MnPAVE Training

Presentation 2

Fundamentals of M-E Design

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Spring 2002

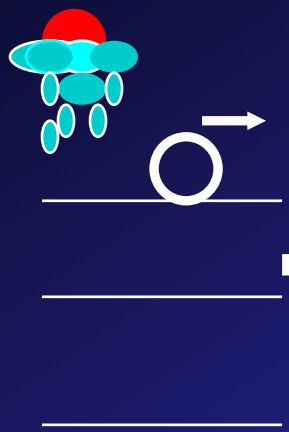
Definition of M-E Design

- Mechanistic component: determine pavement response due to loading through structural model (mathematical model).

- Empirical component: relates calculated pavement response from the model to pavement performance. (Fatigue cracking and Subgrade rutting, etc)

Key Components in M-E Design

Inputs



Structural model

Response (stress,strain)

Performance model

Failure criteria

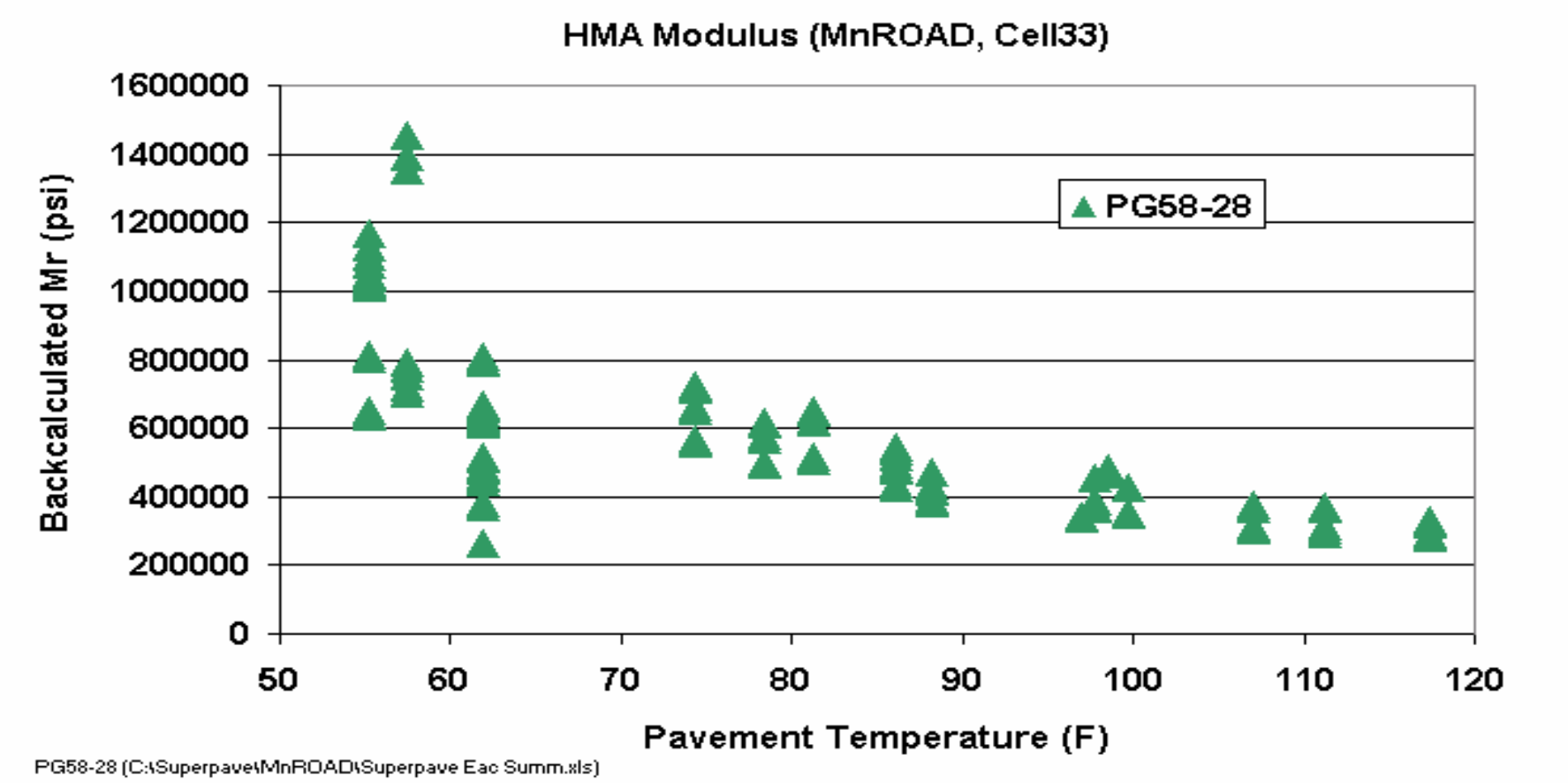
When will the pavement fail

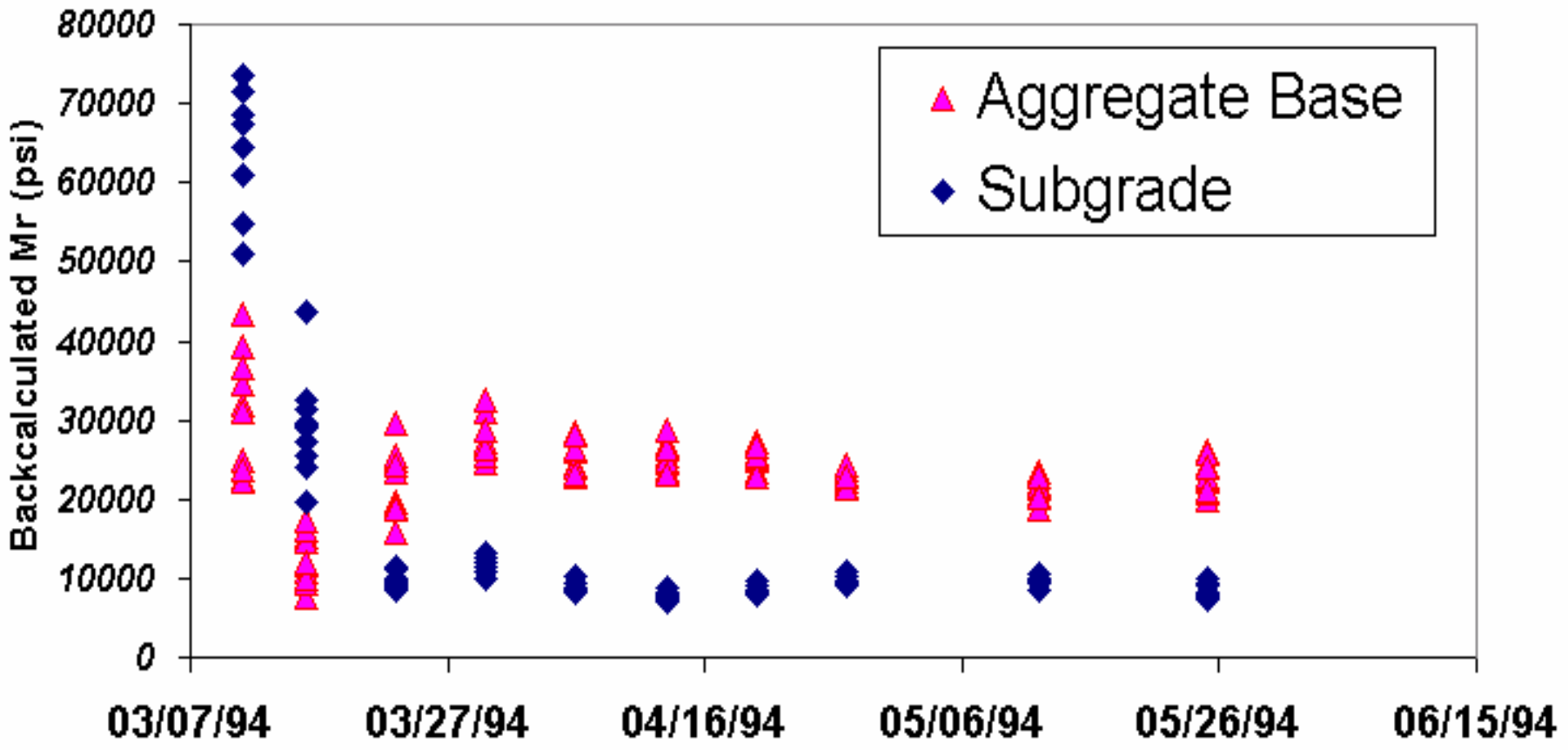
Output

Response (stress,strain)

Inputs

- **Climate:**
  - Temperature effects on HMA property
  - Seasonal effects on aggregate and subgrade




Backcalculated Mr (psi)
80000
70000
60000
50000
40000
30000
20000
10000
0
03/07/94
03/27/94
04/16/94
05/06/94
05/26/94
06/15/94
Aggregate Base
Subgrade

- **5 Seasons**
  - Early spring, late spring, summer, fall and winter
  - Based on layer modulus changes
- **Season lengths**
  - Based on test results from MnROAD sections
  - Determined using air temperature indices

Inputs

- **Material property**
  - Dynamic modulus for HMA.
    - Replace GE for bituminous mixture: GE=2.25
  - Resilient modulus for agg. base and subgrade.
    - Replace GE for agg. base and R-value for subgrade
  - Basic Level: use default values (Mn/DOT, AASHTO and Unified).
  - Intermediate Level: need some tests, such as R value, DCP, or Mr.
  - Advanced Level: need seasonal Mr.

