

MnPAVE Training

Presentation 2

Fundamentals of M-E Design

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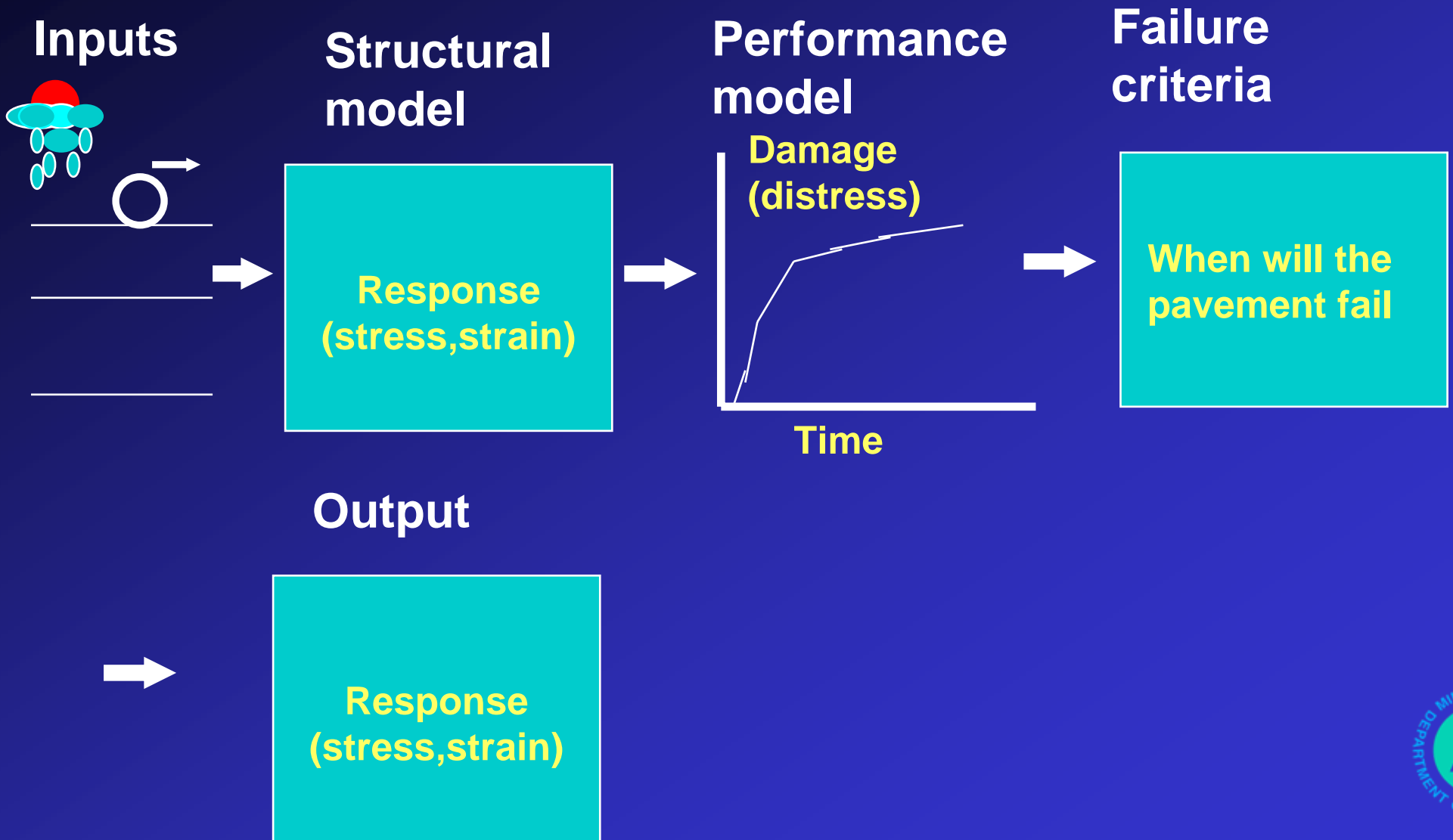


