

NEW GENERATION AIRCRAFT

FLEXIBLE PAVEMENT DESIGN CHALLENGES

M. Thompson
U of IL @ Urbana-Champaign

NEW GENERATION AIRCRAFT

BOEING-777 (1995)

-Gross Load 632,000 lbs



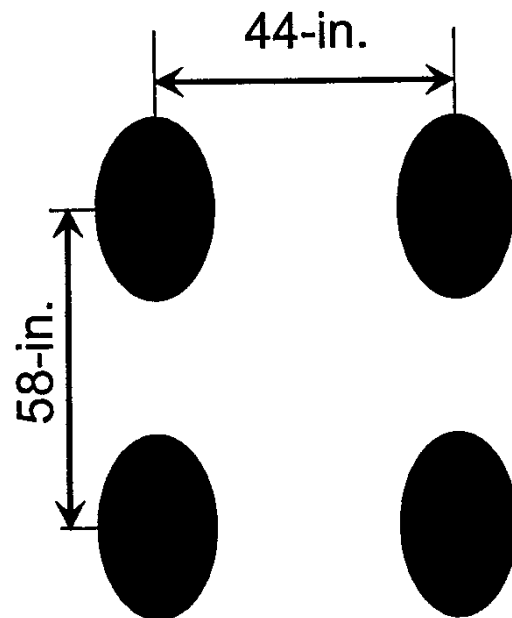
A380-800 (2006)

-Gross Load 1.23 million lbs

AIRCRAFT	WHEEL LOAD (KIPS)	PRESSURE (psi)
A-340	65.3	228
A-380*	62	197
B-747-400ER	53.4	225
B-767-400	55.8	215
B-777-300ER*	57.9	218
B-747-400	51.1	200

