Development of the F_n and F_t Candidate SPT

- Bevan Sullivan

Overall Objective 9-19 Project

- To develop a “fundamentally” based material test that can be used to accurately predict permanent deformation potential.

Primary Study Objective:

- Determine the best candidate SPT from the F_n and F_t test (un/confined).

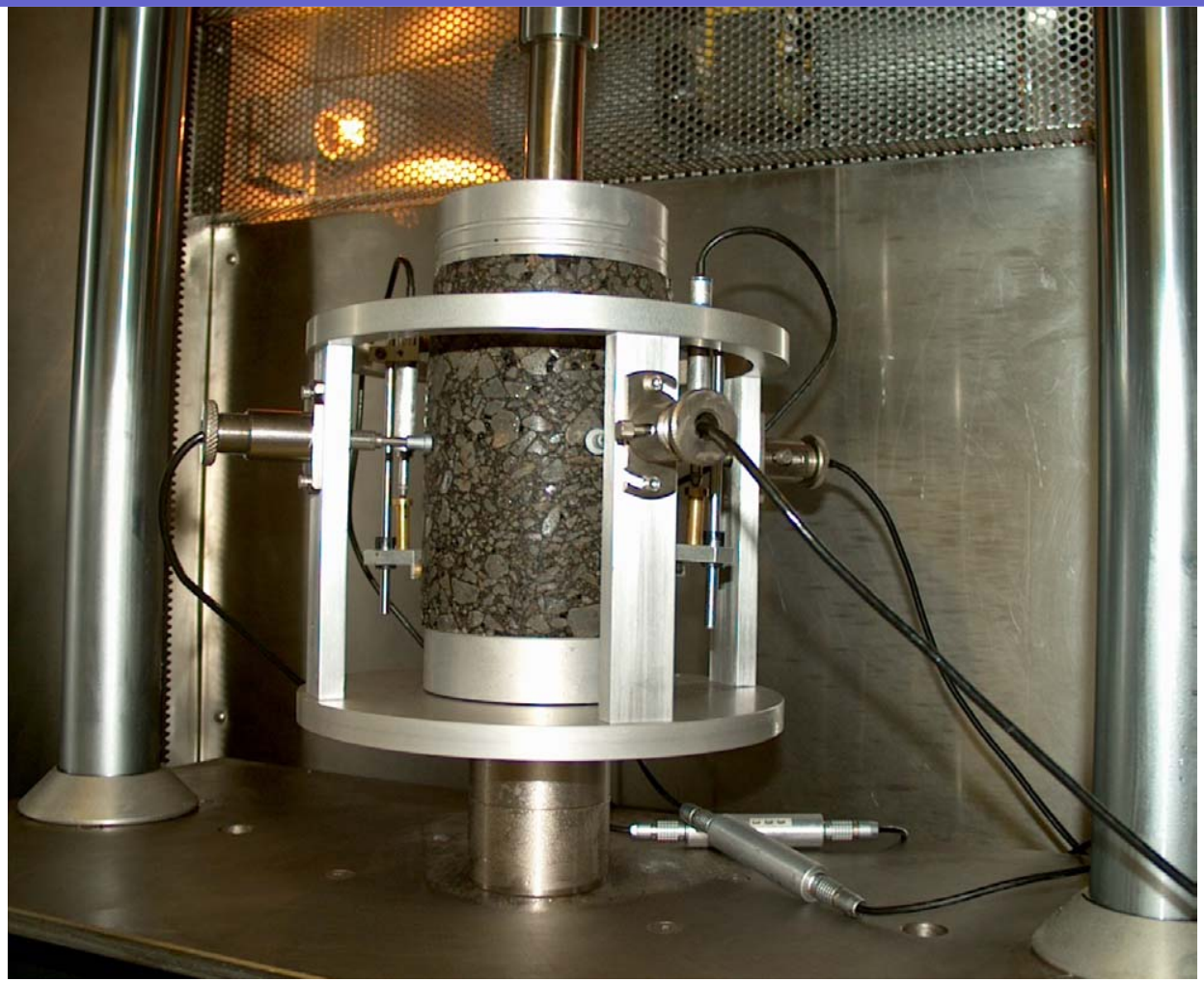
Presentation Outline

- Background
- Introduction to the 3 candidate SPT
- Summary Ancillary/Simplification Studies
- Distribution of Strain Measurements at Flow
- Conceptual Criteria Development

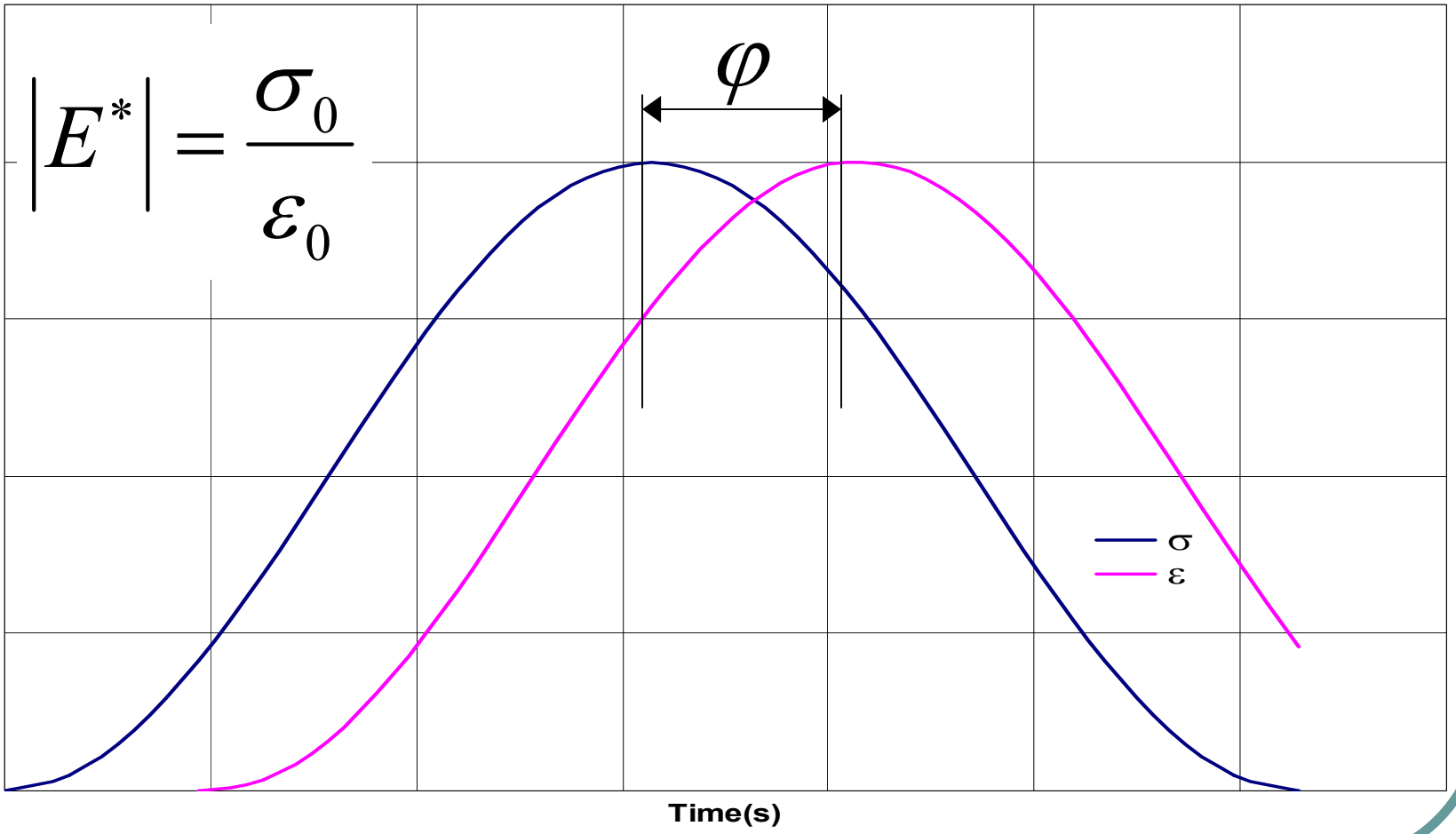
Need for the SPT (Why?)

- Current material tests, at best only give a fair indication of performance potential.
- Volumetric design alone does not answer the problem.