Definition of M-E Design

- **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)**



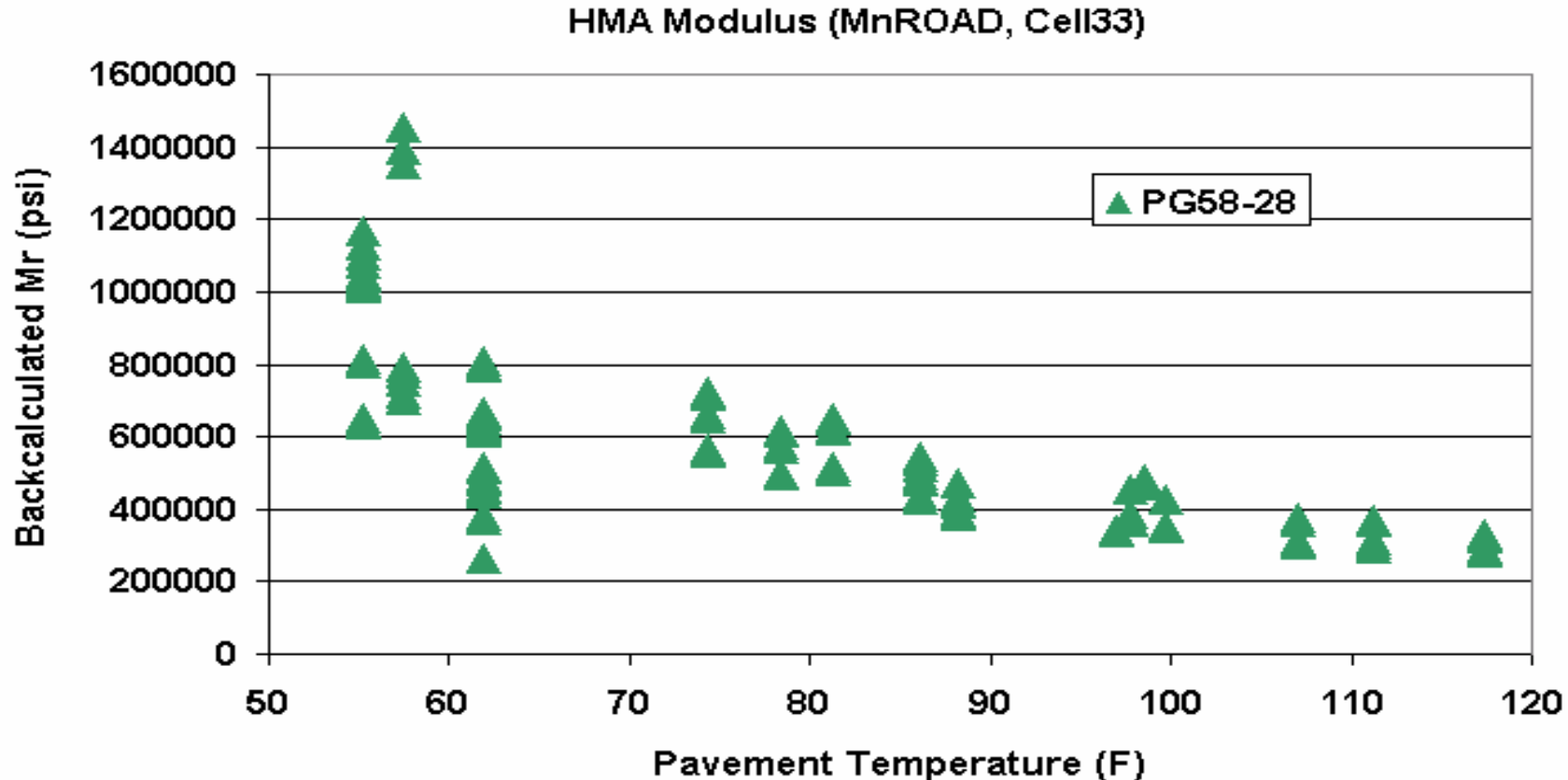
Key Components in M-E Design