* DUAL-TRIDEM

Boeing 747-400 Main Gear

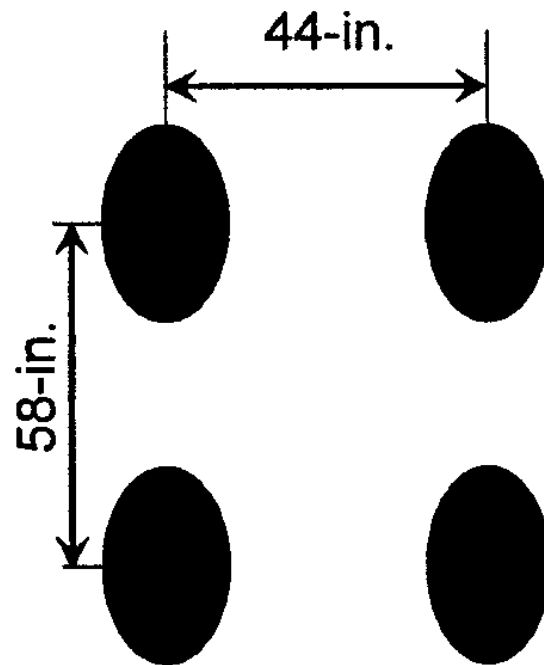


Wheel Load: 51,120-lbs

Contact Radius: 9.02-in

Contact Pressure: 200-psi

Boeing 747-400ER Main Gear

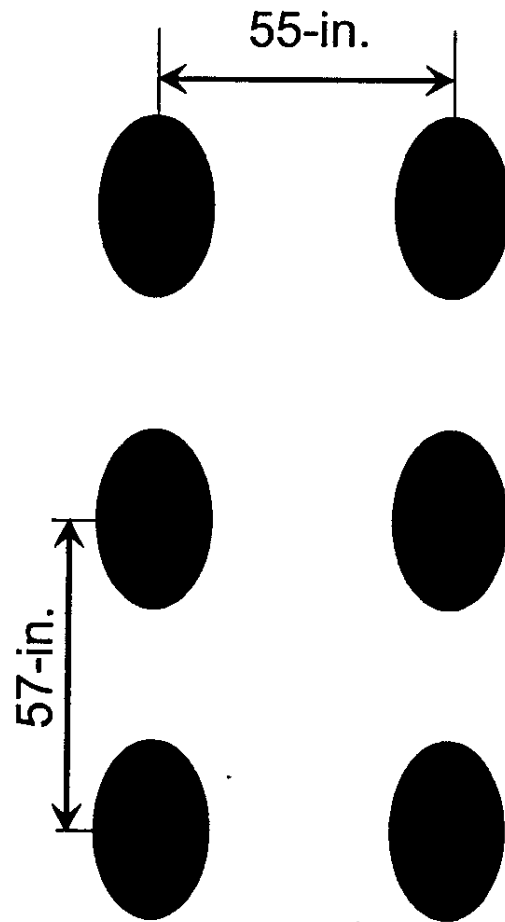


Wheel Load: 53,380-lbs

Contact Radius: 8.69-in

Contact Pressure: 225-psi

Boeing 777-300ER Main Gear

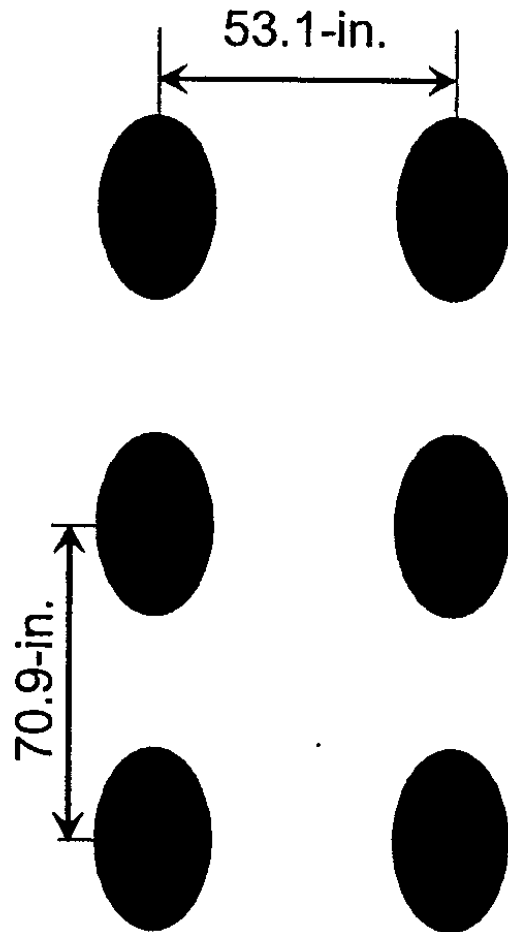


Wheel Load: 57,500-lbs

Contact Radius: 9.26-in

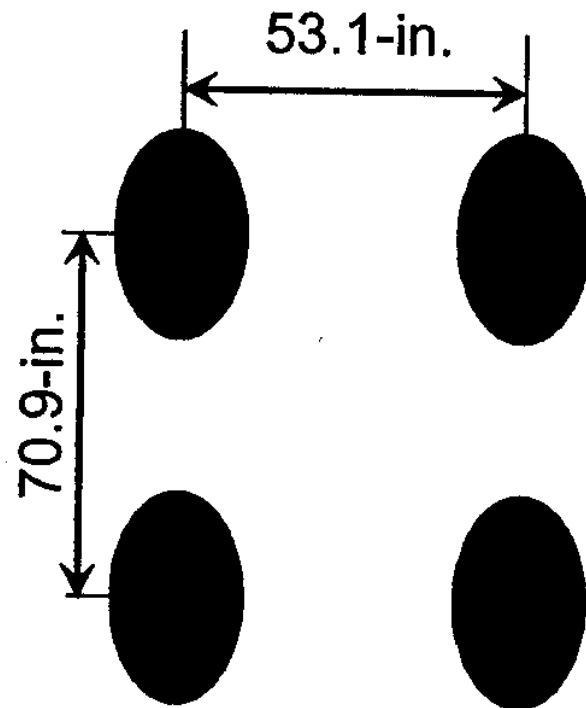
Contact Pressure: 218-psi

Airbus 380 Main Gear



***Wheel Load: 62,000-lbs
Contact Radius: 10.01-in
Contact Pressure: 197-psi***

Airbus 380 Wing Gear

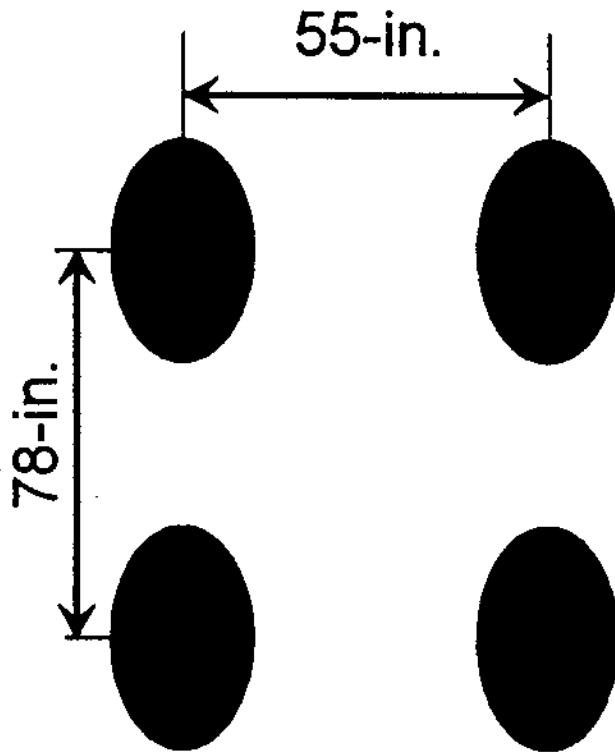


Wheel Load: 62,000-lbs

Contact Radius: 10.01-in

Contact Pressure: 197-psi

Airbus 340 Main Gear

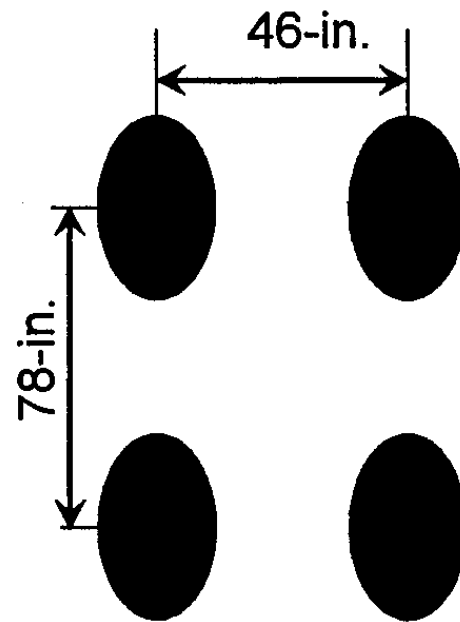


Wheel Load: 65,300-lbs

Contact Radius: 9.55-in

Contact Pressure: 228-psi

Airbus 340 Belly Gear

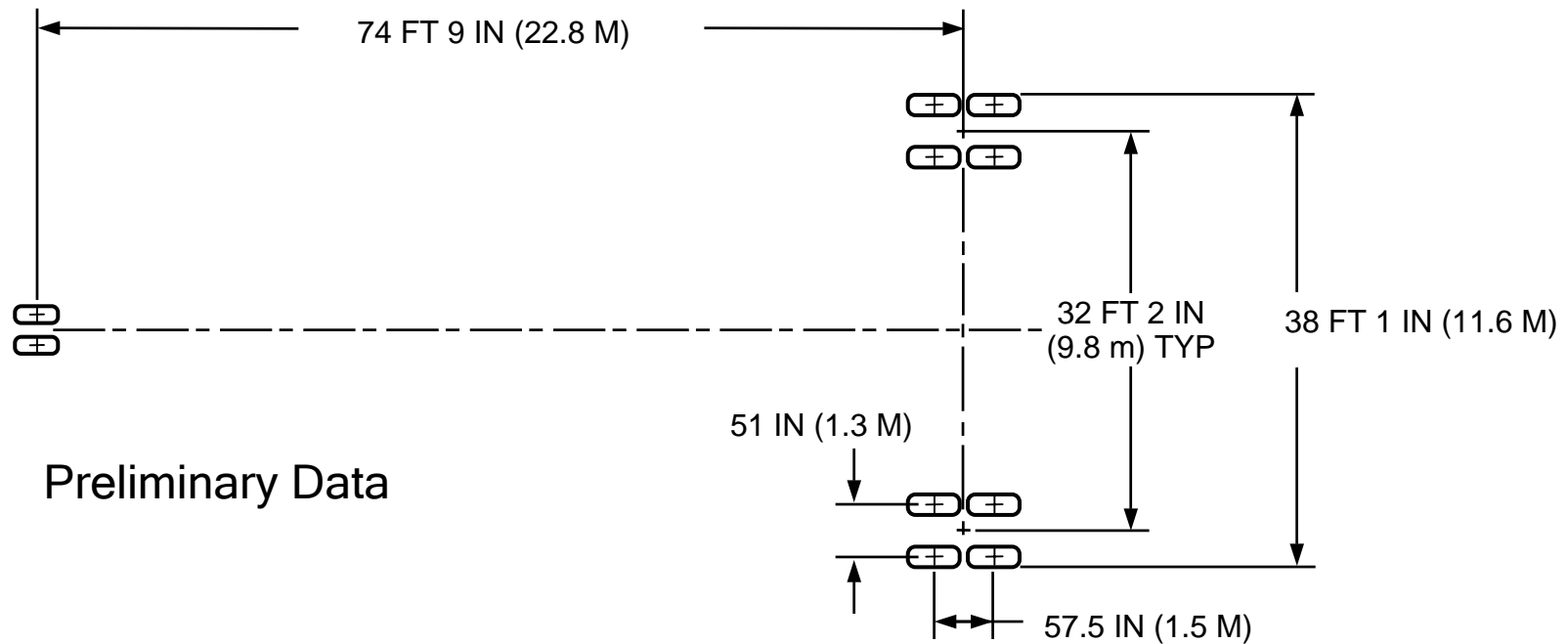


Wheel Load: 65,300-lbs

Contact Radius: 9.55-in

Contact Pressure: 228-psi

787-8 Landing Gear Footprint



MTOW: 482 kips

MAIN GEAR TIRE LOAD: 55.5 kips

MAIN GEAR TIRES: 221 psi

CBR-BASED DESIGN

(COE / FAA AC No. 150/5320-6D)

BASED ON ESWL

Is ESWL Adequate
for
Dual Tandem & Dual-Tridem ???

Mechanistic-Based
Pavement Design Concepts
for
NEW GENERATION AIRCRAFT

Mechanistic-Empirical Approach

- Combines the **practicality** of empirical methods with the **technical soundness** of mechanistic solutions.
- Uses **mechanistic analysis**, to determine the **pavement response** to imposed loads...then applies “**empirical**” formulations (i.e. “transfer functions”) to determine the **development of distress** due to the load-induced pavement response.