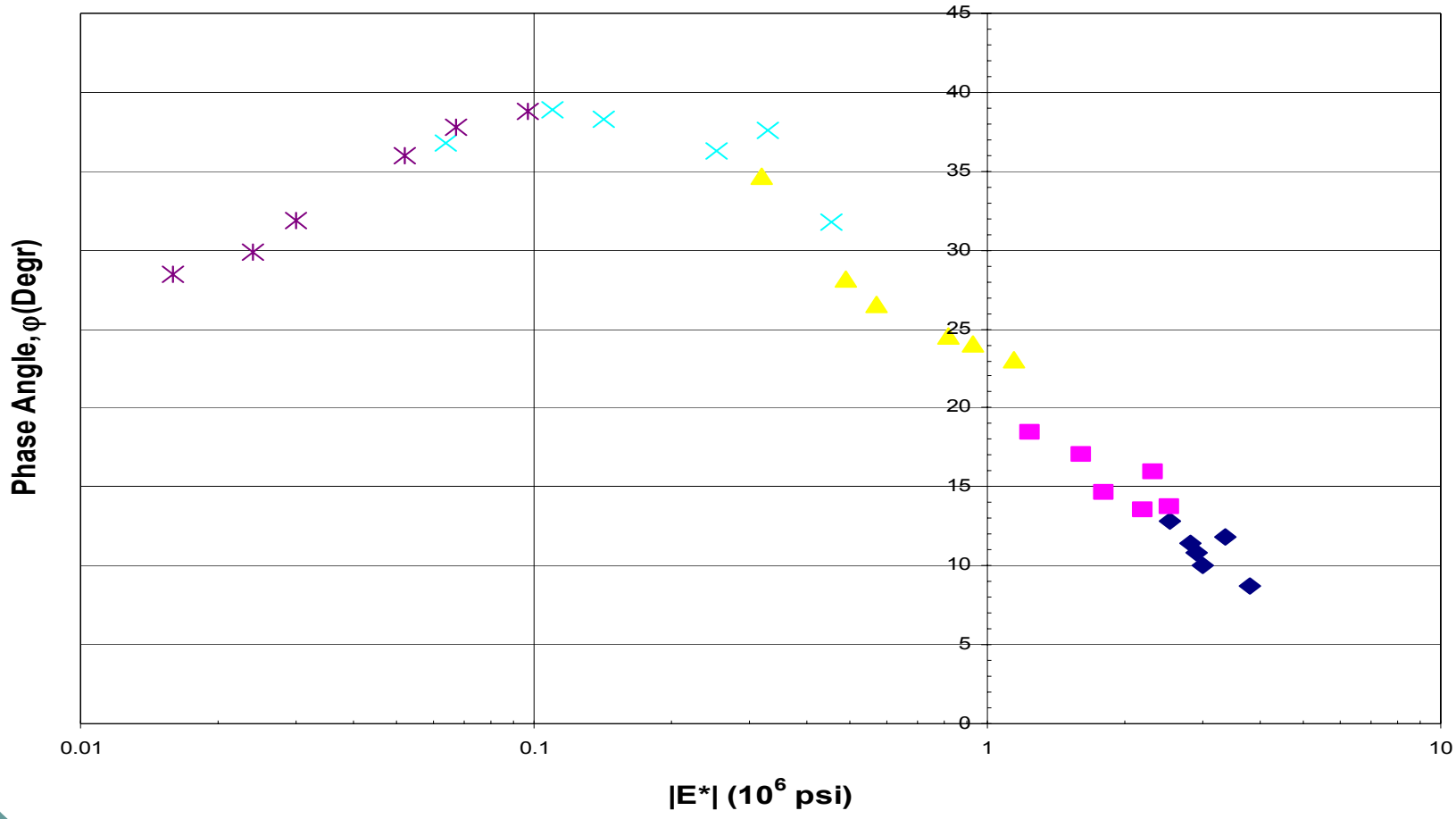
Instrument Setup



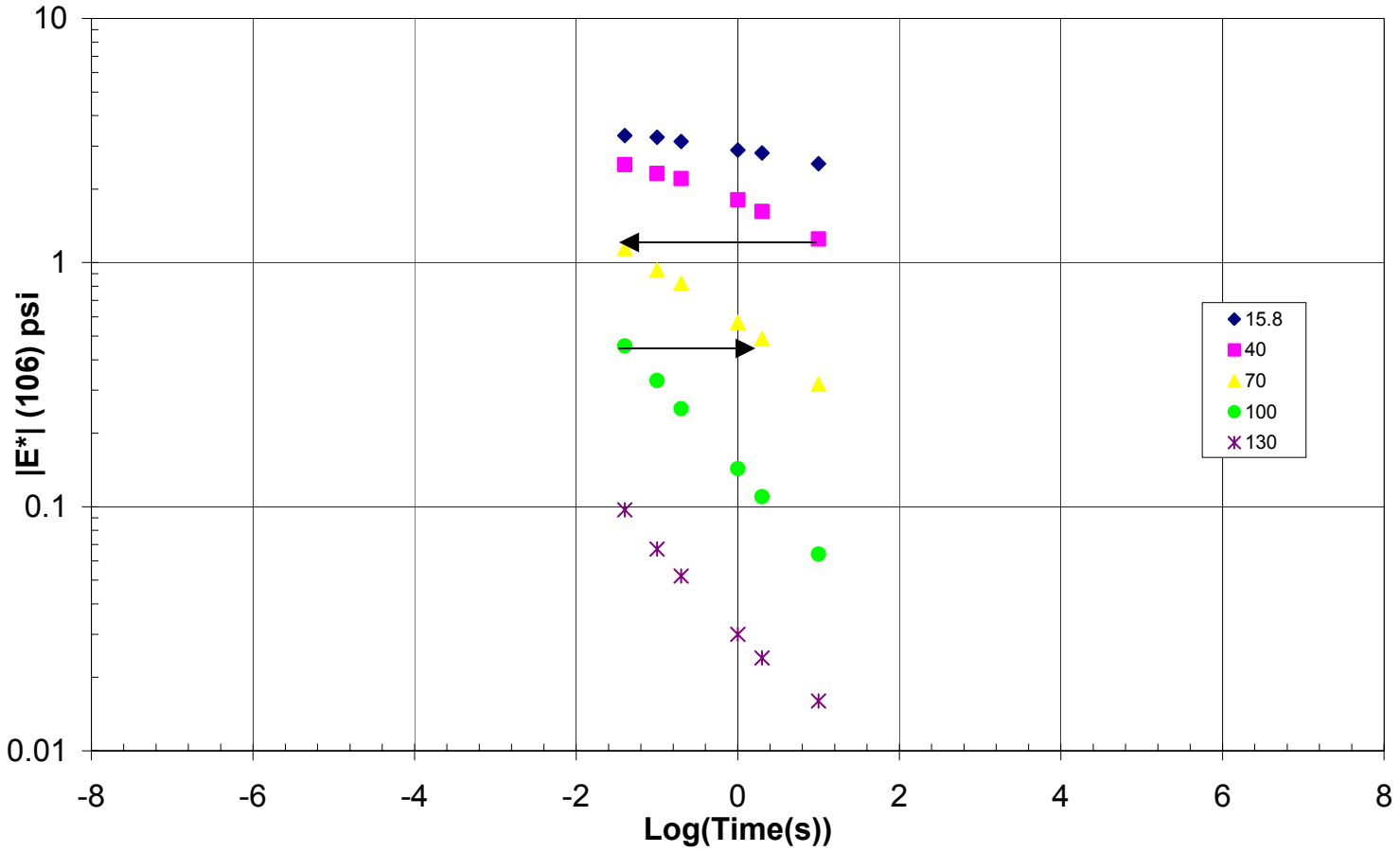
Dynamic Modulus, Viscoelastic Test



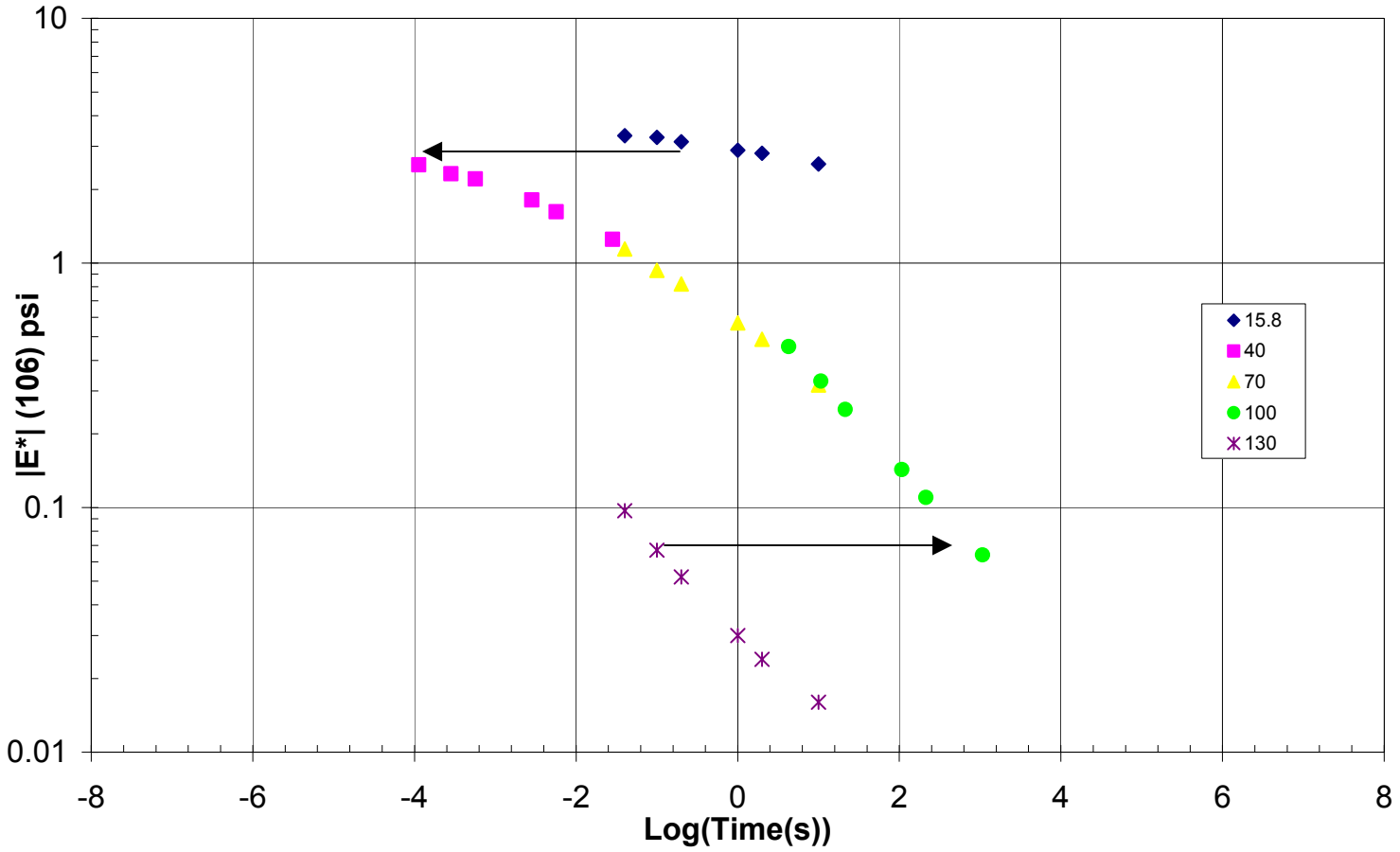
Asphalt Mixture Black Space



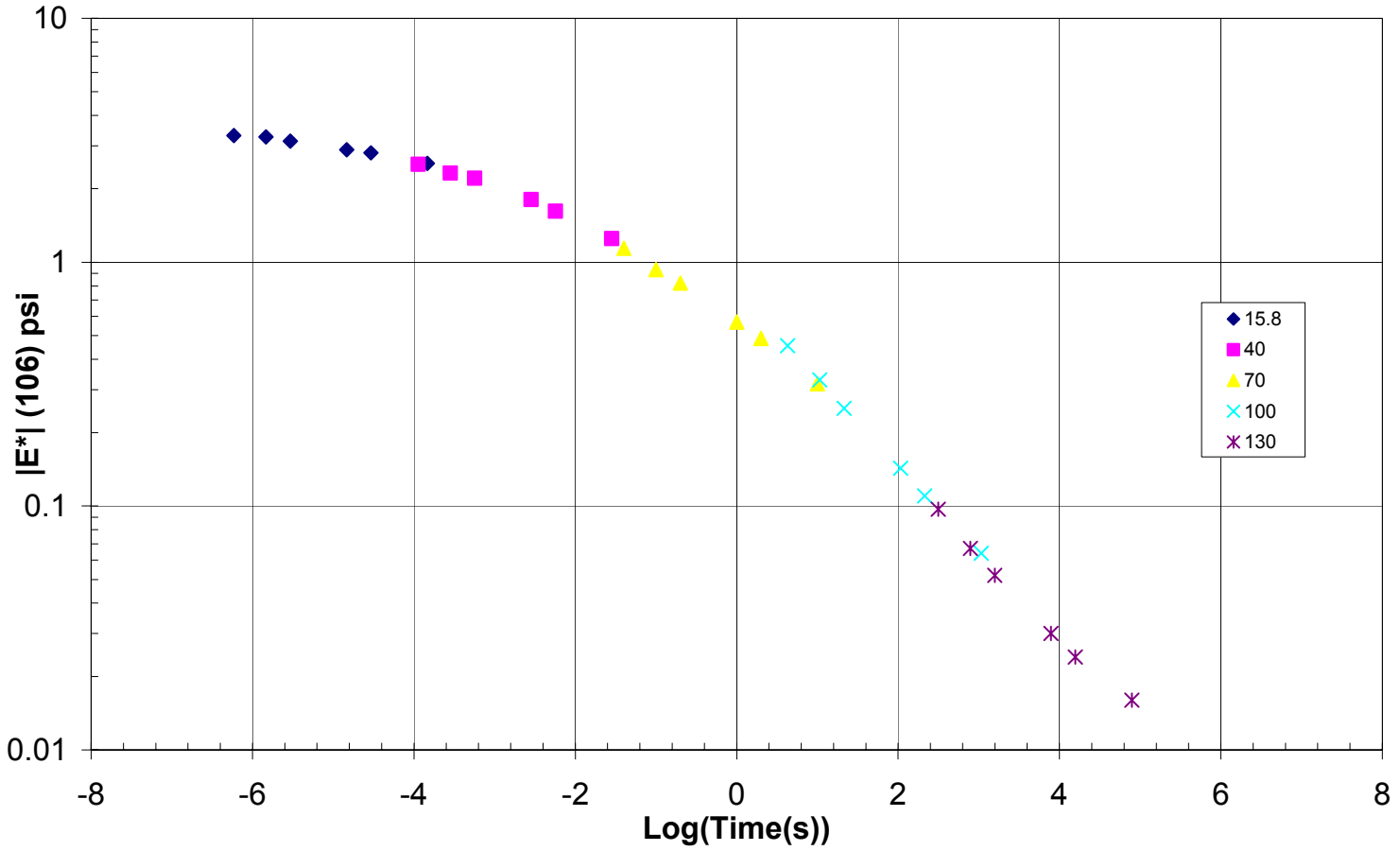
Master Curve



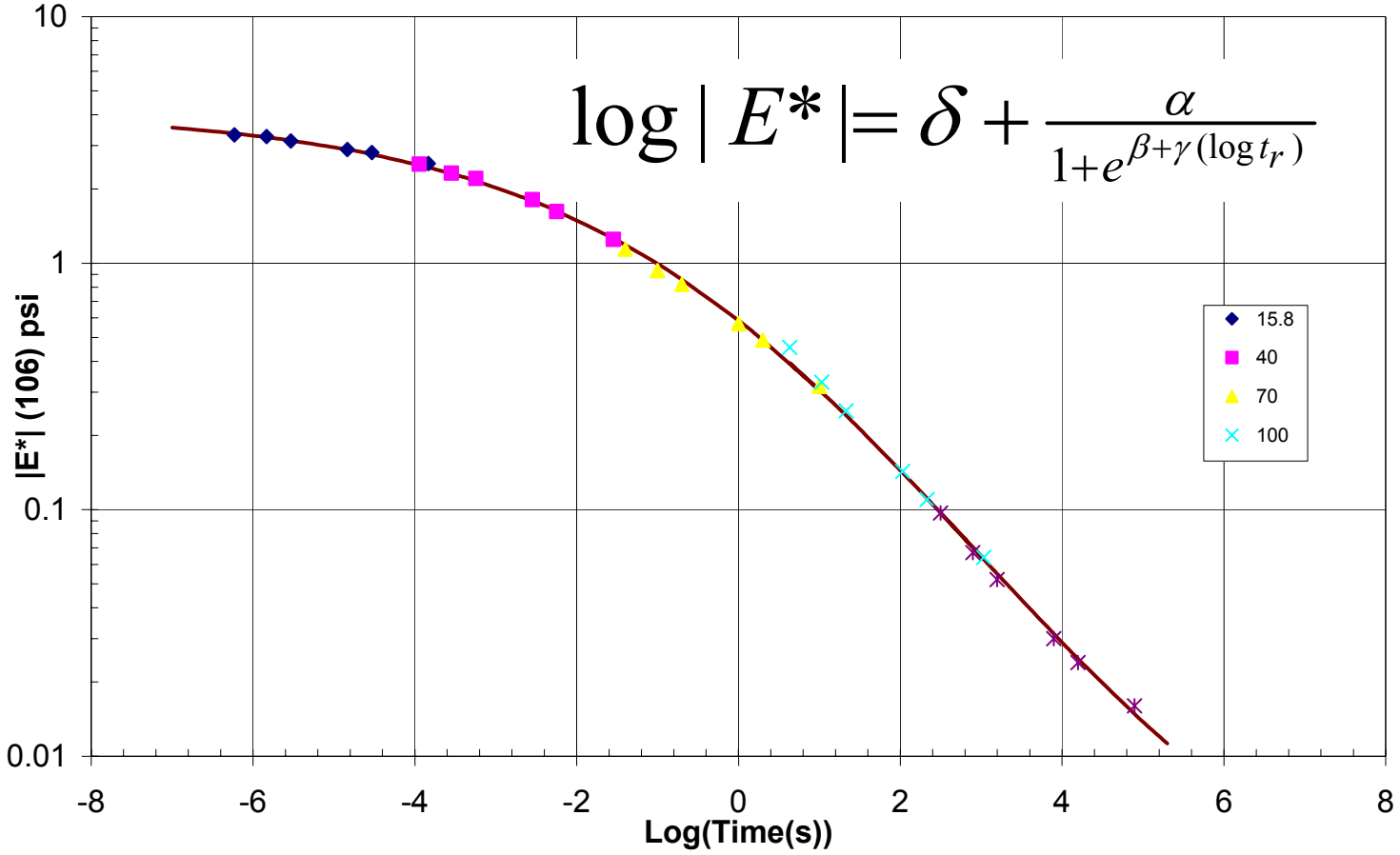
Master Curve



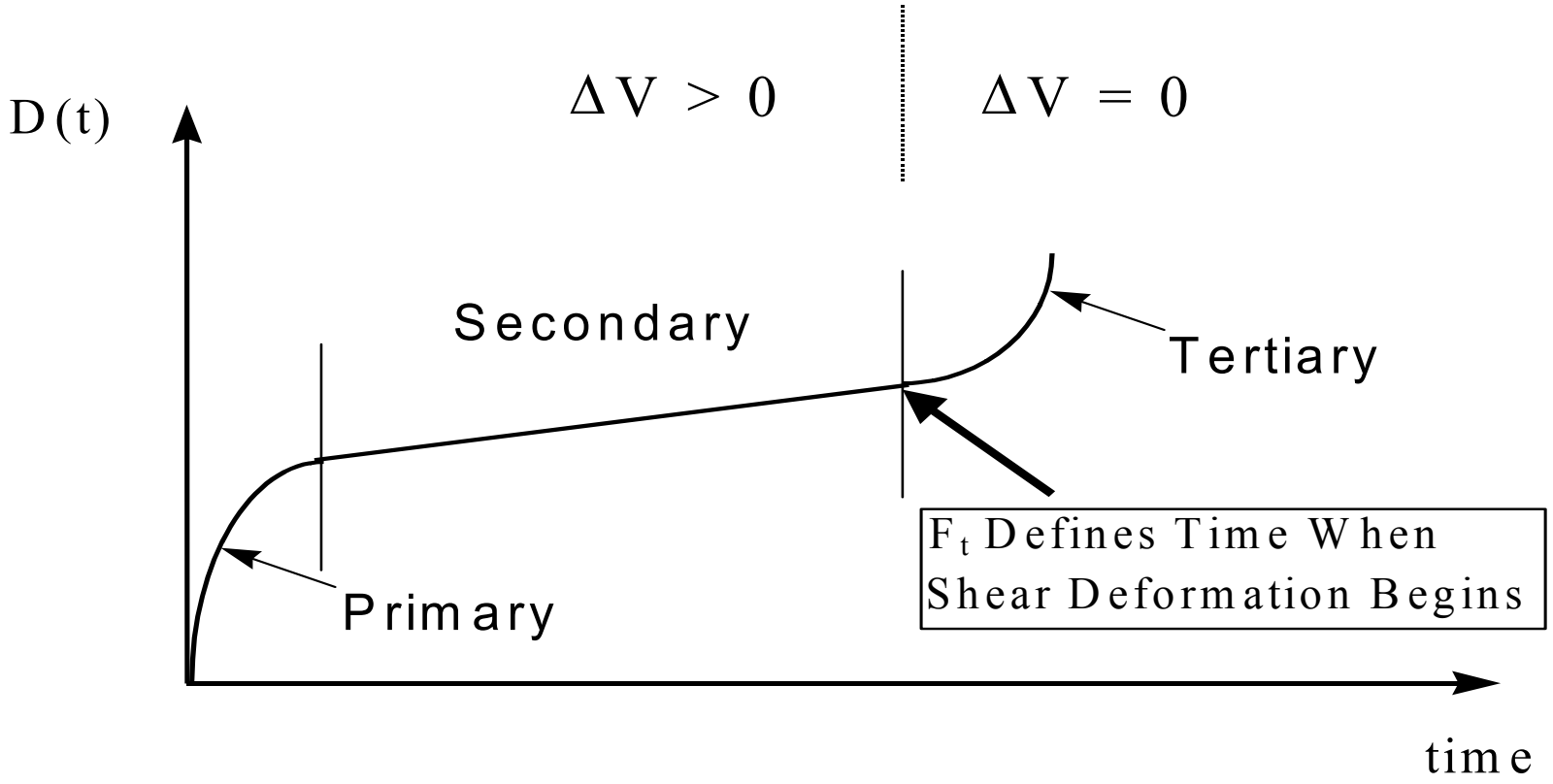
Master Curve



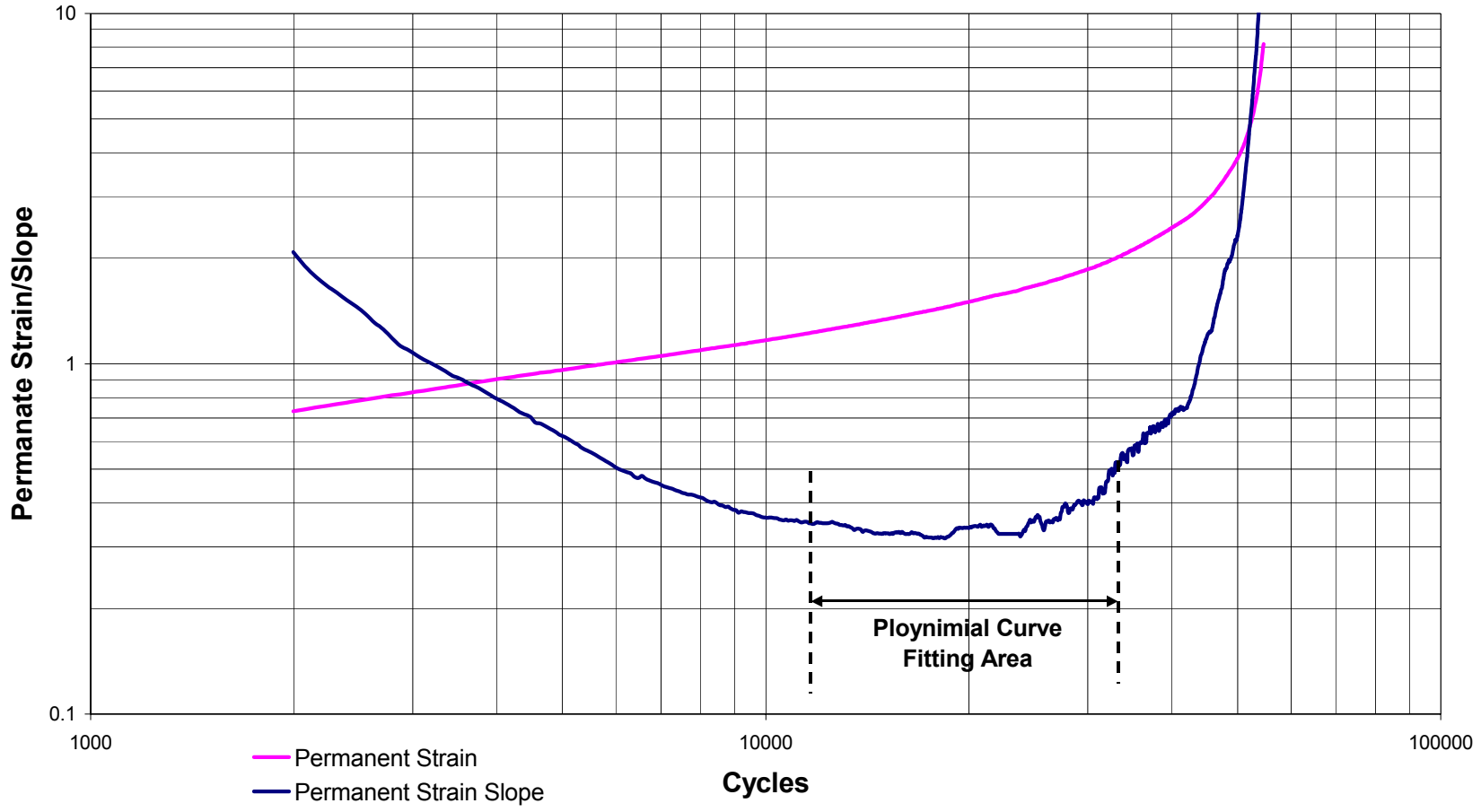
Master Curve



Definition of Flow Time (F_t) Static Creep



Definition of Flow Number (F_n) Dynamic Creep



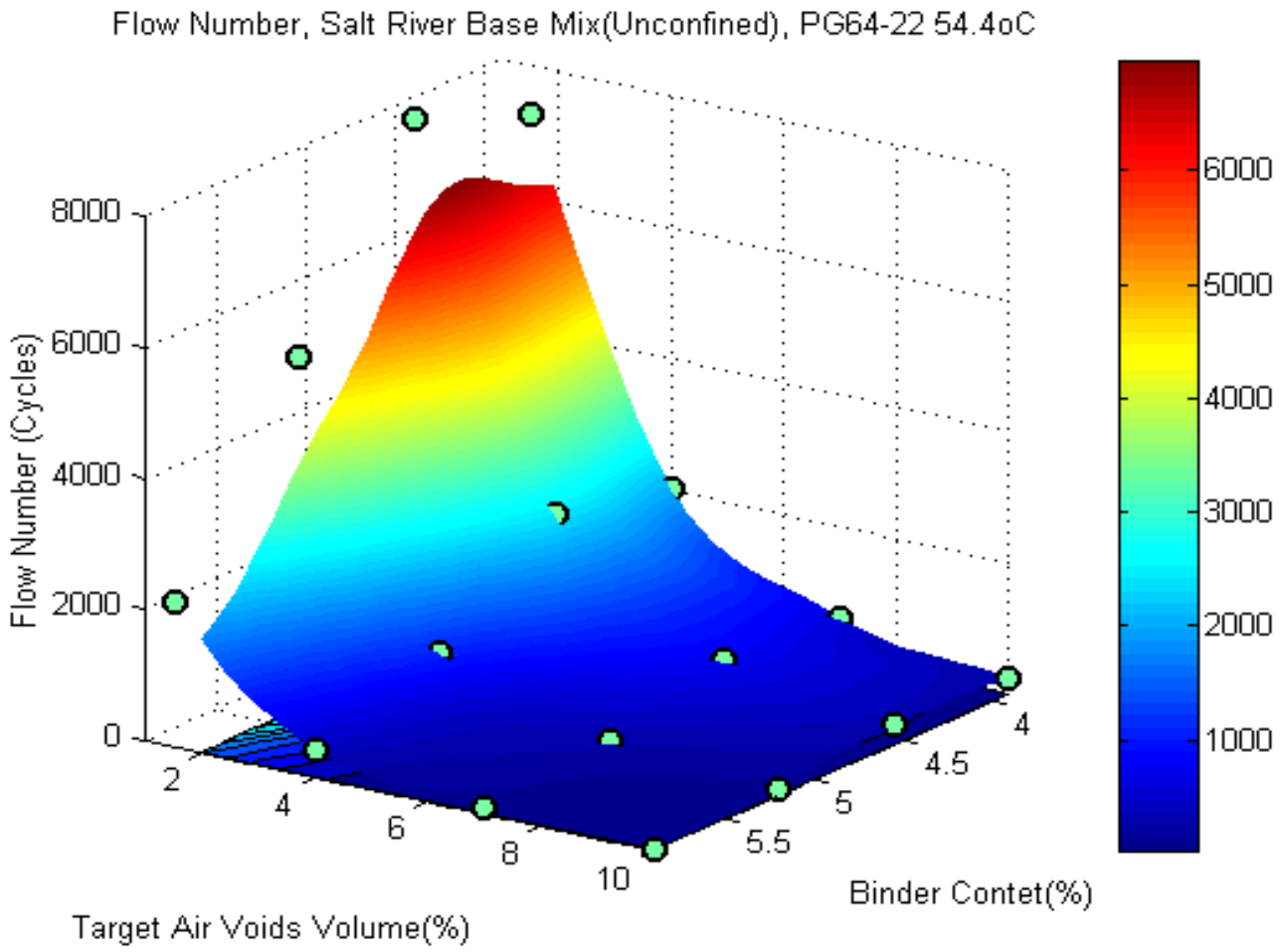
Scope of the Research

- Development of the F_n and F_t tests:
  - Sensitivity of the candidate SPT
  - Actuator/radial comparison
  - Use of full size gyratory plugs