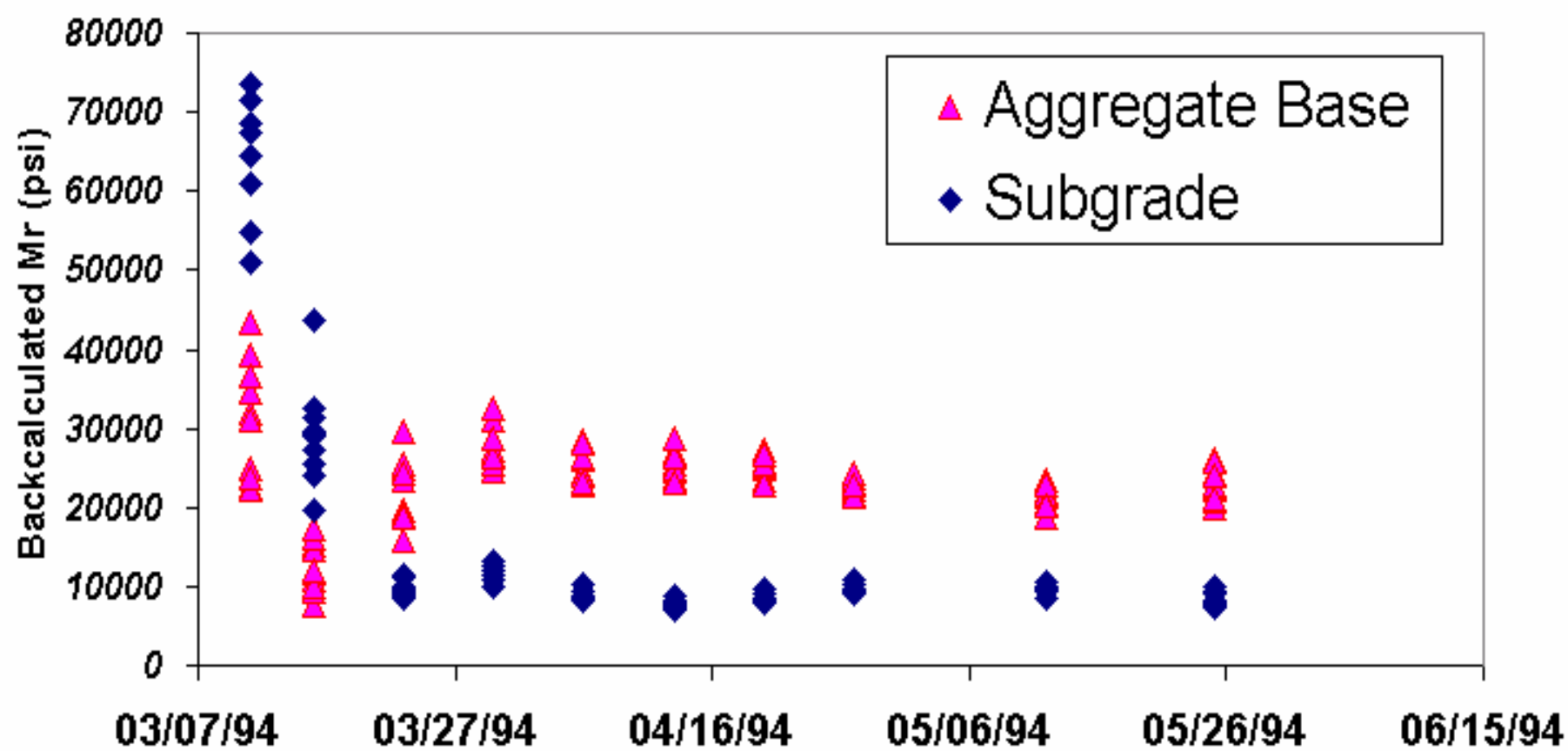


Inputs

■ Climate:

- ◆ Temperature effects on HMA property
- ◆ Seasonal effects on aggregate and 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