DESIRABLE M-E DESIGN

FEATURES

“Technically Sound”

“Understandable”

“Minimum Inputs”

“User Friendly”

M-E IMPLEMENTATION

CONCERNS

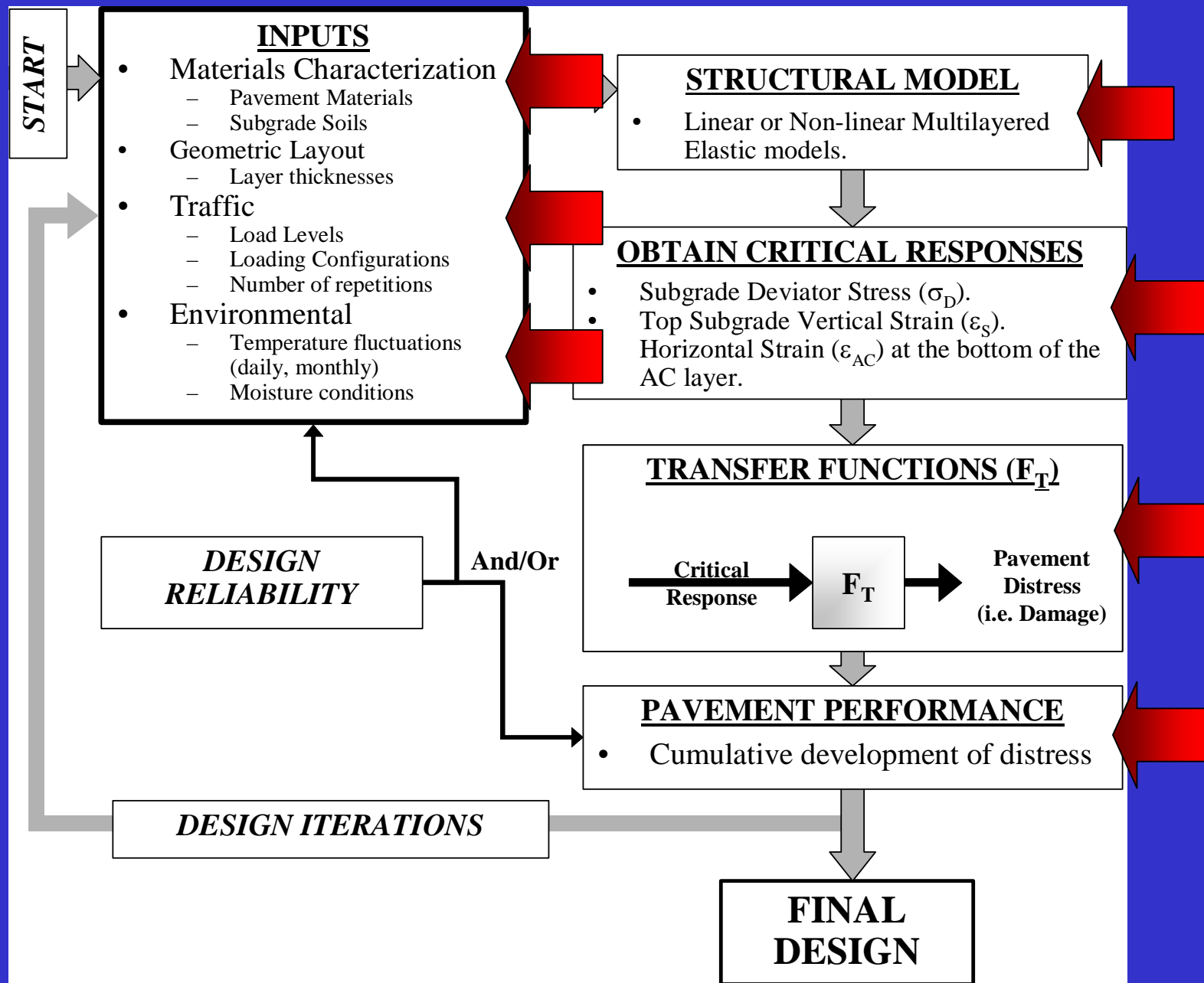
Airport Agency Resources

Input Data

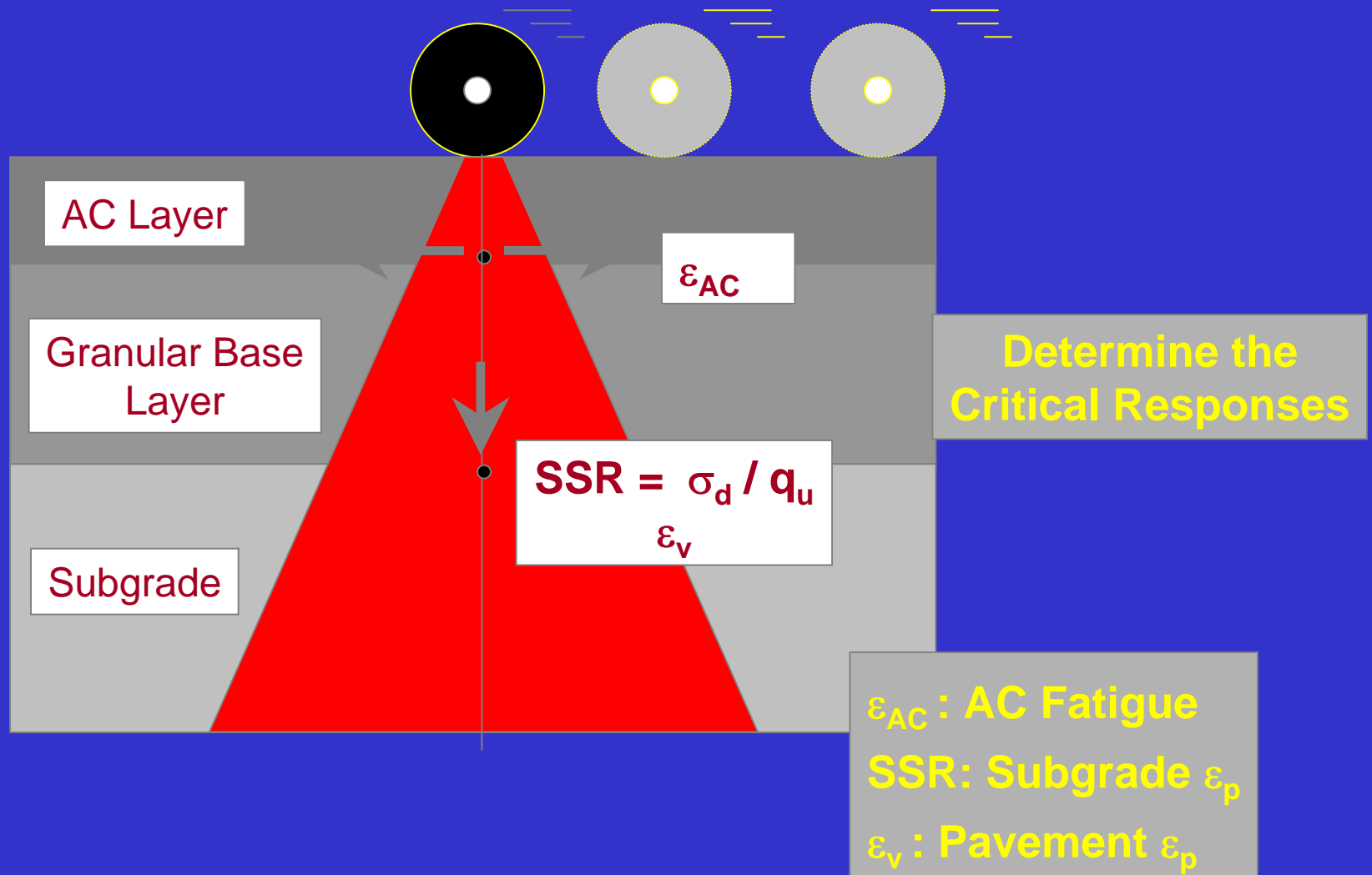
Transfer Functions

Calibration Data

Mechanistic-Empirical Approach



Mechanistic-Empirical Approach



STRUCTURAL RESPONSES

- * STRESSES

- * STRAINS

- * DEFLECTIONS

STRUCTURAL MODEL

STRUCTURAL MODEL

SHOULD ACCOMMODATE

“MATERIAL PROPERTIES”

Material Characterization

- Resilient Modulus
- Pavement Materials:
 - + **Asphalt Concrete**: Temperature, frequency.
 - + **Unbound Granular**: “Stress hardening”.
- Subgrade Soils:
 - + **Fine-grained soils**: “Stress softening”
 - + **Granular**: “Stress hardening”.

