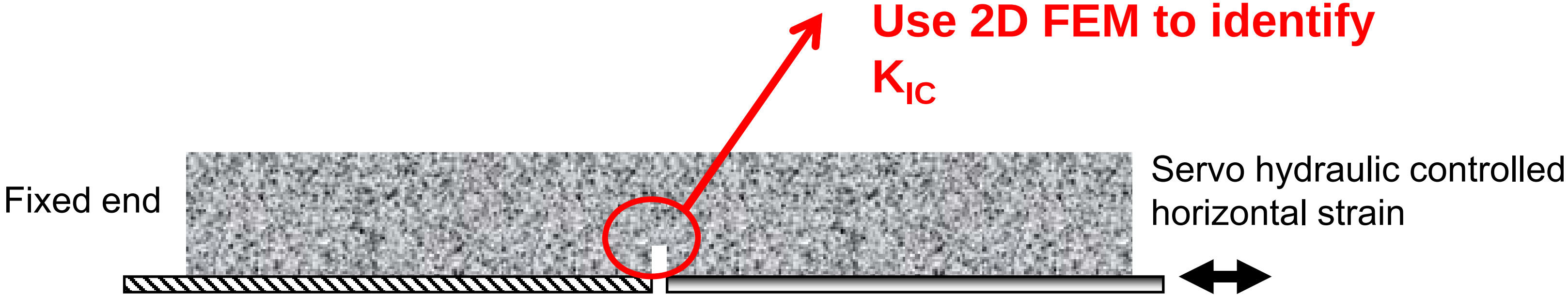
Generalized Equation

$$N_f = A_f \left(1 + \frac{13{,}909E^{0.4} - 1}{1 - \exp^{(1.354h_{ac} - 5.408)}}\right)\left(0.0252PI - 0.00126PI(V_b) + 0.00673V_b - 0.0167\right)^5 \left(\frac{1}{\varepsilon_t}\right)^5 \left(\frac{1}{E^*}\right)^{-1.4}$$

Laboratory to field adjustment factor (default – 1.0)