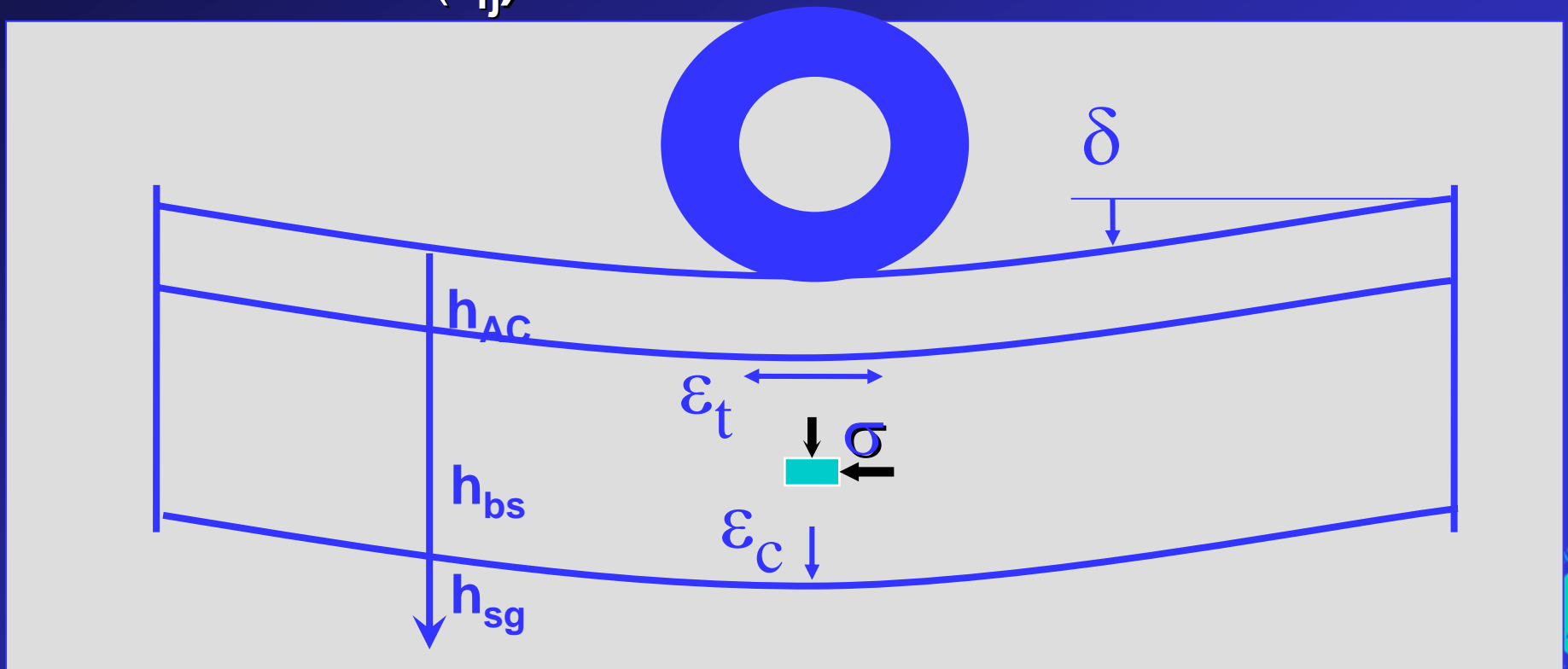
- **Traffic**

- ◆ 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}).