  - Temperature and stress effects
  - Distribution of strain values at failure
  - Development of provisional criteria

Sensitivity of the SPT

- Objective:
  - To determine if the F_n and F_t response to volumetric changes, follow rational logic expected of mixture behavior.
- Test Setup
  - 1 mixture (Salt River Base)
  - 4 air void levels
  - 4 binder contents
  - 1 stress level for both confined and unconfined

Sensitivity Unconfined F_n



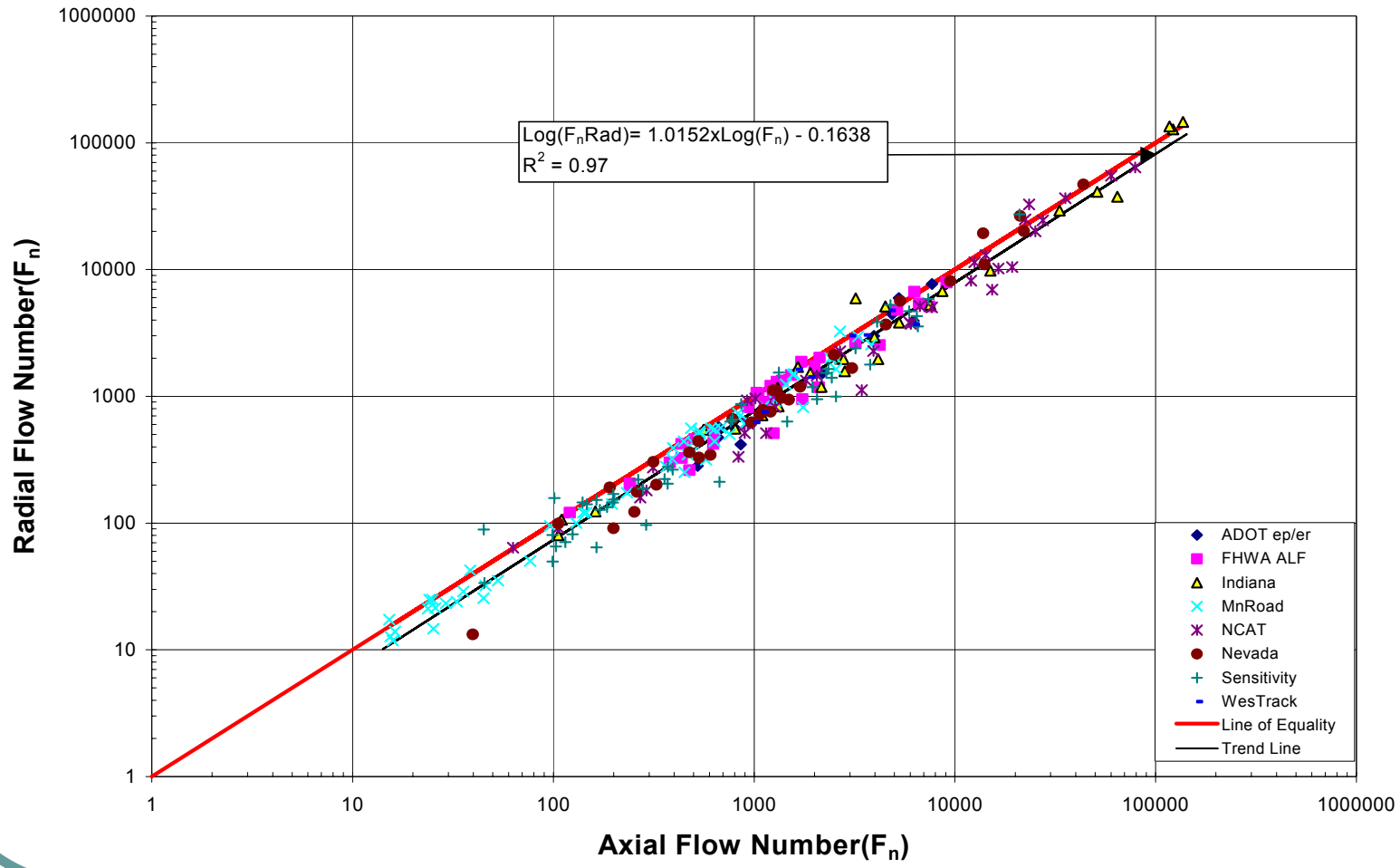
Sensitivity Study Implications

- Not one test stood out ,in responding to all expected performance rationale.
- All test had $^{12}/_{16}$ correct responses.
- If F_n (C & UC) or F_t (UC) are selected
  - Need specification, to ensure air void levels do not fall below the critical threshold.