Overlay Tester





$$\frac{dc}{dN} = A(\Delta K)^n$$

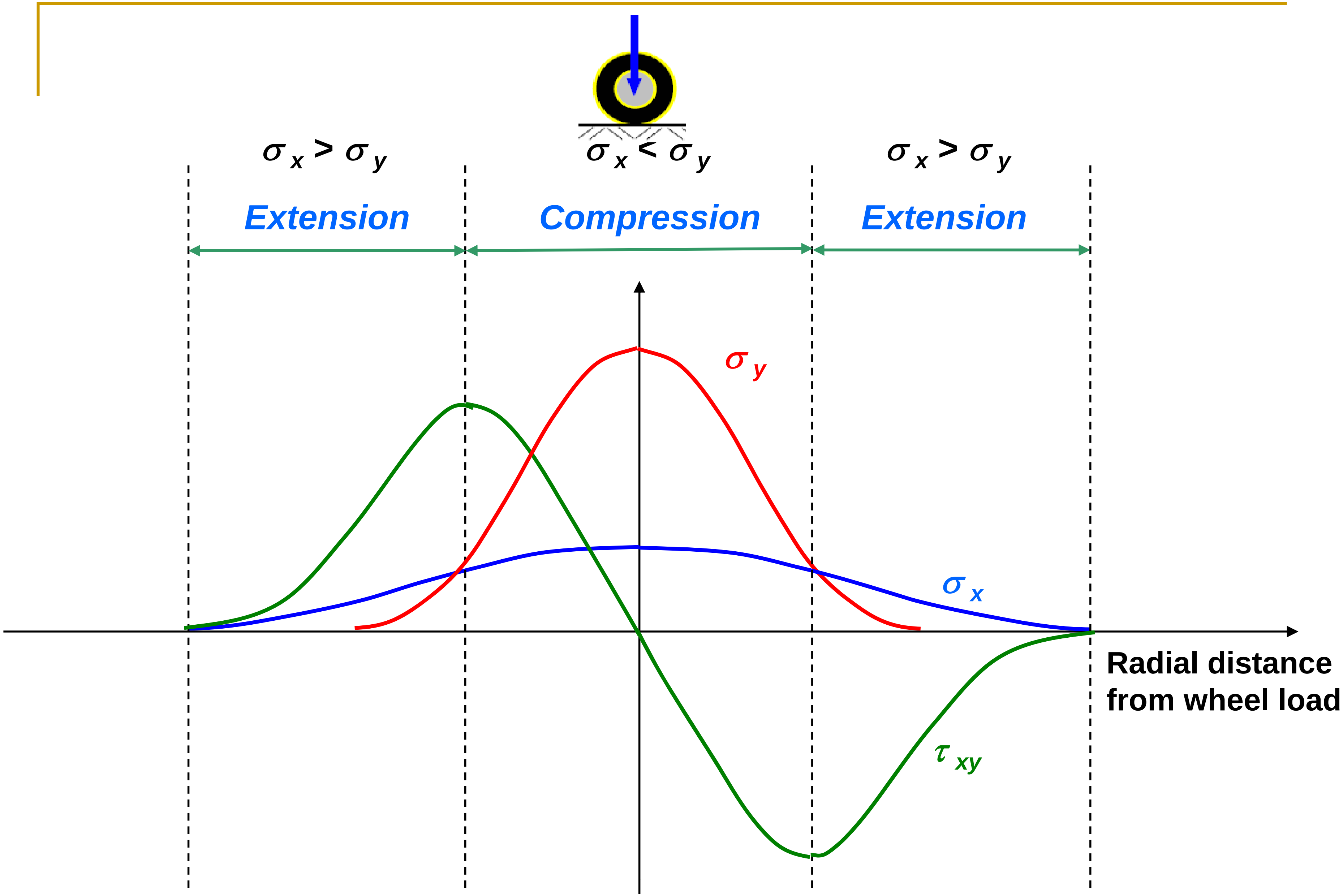
$$K_2 = n$$

$$K_1 = f\left(K_2, E, A\right)$$

$$N_{total} = N_i + N_p$$

$$N_i = K_1 (\varepsilon_t)^{K_2} (E^*)^{K_3}$$

$$N_p = \int_{c_0}^{h} \frac{1}{A(\Delta K)^n} dc$$



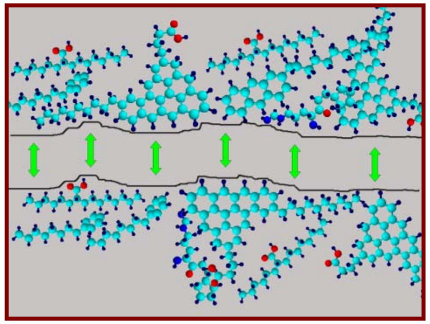
σ x > σ y
σ x < σ y
σ x > σ y
Extension
Compression
Extension
σ y
σ x
τ xy
Radial distance
from wheel load

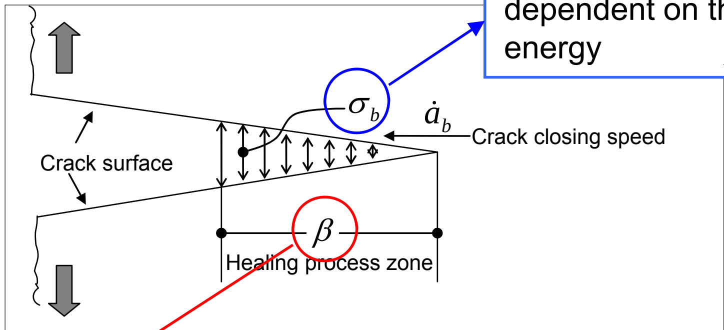
Benefits

- K_1 shift factor is reduced from a range of about 200 to about 14,000 to 1 to 2
- Validation from FHWA-ALF and Westrack

Healing Mechanisms

Step 1: Interfacial Wetting





<u>Bonding stress:</u> Indirectly dependent on the surface energy

<u>Healing process zone:</u>
=β when $\Delta R_N > \beta$
=ΔR_N when $\Delta R_N < \beta$

For example, rest periods at frequent intervals or after few cycles (N) => smaller ΔR_N and hence maximization of the healing process zone

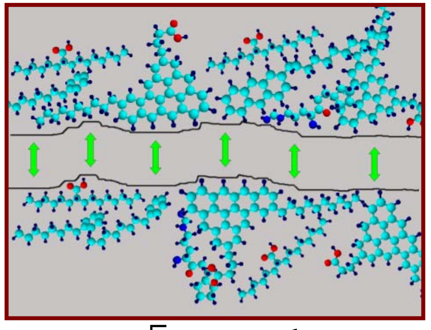
<u>Work of cohesion:</u> From surface energy

$$\frac{d\phi(t,X)}{dt} = \dot{a}_b = \beta\left[\frac{1}{D_1 k_m}\left\{\frac{\pi W_c}{4(1-\nu^2)\sigma_b^2\beta} - D_0\right\}\right]^{-1/m}$$

<u>Viscoelastic property:</u> Creep parameters from power law, $\varepsilon(t)=D_0+D_1 t^m$

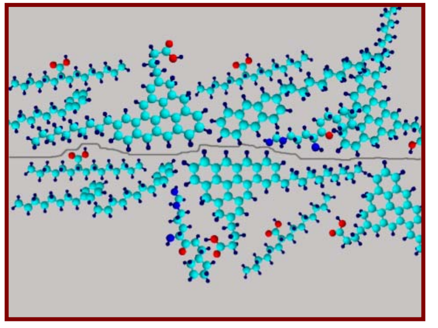
Healing mechanisms

Step 1: Interfacial Wetting



$$\frac{d\phi(t,X)}{dt} = \dot{a}_b = \beta\left[\frac{1}{D_1 k_m}\left\{\frac{\pi W_c}{4(1-\nu^2)\sigma_b^2\beta} - D_0\right\}\right]^{-1/m}$$

Step 2: Strength Gain



$$R_h(t) = R_0 + p\left(1 - e^{-qt^r}\right)$$

The two processes are combined using the approach originally proposed by Wool and O'Connor as follows:

$$R = \int_{\tau=-\infty}^{\tau=t} R_h(t-\tau)\frac{d\phi(\tau,X)}{dt}\,d\tau$$