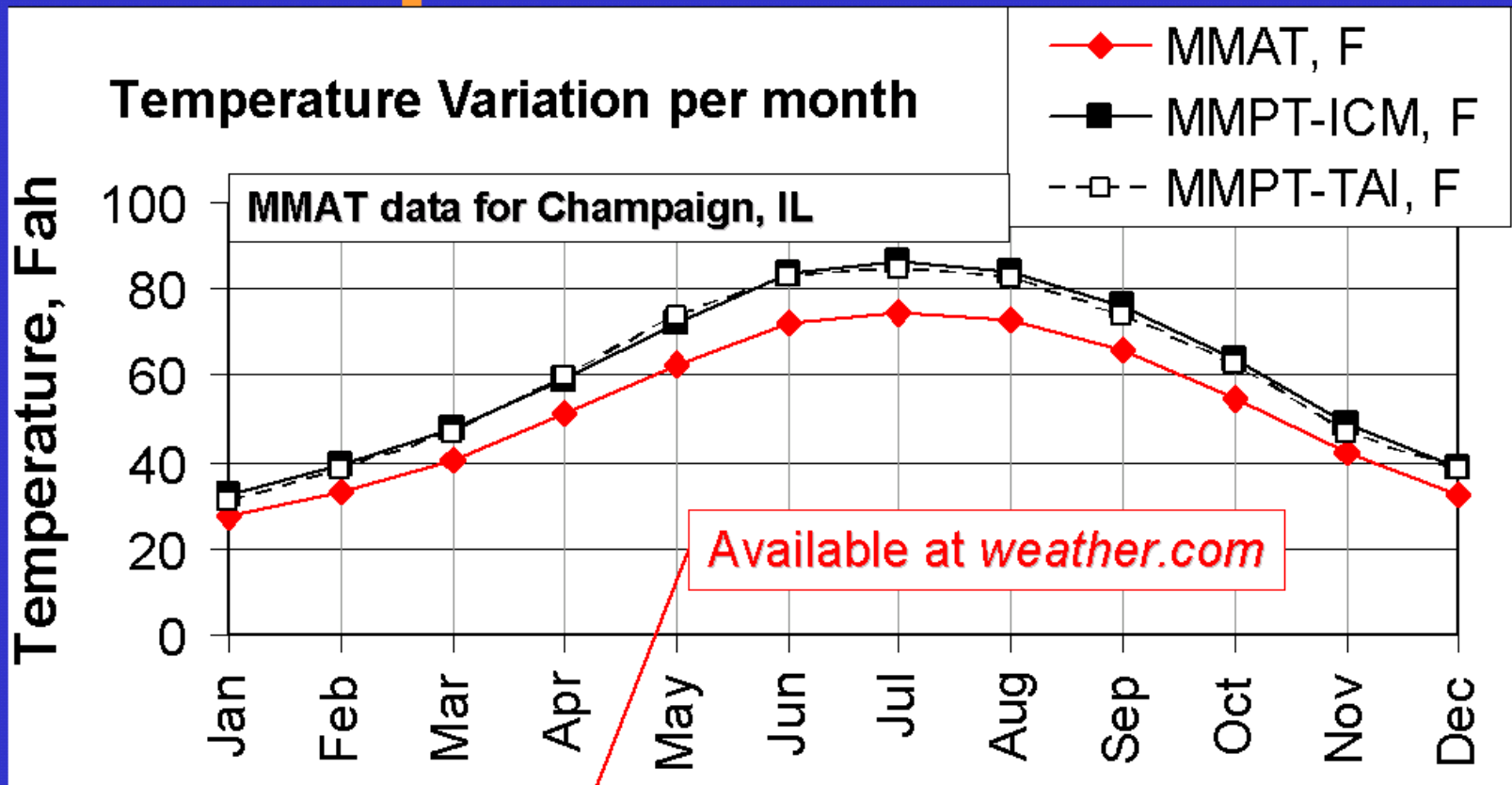
Material Characterization

Asphalt Concrete Modulus

- * Temperature Dependent**
- * Frequency Dependent**
- * Must consider in M-E Design!!!**

Inputs: Materials ...

Asphalt Concrete



Asphalt Institute Procedure

$$\text{MMPT} (^{\circ}\text{F}) = \text{MMAT} \left[1 + \frac{1}{Z+4} \right] - \left[\frac{34}{Z+4} \right] + 6$$

Z: inches from surface

MONTH	MMAT(F)	MMPT(F)/ E (ksi)
JAN	15	18/*
FEB	21	25/*
MARCH	28	33/*
APRIL	39	46/1,870
MAY	50	58/1,045
JUNE	57	66/710
JULY	62	72/530
AUG	60	69/615
SEPT	51	59/1,000
OCT	42	49/1,620
NOV	27	32/*
DEC	17	21/*

CALGARY
 Temperature Data
 MMPT @ 3-inch depth

For: $f=10\text{Hz}$

* $> 3,000$ ksi

“ICM”

**NCHRP 1-37A
ENHANCED INTEGRATED
CLIMATIC MODEL
(Dempsey & Larson)**

HIRSCH MODEL

**“Hirsch Model for Estimating the
Modulus of In-Place
Asphalt Mixtures”**

**Christensen - Pellinen - Bonaquist
AAPT Journal - 2003**

INPUTS

VMA - VFA - Asphalt “Modulus”

PREDICTIVE EQUATIONS: Modified Hirsch Model

$$|E^*| = P_c \left[4,200,000 \left(1 - \frac{VMA}{100} \right) + 3|G^*|_{binder} \left(\frac{VFA \cdot VMA}{10,000} \right) \right] + (1 - P_c) \left[\frac{1 - \frac{VMA}{100}}{4,200,000} + \frac{VMA}{VFA \cdot 3|G^*|_{binder}} \right]^{-1}$$

$|G^*|_{binder}$

dynamic modulus

VMA

vol. properties

VFA

$$P_c = \frac{\left(20 + \frac{VFA \cdot 3|G^*|_{binder}}{VMA} \right)^{0.58}}{650 + \left(\frac{VFA \cdot 3|G^*|_{binder}}{VMA} \right)^{0.58}}$$