- F_t (C) results should be used with caution, with mixtures below the optimal binder content.
- F_n and F_t (UC) may be the most practical test, as under compaction is by far the most common problem.

Method for Simplifying the SPT

- The use of full size gyratory plugs against cored sawn gyratory plugs
- Alternative methods for determining the flow parameters.

Radial/Axial Determined F_n



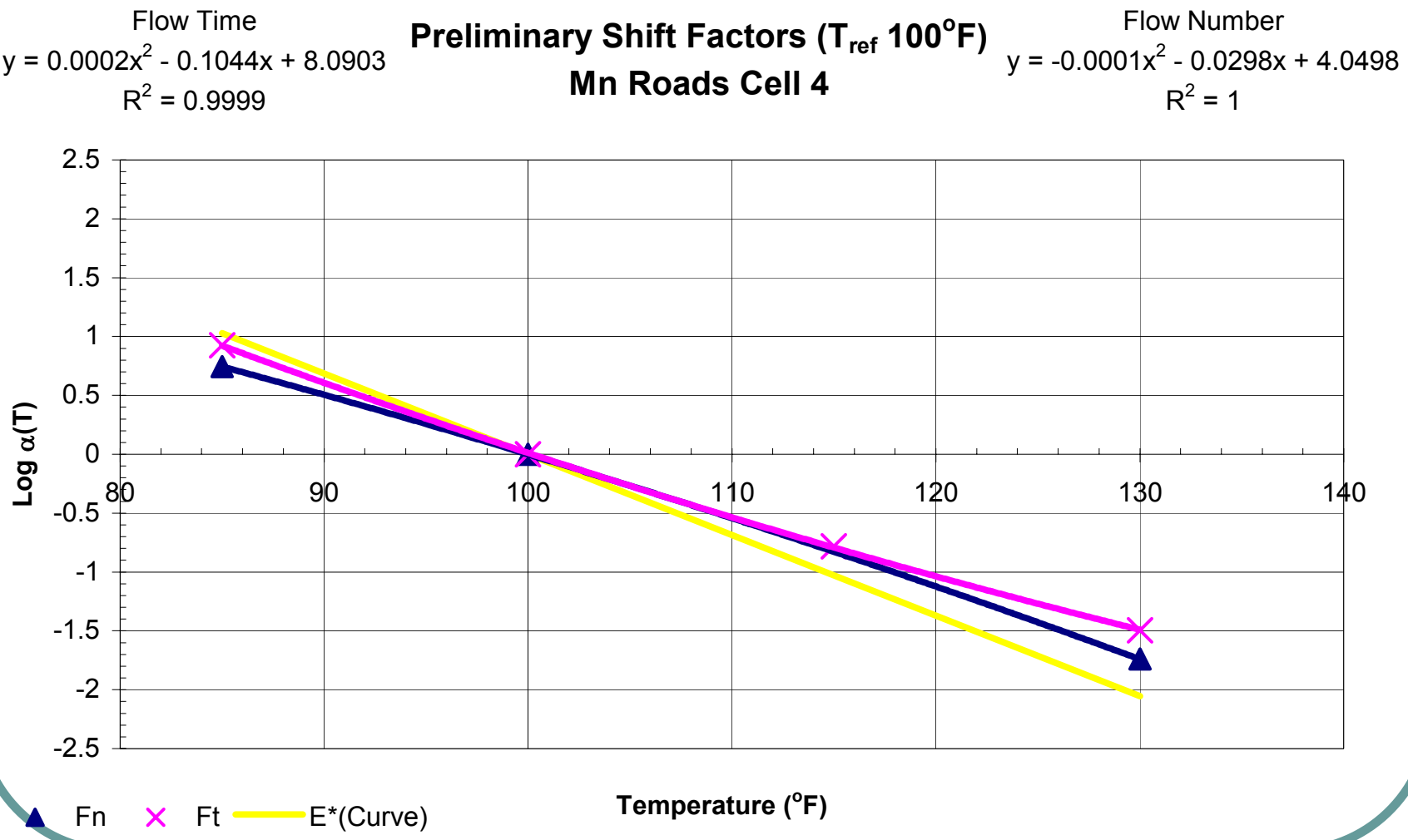
Conclusions; Simplification of SPT

- Simple Performance Test parameter (F_t,F_n) MUST use specimens of 4 inch cored plugs with a height to diameter ratio of 1.5 to 1.
- The F_n and F_t can be measured from either actuator and/or radial displacement measurements