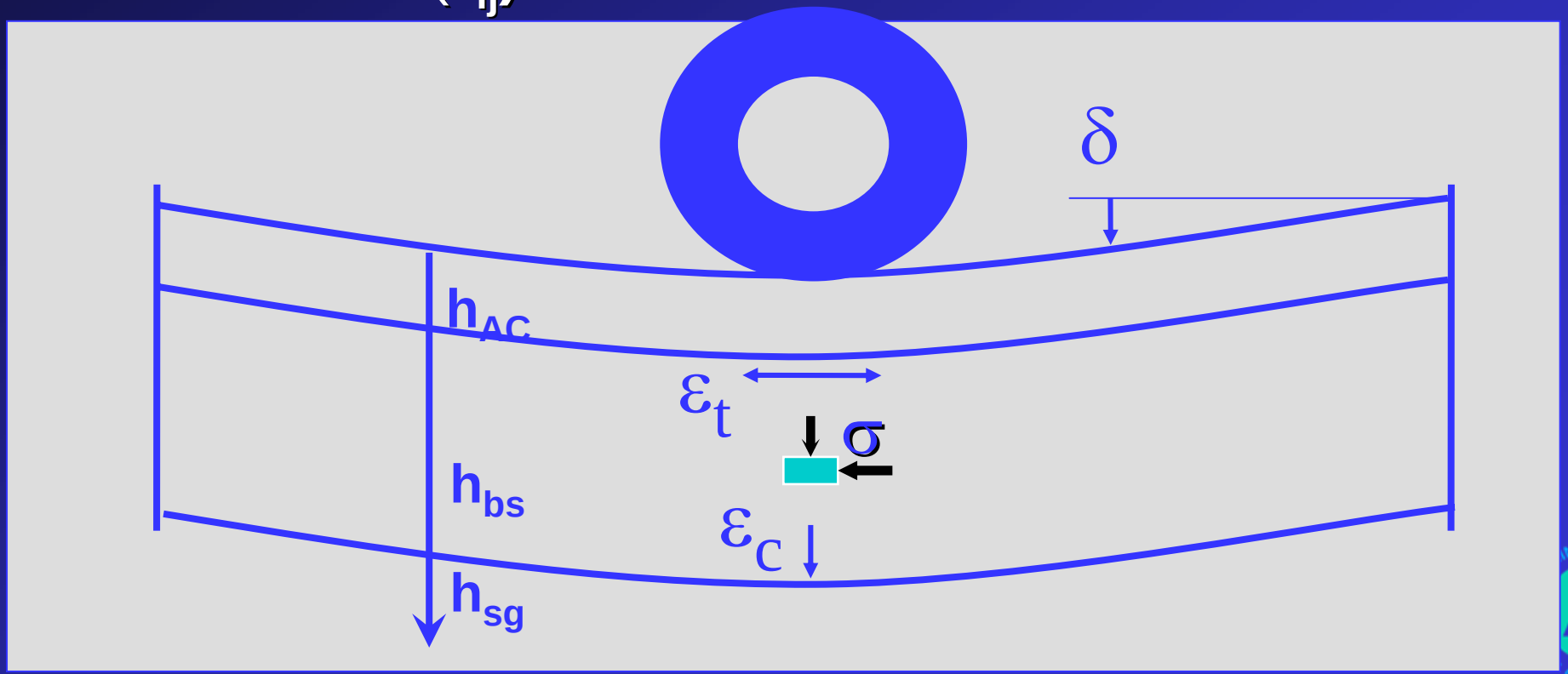
Inputs

- **Traffic**
  - ESAL is currently used.
  - Eventually, Load Spectrum will be used.