HIRSCH MODEL

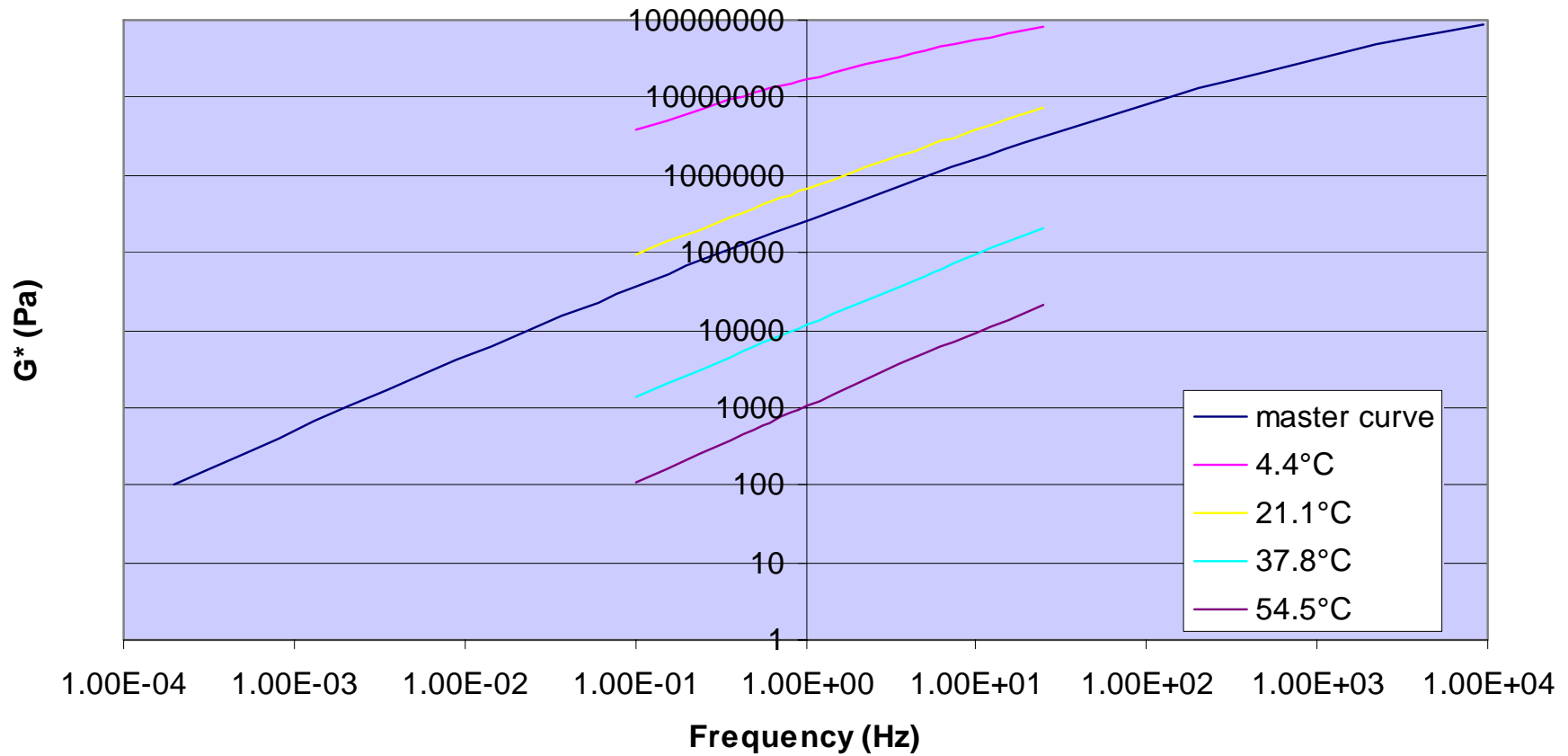
+ G^* INPUT (TEMP / FREQ)
(ASPHALT MASTER CURVE)