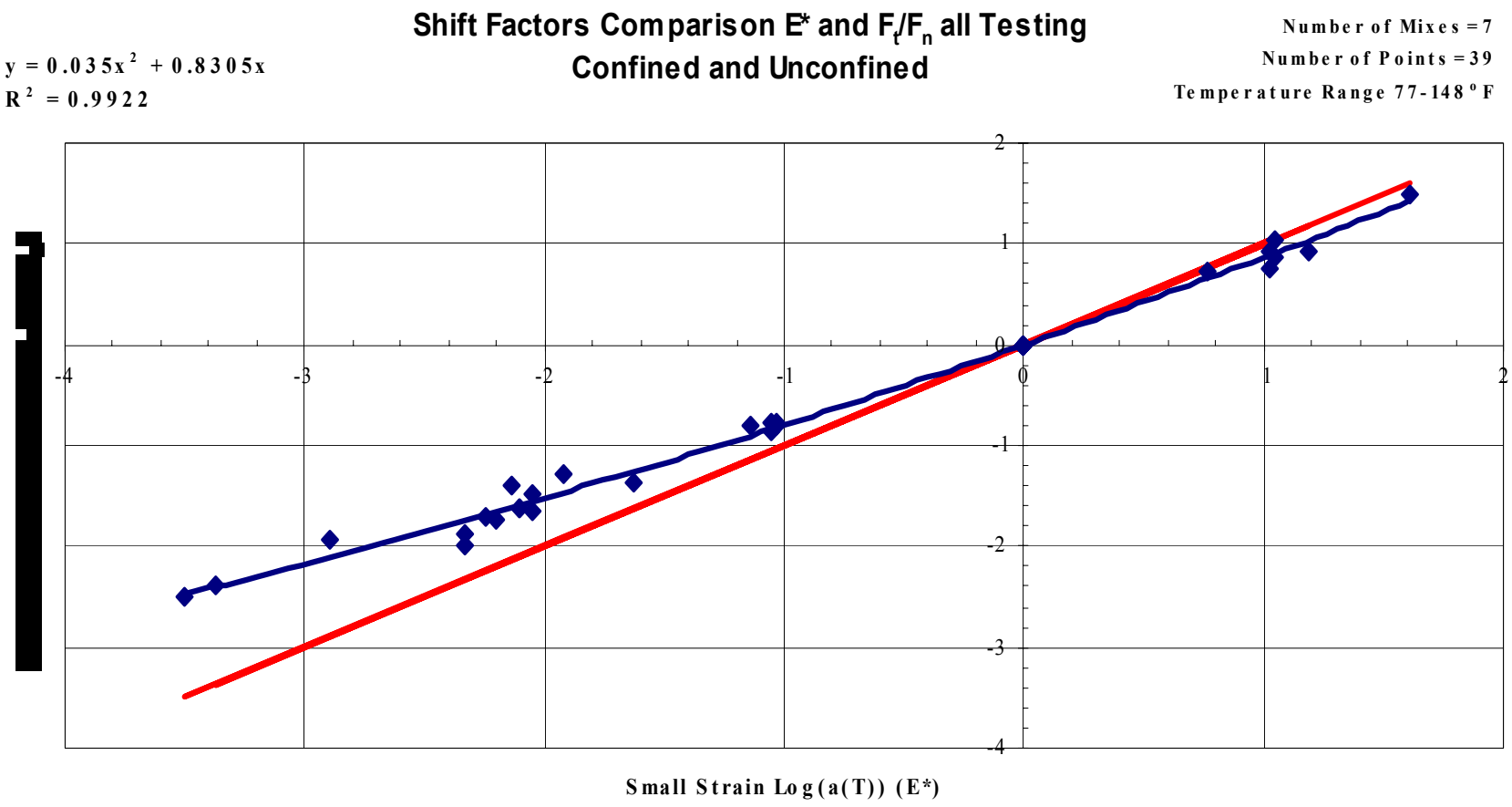
Understanding Temperature/Stress

- The F_n & F_t needs to be shifted from test temperature to field temperature.
- The effect of stress need to be understood for practical implication of the SPT.

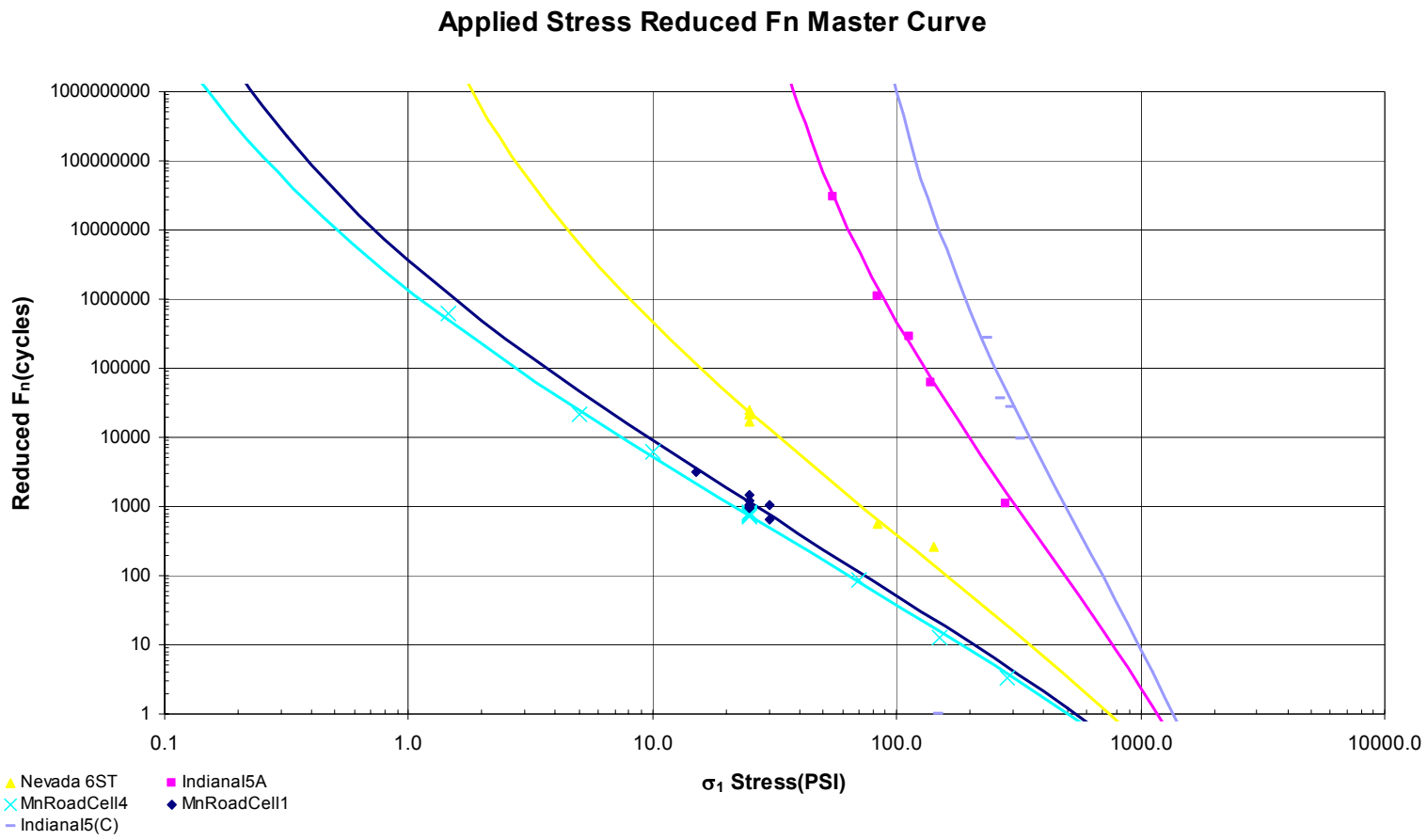
Temperature Shift Factors



Shift Factors (E* vs. F_n & F_t)



Reduced F_n Master Curves



Conclusions; Temperature & Stress

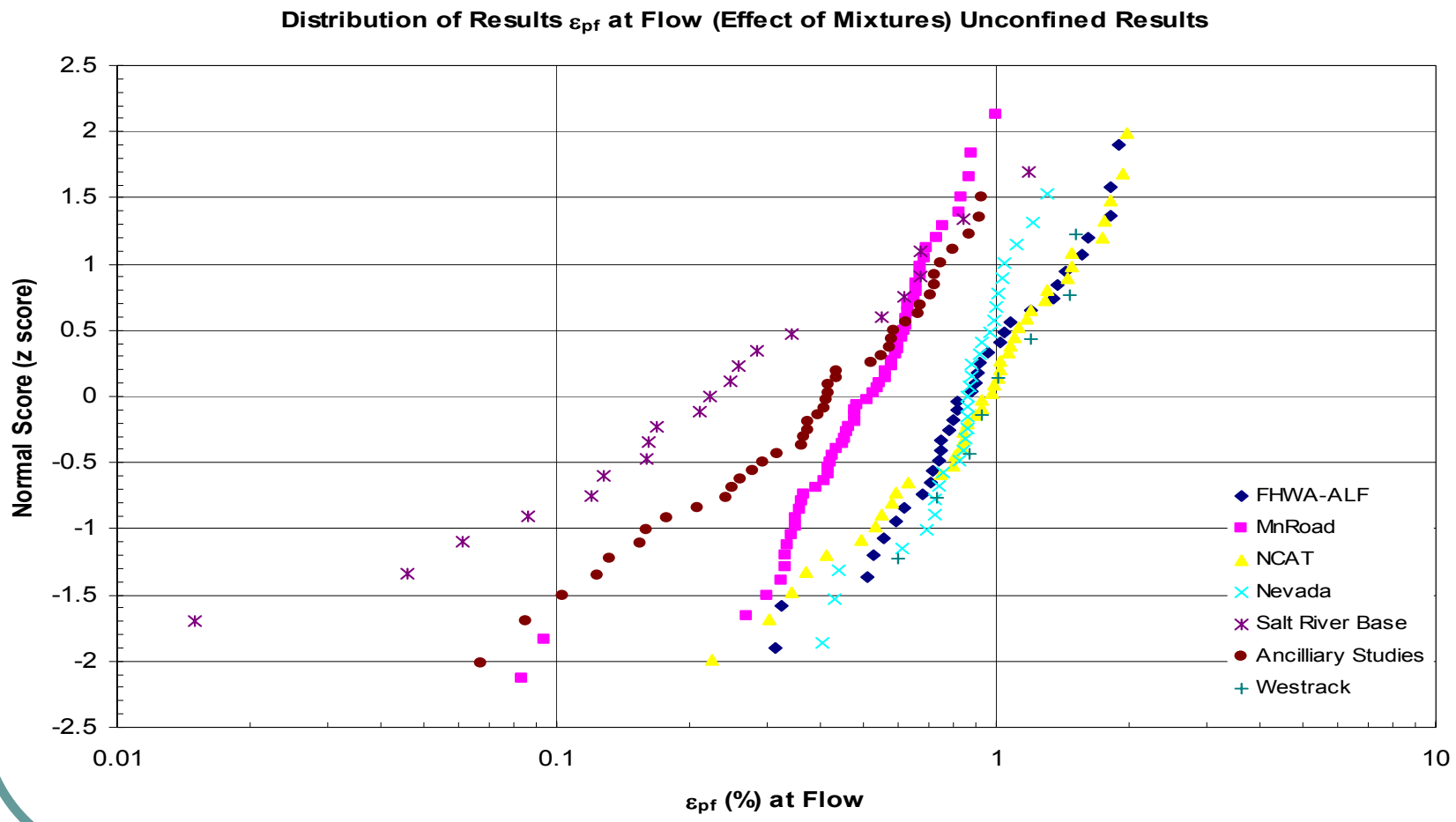
- Temperature effects can be described by the time-temperature superposition principal.
  - Temperature shift factors can be found from F_n/F_t, E* or binder properties.
- Stress effects can be captured by master curves.
  - Stress shifting can be accomplished from global curves, from the results of one test.