- **Expected heaviest axle load**

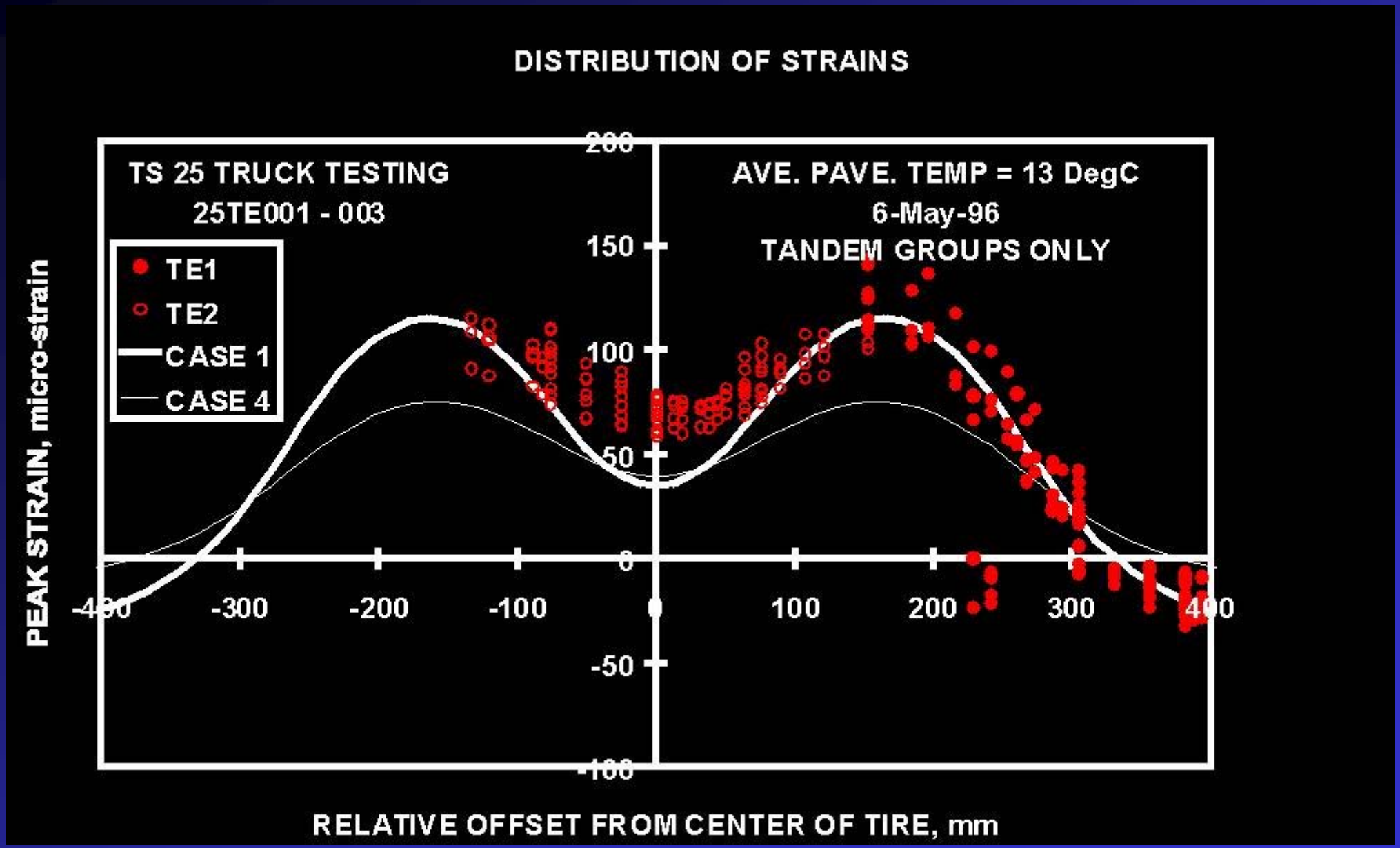
Structural Model (Mathematical Model)