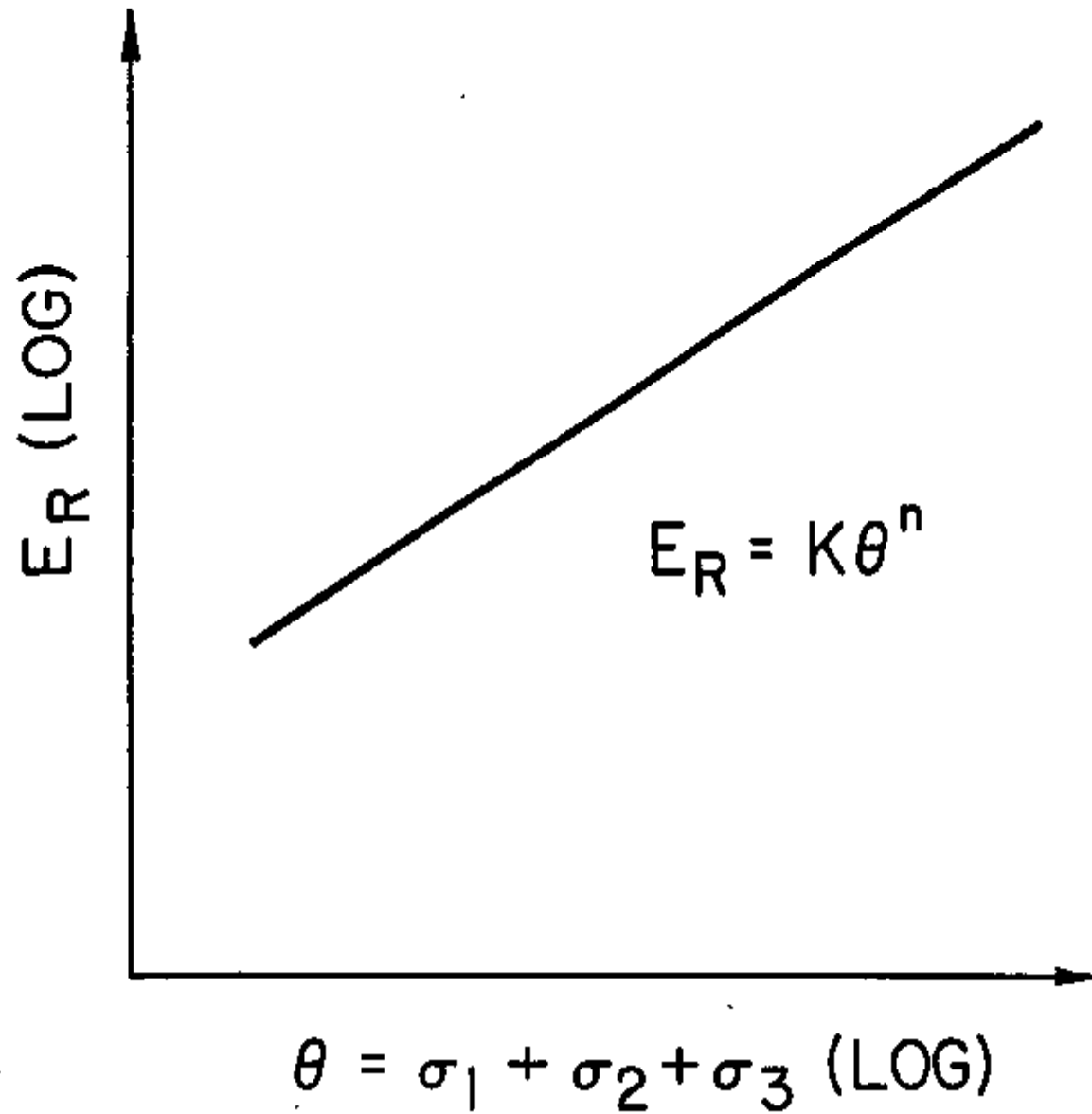
+ G^* COMPATIBLE WITH PG GRADE

+ VFA & VMA FROM MIX DESIGN

PG 58-28

G* master curve



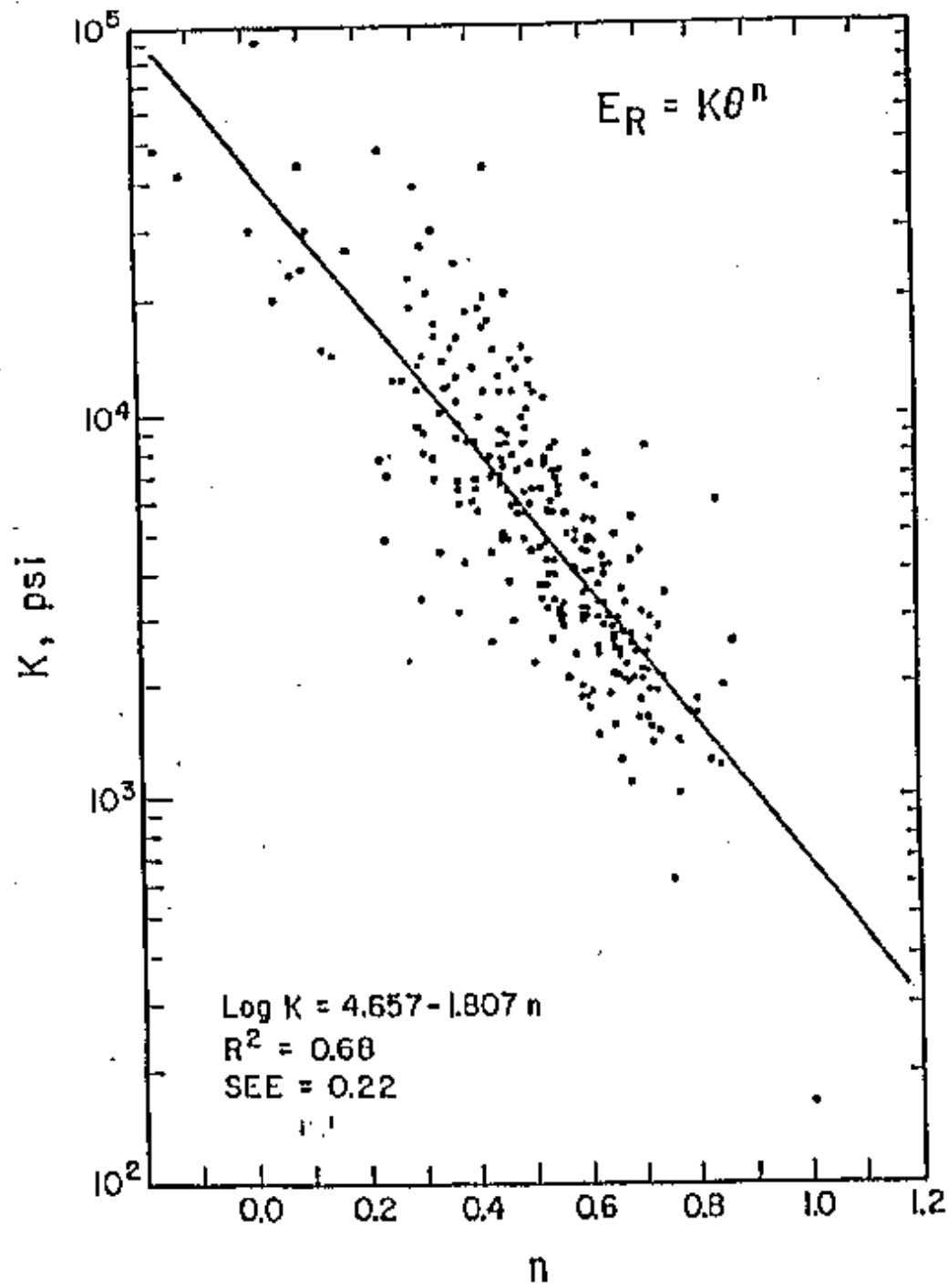


GRANULAR MATERIALS

$$E_R = K\theta^n$$

<u>AGGREGATE CLASS</u>	<u>K, PSI</u>	<u>n</u>
SILTY SANDS (8)	1620	0.62
SAND GRAVEL (37)	4480	0.53
SAND/AGG BLENDS (78)	4350	0.59
CRUSHED STONE (115)	7210	0.45

FROM RADA & WITCZAK



From
Rada & Witczak

UZAN MODEL (1985)

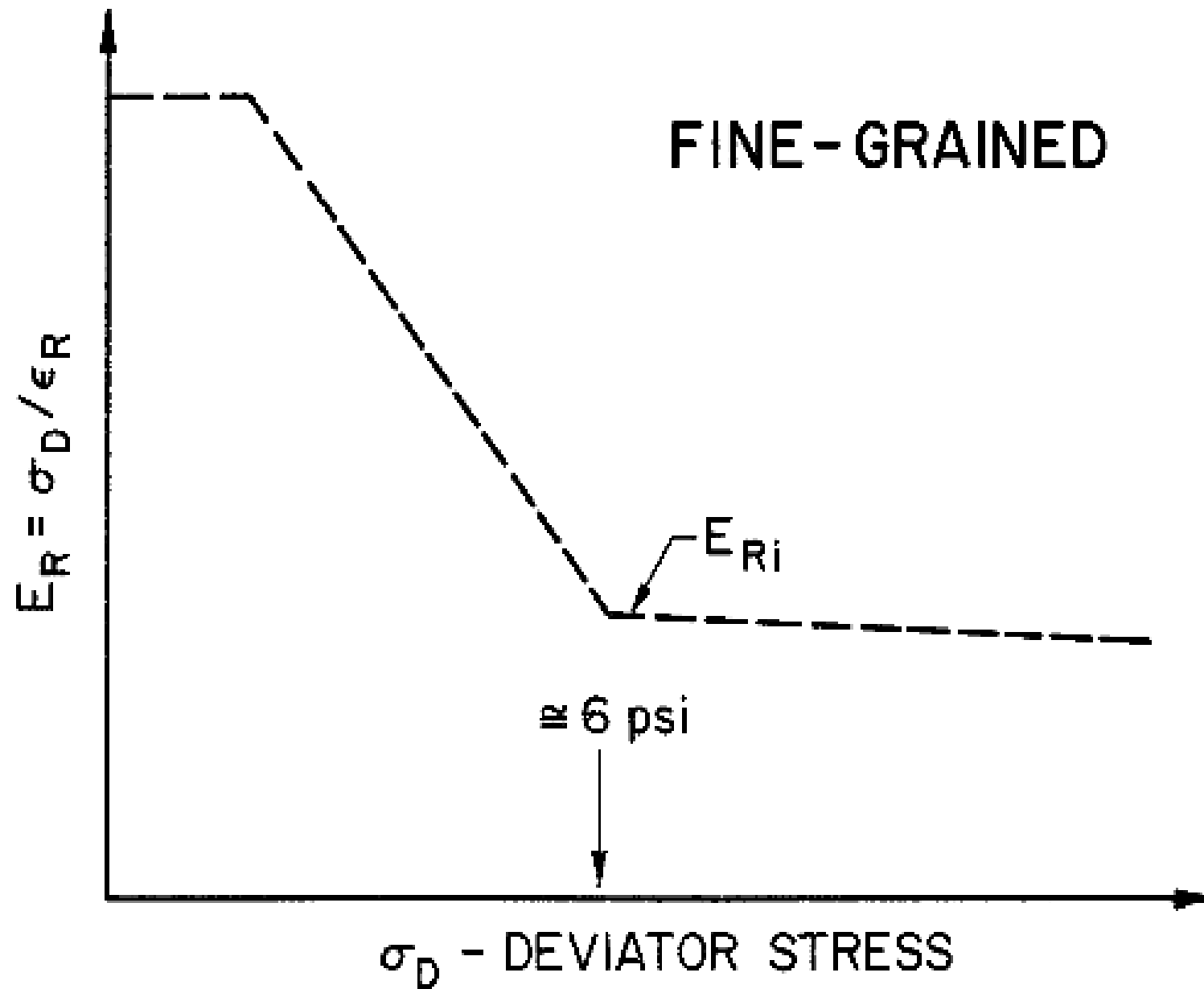
$$M_R = K_1 \Theta^{K2} (\sigma_d)^{K3}$$