Distribution of Strains at Flow

Objective:

- **If a single parameter relating to strain of failure (ε_p, $\varepsilon_p/\varepsilon_r$ & D(t)) was found to be constant at flow (F_t or F_n). This parameter could be used to development of criteria for F_t and or F_n.**
- **If no single parameter was found to be constant at flow (F_t or F_n) the F_t or F_n parameter *alone* can not be used to develop criteria.**

Effect of Mix Type (ε_{pf}) F_n



Factor Affecting Strain at Failure

All strain measurements affected by mixture gradation

For any mix the level of ε_{pf} is a constant at any confinement level

ariables	$\varepsilon_{pf}(F_n)$	$\varepsilon_{pf}/\varepsilon_r(F_n)$	$D(t)_f(F_t)$
Binder content	Some	limited	No
Air voids	Yes	No	Yes
Mix Gradation	Yes	Yes	Yes
evel	Yes	No	Yes
e	No	Some	No
Test Temperature	No	Yes	No
Stress Level	No	Yes	Yes

Implications of Failure Zone

- F_n and F_t alone will not give an accurate prediction of rut depth across a wide range of mixtures
- The SPT will need to incorporate a measure of strain at failure, to give accurate rutting predictions.

Suggested Additional Factor

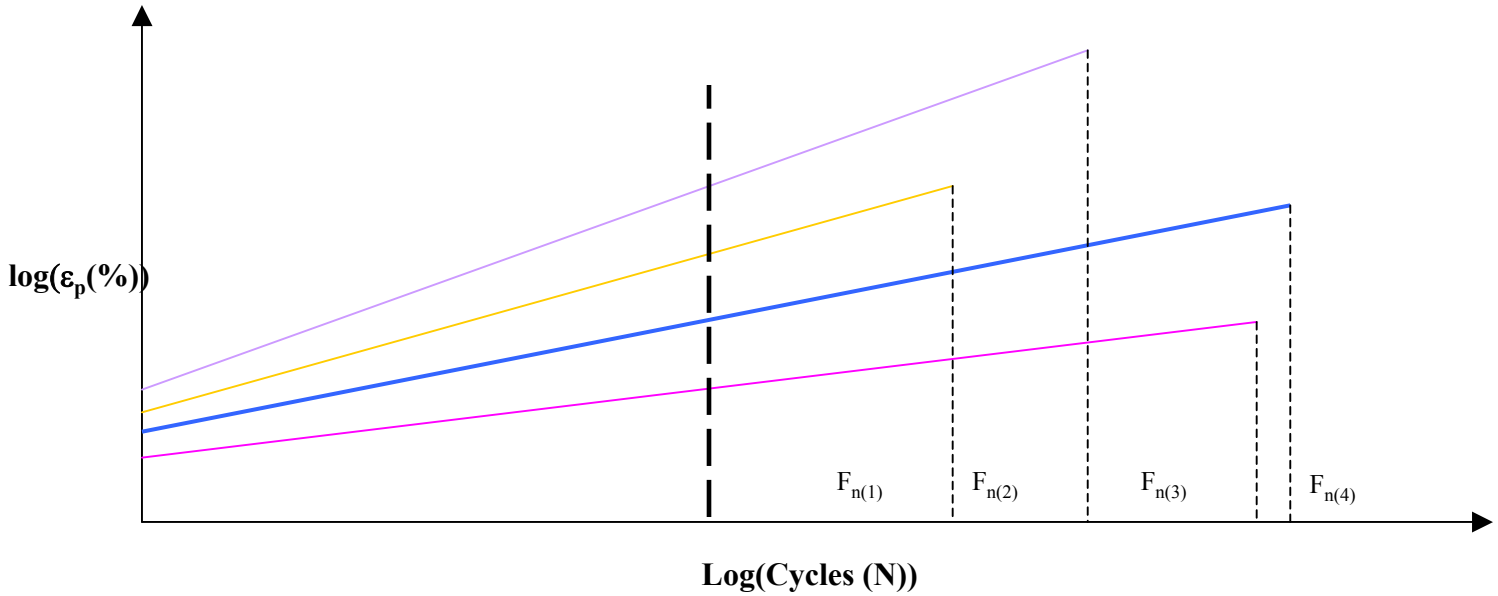
- ε_{pf} is independent of stress or temperature at any confinement level, unlike D(t) and $\varepsilon_{pf}/\varepsilon_r$.
- ε_{pf} should be closely related to the rut depth at failure.
- Suggested approach, is to incorporate F_n with ε_{pf} to determine the rutting potential.

Prioritized Criteria Development

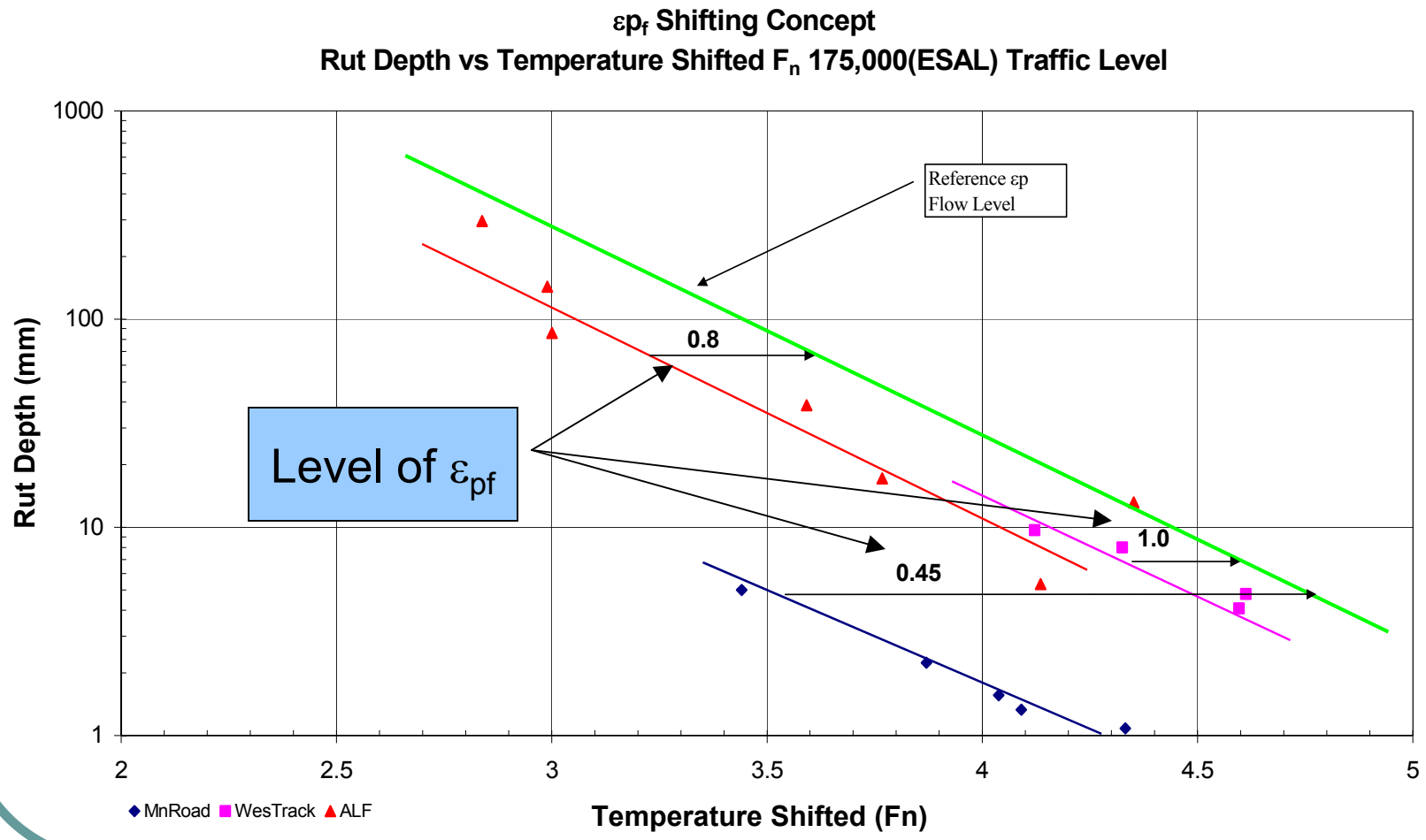
- Unconfined F_n & ε_{pf}
- Confined F_n & ε_{pf}
- Link F_n with F_t

Conceptual Criteria for F_n and ε_{pf}

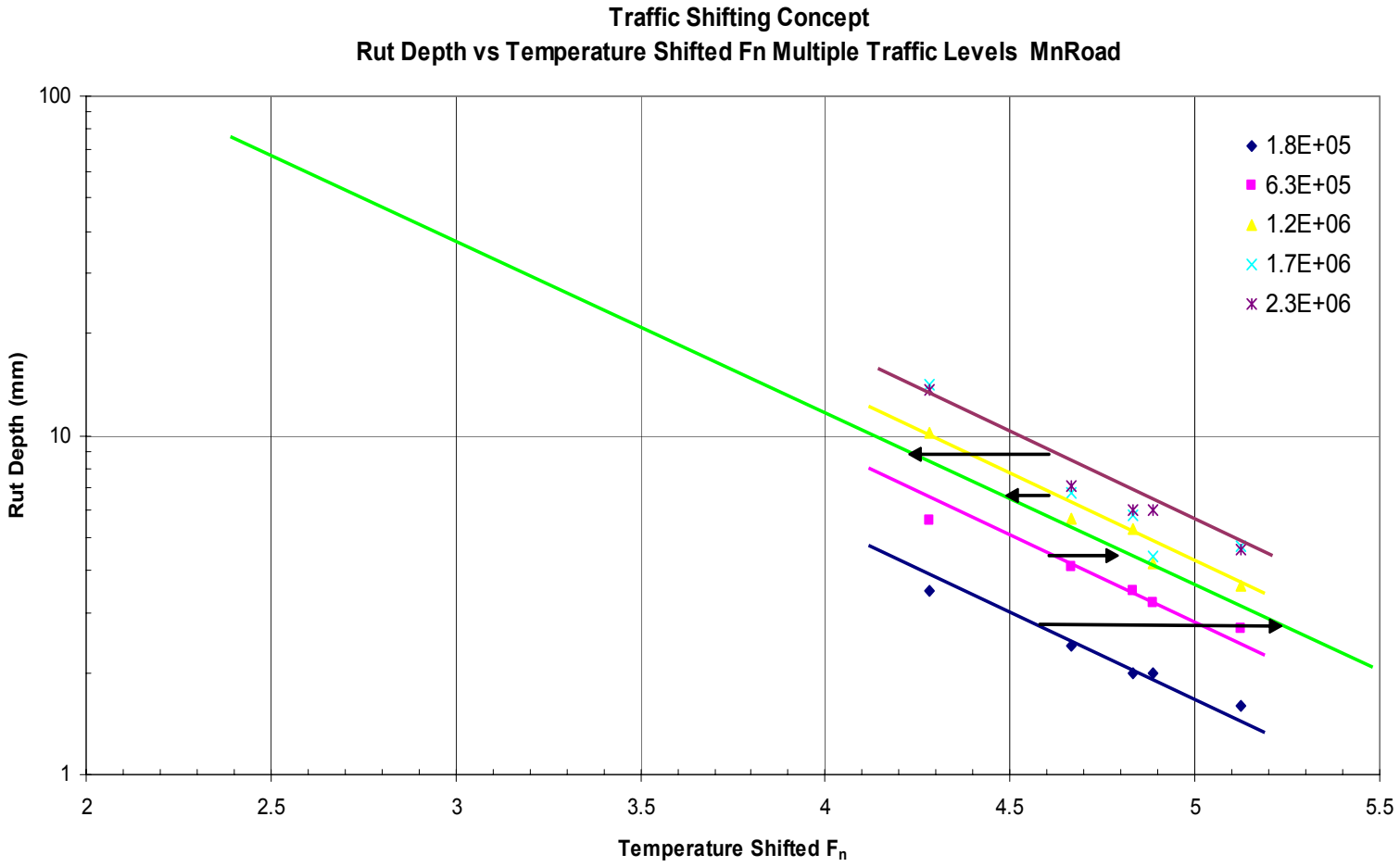
- The measured F_n will have to be adjusted by the ε_{pf} to enable accurate prediction of rutting potential