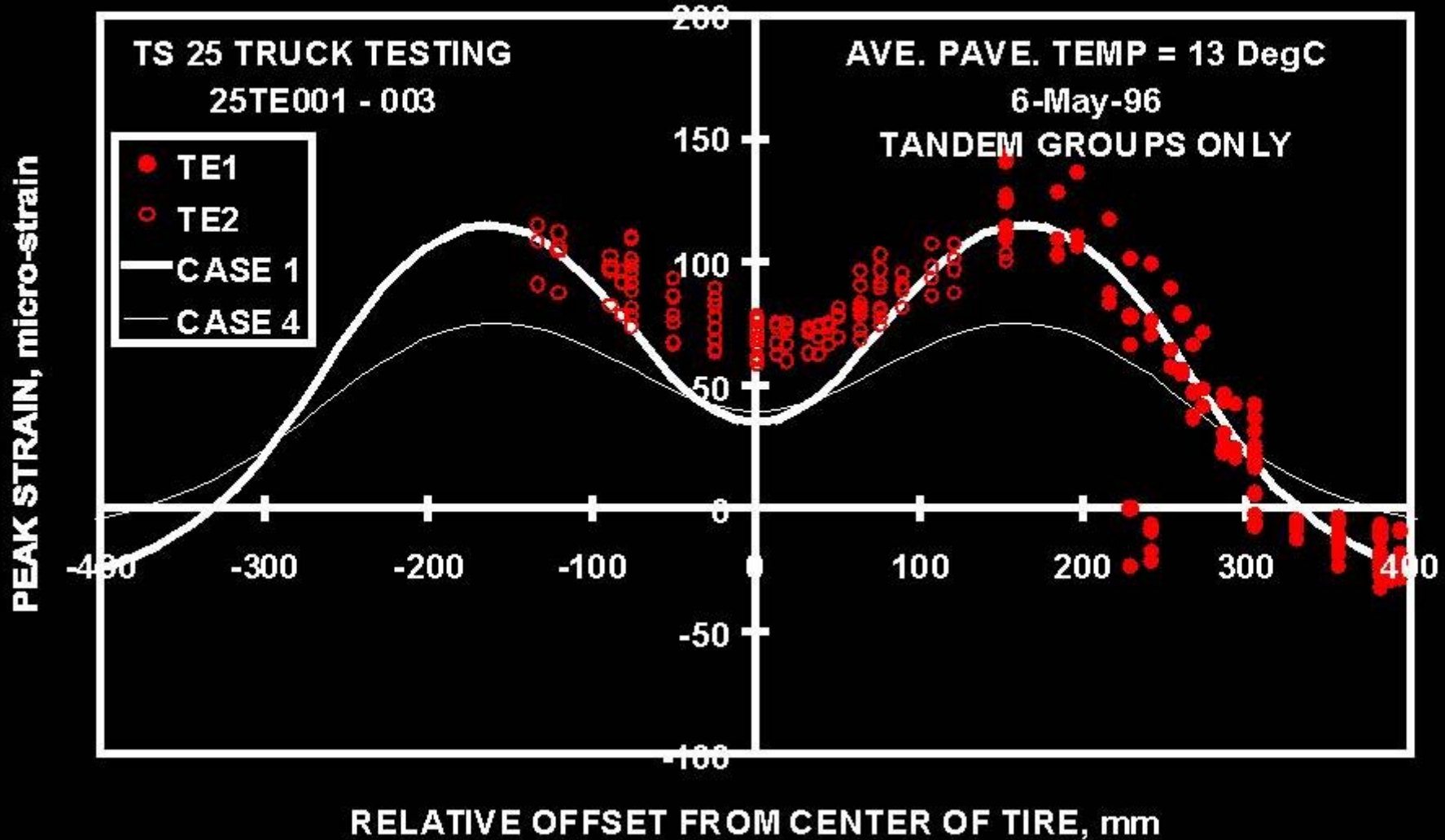


Verification of Structural Model

- MnROAD sections used to verify the structural model



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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:
$$N = C \times S \times (k_1) \varepsilon_t^{k_2} E^{k_3}$$

- ◆ Aggregate base rutting:
$$\tau < C + \sigma \text{Tan} (\varphi)$$

- ◆ Life due to subgrade rutting:
$$N = k_5 \varepsilon_c^{k_4}$$

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 ≥ 1 indicates failure

- Allowable stress failure criteria in aggregate base

- ◆ Currently, Class 5 is implemented in MnPAVE

$\tau \geq C + \sigma \tan(\phi)$ 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