Θ =BULK STRESS

$$\Theta = \sigma_1 + \sigma_2 + \sigma_3$$

$$M_R = K_1 \Theta^{K2} (\sigma_d)^{K3}$$

K1 & K2 MOST IMPORTANT !!



$$E_{Ri} \text{ (ksi)} = 0.307 Q_U \text{ (psi)} + 0.9$$

MODULUS CLASSES FINE-GRAINED SOILS

SOIL	E_{Ri} (ksi)	Qu (psi)	CBR
STIFF	12.3	33	8
MEDIUM	7.7	23	5
SOFT	3.0	13	2
VERY SOFT	1.0	6	1

$$E_{Ri} \text{ (ksi)} = 0.42 \text{ Qu (psi)} - 2$$

ESTIMATING E_{Ri}

$$E_{Ri} \text{ (OMC)} = 4.46 + 0.098 (\%C) + 0.119 (\text{PI})$$

E_{Ri} (ksi) @ 95% T-99
C - %Clay

Average E_{Ri} Values for Various Soil Classifications

Soil Classification	Average E_{Ri} , ksi
<u>AASHTO</u>	
A-7-6	9.2
A-7-5	6.3
A-6	5.6
A-4	3.8
A-5*	4.5
 <u>USDA Textural Class</u>	
Silty Clay, Clay	9.5
Silty Clay Loam, Clay Loam	7.3
Silt Loam, Loam, Silt	6.2
Sandy Clay*	9.0
Sandy Clay Loam*	7.0
 *Estimated	
Note: (95 percent of AASHTO T-99 maximum dry density and moisture contents 2 percent wet of optimum)	

E – CBR RELATIONS

COE/FAA: $E \text{ (psi)} = 1,500 \text{ CBR}$

TRL/UK : $E \text{ (psi)} = 2,555 \text{ CBR}^{0.64}$
(CBR: 2 -12)
(TRL Report # 1132)

Deviator Stress = ????

STRUCTURAL MODELS

- ELASTIC LAYER PROGRAMS
- FINITE ELEMENT PROGRAMS (2-D / 3-D)

ELASTIC LAYER PROGRAMS

+ LINEAR ELASTIC MATERIALS

+ MODULUS CONSTANT WITHIN THE LAYER

+ NO FAILURE CRITERION

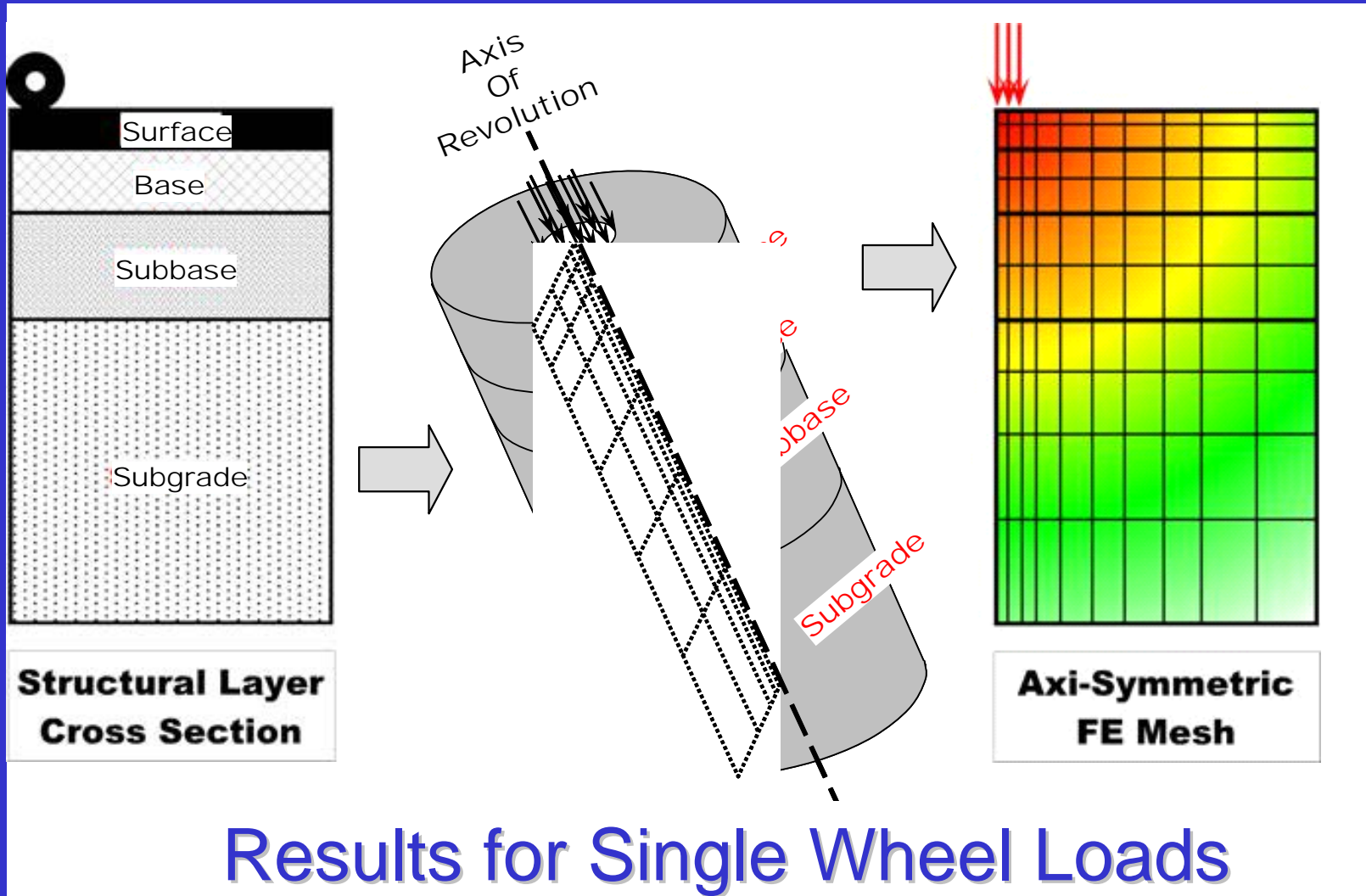
Structural Models

- Elastic Layered Programs (ELP)
 - All materials **linear elastic**, homogenous, isotropic (newer versions are improved).
- 2D “Axi-symmetric” Non-linear Finite Element:
 - Can incorporate a wide range of material models, more specifically “**Stress dependent**” models.
 - Results for **Single Wheel** Loads (in theory)
- 3D Non-Linear Finite Element:
 - Same as 2D but can apply **Multiple Wheel** Loads.

Structural Models: ILLIPAVE

- Analysis for **Single Wheel Load (SWL)**...Uses **superposition** to extend results to **MWL**.
- “**Stress dependent**” material **models** for Coarse and Fine Grained soils.
- **Mohr-Coulomb** Failure criteria.
- 32-bit application, **run-time ~5-30 sec** for typical pavement geometry.
- **Up to 7000 elements** can be used.
- User-friendly **GUI input** software for Windows.

ILLI-PAVE: 2D FEM



Structural Models: 2D FE

- 3D Non-linear FEMs are very inefficient even with computing power today...
- Consider the possibility of using 2D Non-linear FEMs with superposition to extend the single wheel results to multiple wheel.
- Must validate the Principle of Superposition for “Engineering” purposes.