F_n and ε_{pf} Shifting Concept



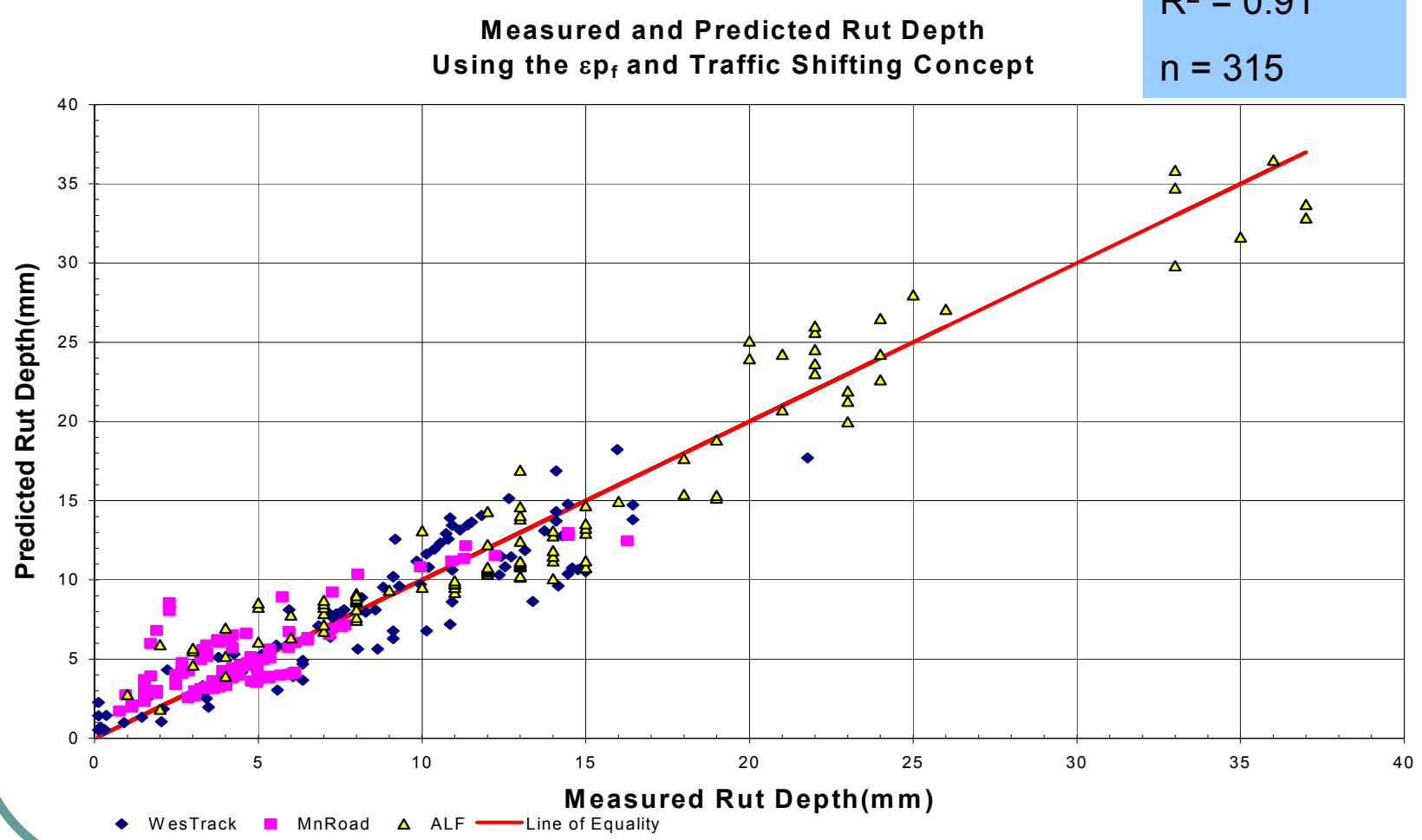
F_n and Traffic Shifting Concept



Results of Shifting

$R^2 = 0.91$

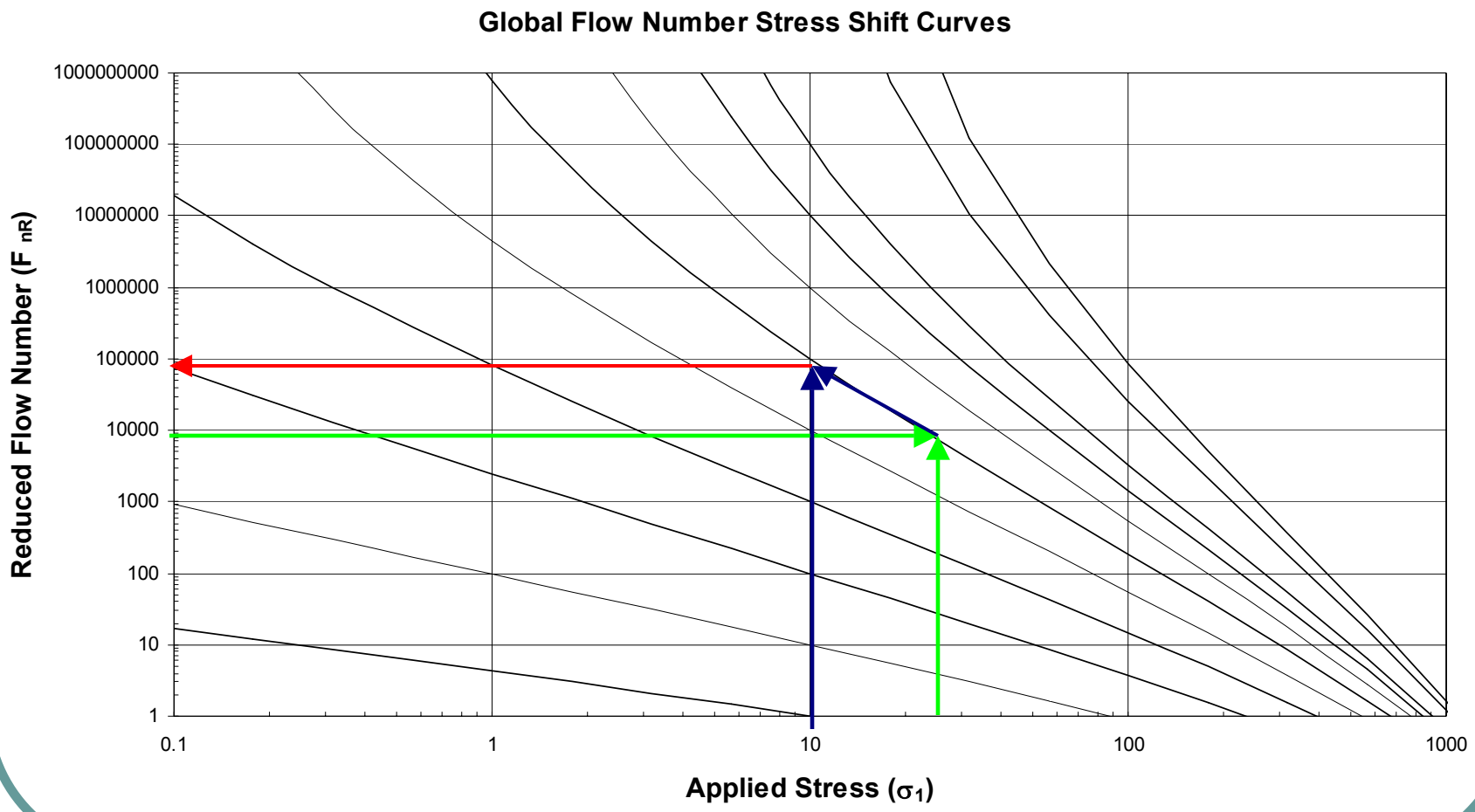
n = 315



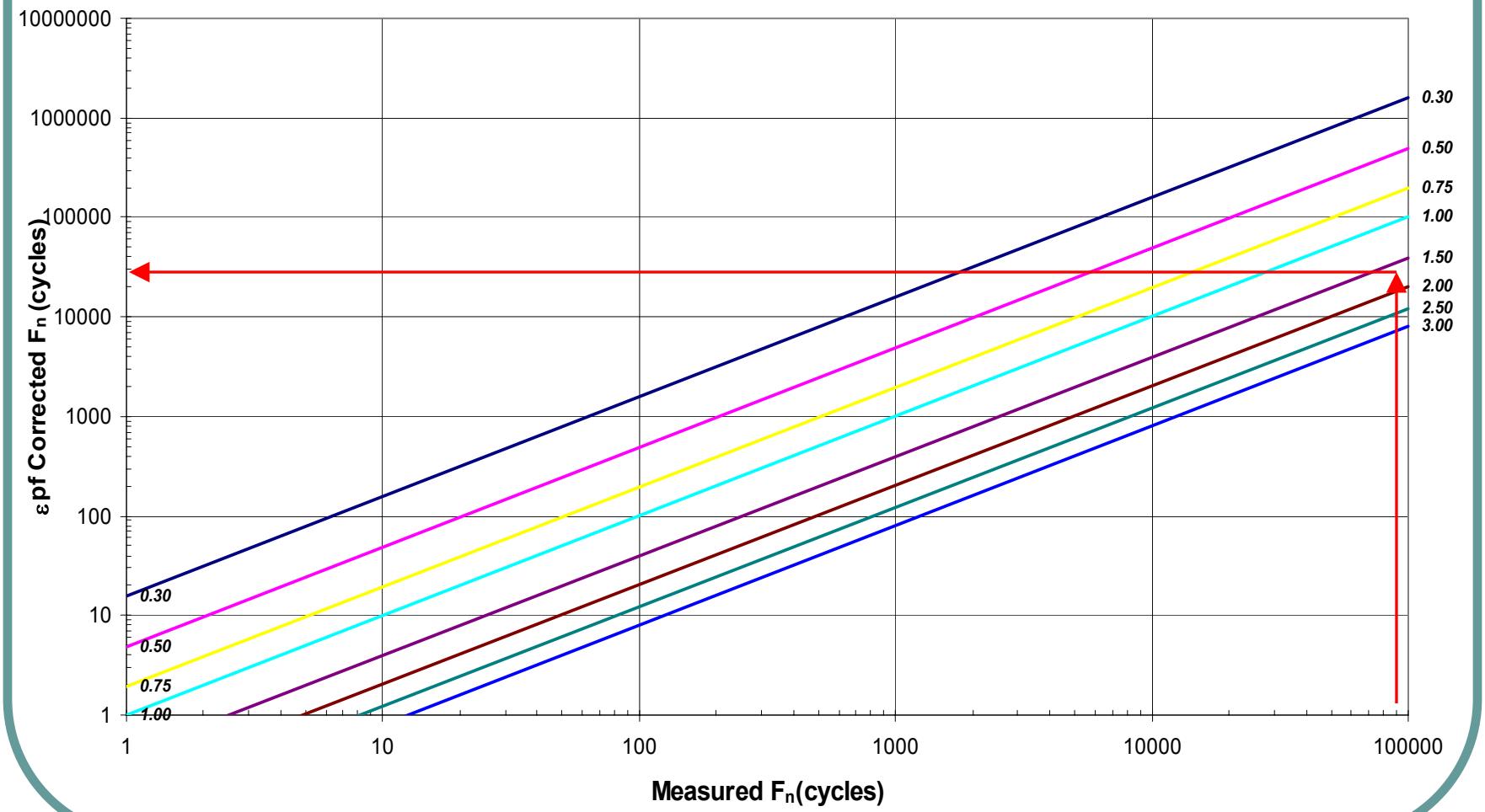
Suggested SPT Approach

- Complete F_n Test: record F_n and the level of ε_{pf}
- Correct The F_n to the effective pavement temperature.
- Correct the F_n to the reference stress.
- Correct the F_n by the level of ε_{pf} to the reference.
- Estimate the rut depth at 1E6 ESAL.
- Estimate the rut at any other traffic level.