- **Assume that pavement system can be modeled as a layered elastic system.**
  - Determine pavement responses: stresses (σ_{ij}) and strains (ε_{ij}).



Verification of Structural Model

- MnROAD sections used to verify the structural model


DISTRIBUTION OF STRAINS
TS 25 TRUCK TESTING
25TE001 - 003
AVE. PAVE. TEMP = 13 DegC
6-May-96
TANDEM GROUPS ONLY
TE1
TE2
CASE 1
CASE 4
PEAK STRAIN, micro-strain
RELATIVE OFFSET FROM CENTER OF TIRE, mm
200
150
100
50
0
-50
-100
-400
-300
-200
-100
100
200
300
400

Performance Models in MnPAVE

- **Performance models (Transfer functions) ---- link the pavement response to the pavement distress, then to predict performance**
  - **Life due to HMA fatigue:** $N = C \times S \times (k_1)\varepsilon_t^{\,k2} E^{\,k3}$
  - Aggregate base rutting: $\tau < C + \sigma \tan(\varphi)$
  - **Life due to subgrade rutting:** $N = k_5 \varepsilon_c^{\,k4}$

Performance Models in MnPAVE

- **Incremental damage ---- considering temperature & seasonal effects on material property**

$$Damage = \sum_{i=1}^{k} \frac{n_{season\ i}}{N_{season\ i}}$$

☞----Miner's equation

Failure Criteria

- **The success or failure of the selected trial design is determined by damage:**

  Damage $\geq$ 1 indicates failure

- **Allowable stress failure criteria in aggregate base**
  - Currently, Class 5 is implemented in MnPAVE

    $\tau \geq C + \sigma \text{ Tan } (\varphi)$ indicate failure

- **How were the failure criteria established:**
  - Calibrated the transfer function against R-value design, soil factor design and MnROAD sections

Output

- **Pavement damage**
  - Target design damage is less than and close to 1.
- **Pavement life**
  - Target design life is 20 years

Review

- **Pavement design is moving towards M-E (MnPAVE) design.**

- **Components in the MnPAVE design.**
  - **Inputs**
    - Climate, Material Property and Traffic
  - **Structural model (Mathematical model)**
  - **Performance models: Transfer functions**
    - Fatigue cracking
    - Subgrade rutting
  - **Failure criteria**
  - **Output**