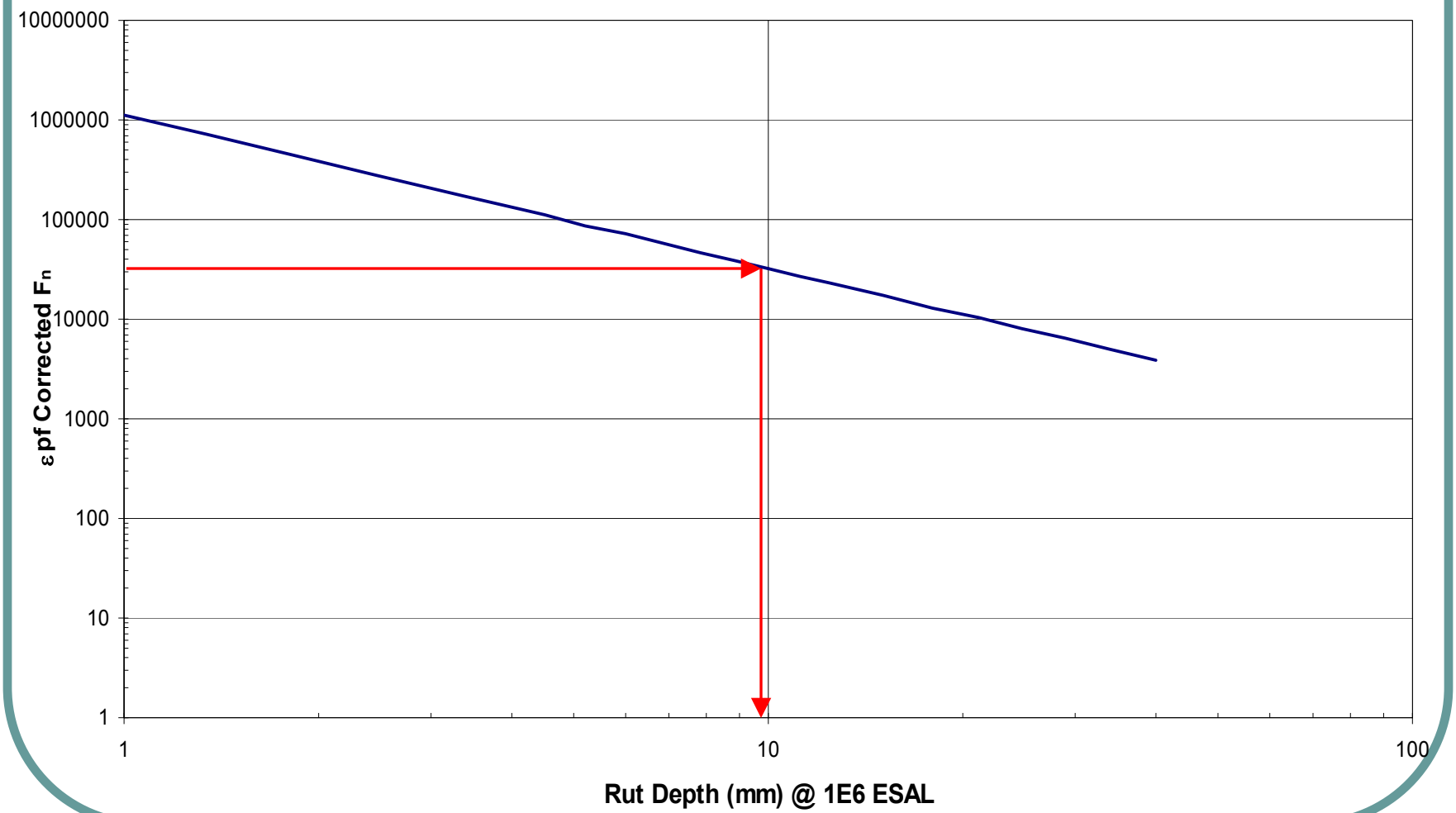
F_n Stress Shifting



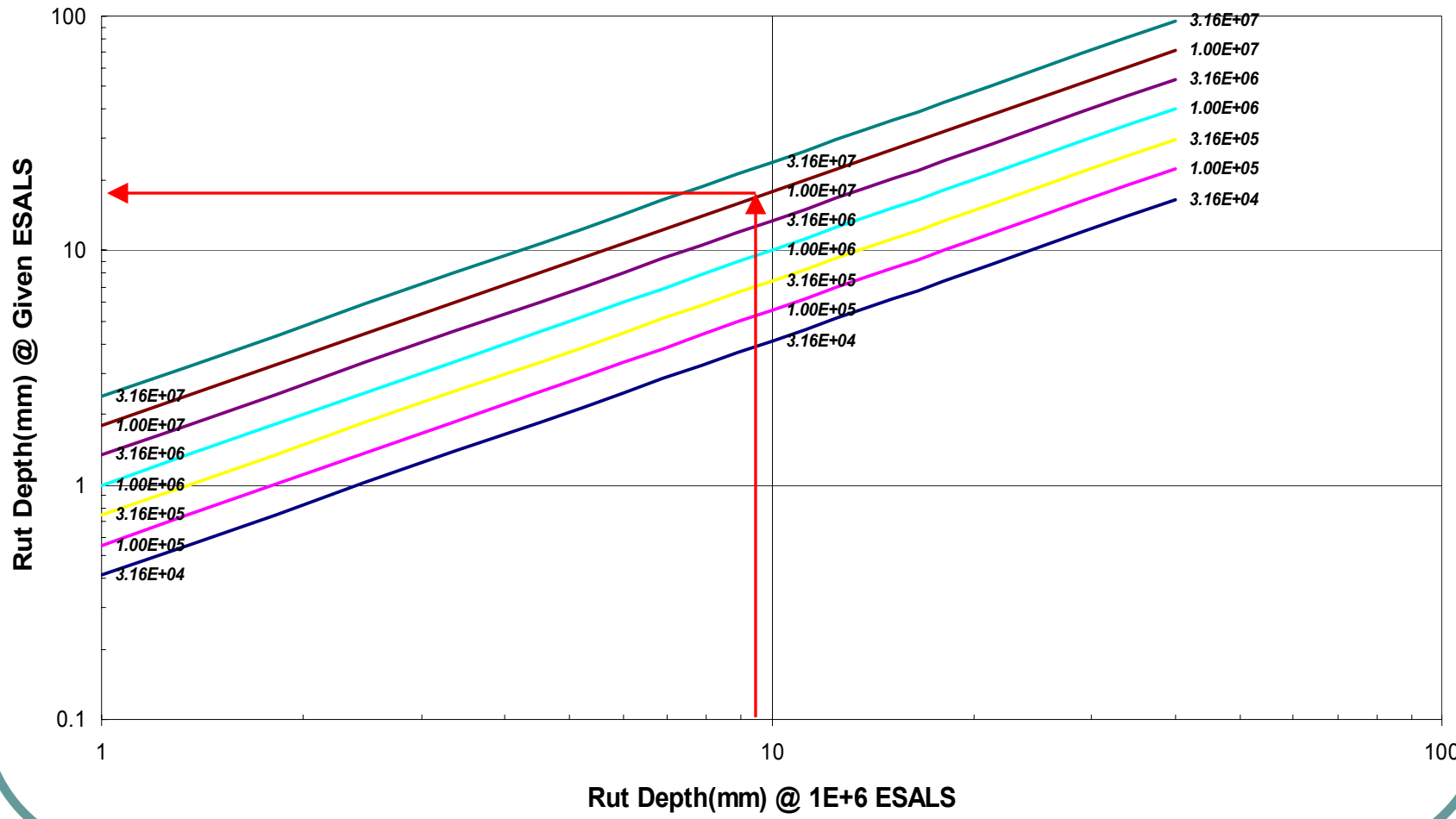
ε_{pf} Shift Curve



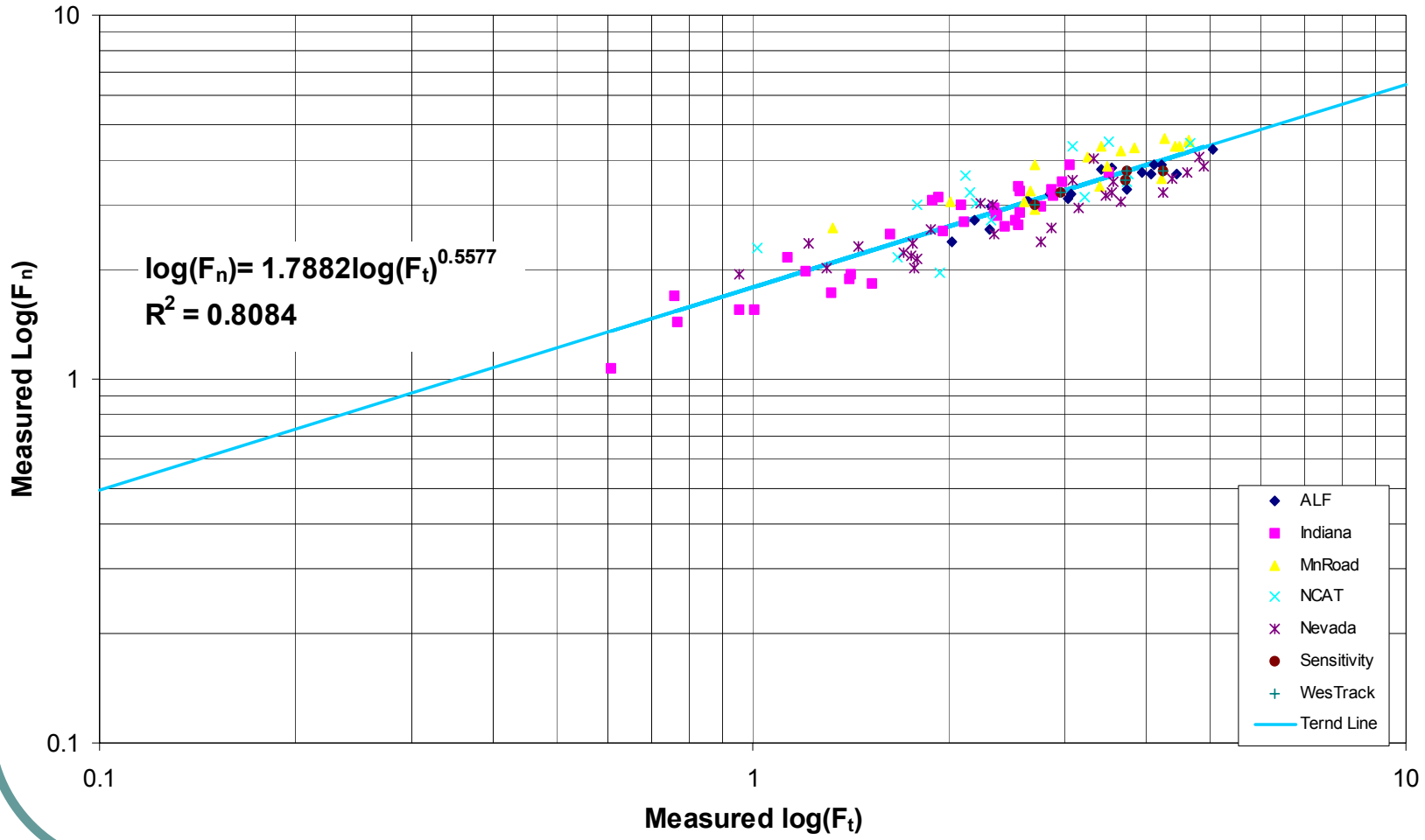
Standard Traffic Curve



Traffic Shifting Curve



Relationship Between F_n and F_t



Conceptual Criteria for |E*|

- Use the ratio of plastic to elastic strain equations
- Will be based on the national (U.S.) calibrated 2002 Design Guide

$$\frac{\varepsilon_p}{\varepsilon_r} = aN^b T^C$$

Conclusions

- F_n used in conjunction with ε_{pf} will give an accurate estimate of rutting potential
- Confined or Unconfined results, at present appear to give the same accuracy.
- F_t results may be able, to be linked to the F_n procedure.

Recommendations Further Studies

- Validation of traffic ε_{pf} shifting concept.
- Validation of stress shifting concept.
- Validation of temperature shifting concept.
- Abridged test procedure for F_t.
- Mechanistic based procedure.

What is Needed for Australia

- A database of the fundamental material properties for pavement design and performance potential prediction.
- Design method to incorporate asphalt mixture design and pavement design.
- Fundamental test method for asphalt mixture characterization to predict performance potential.

Thank You!

- Any Questions?