ILLIPAVE MODEL

- * **“Stress dependent” material models for Granular Materials and Fine Grained soils.**
- * **Mohr-Coulomb Failure Criteria.**
- * **Analysis for Single Wheel Load (SWL)**
- * **SUPERPOSITION to extend results to MWL.**

MULTIPLE WHEEL SOLUTION

Chou & Ledbetter (1973)

MWHGL TESTS @ WES

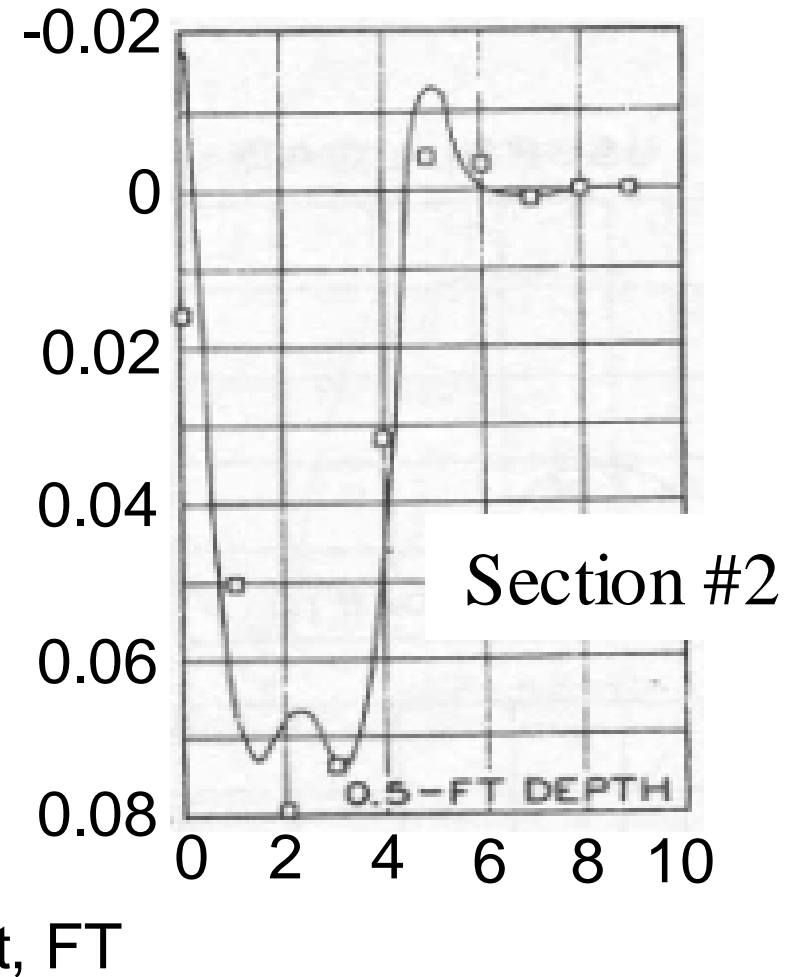
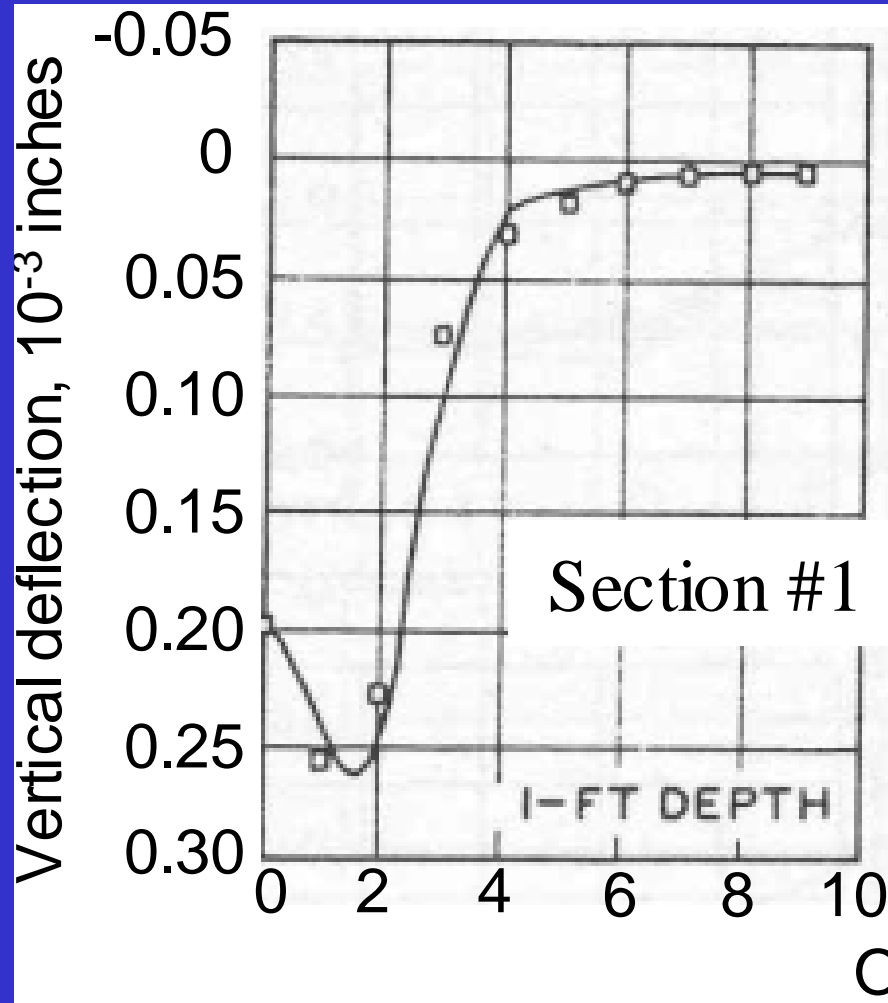
SUPERPOSITION WORKS

for

FLEXIBLE PAVEMENTS !!

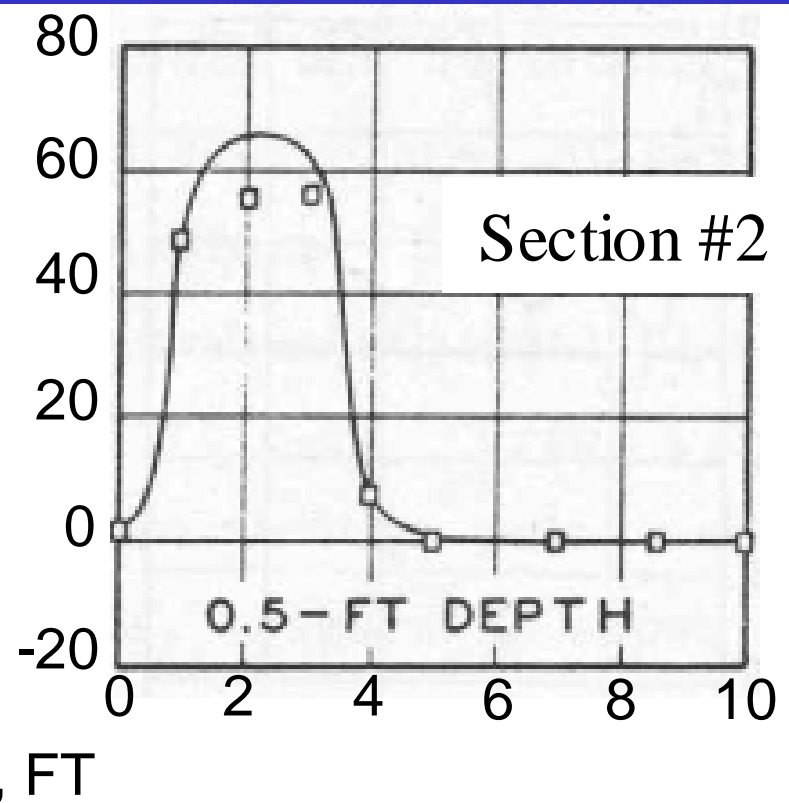
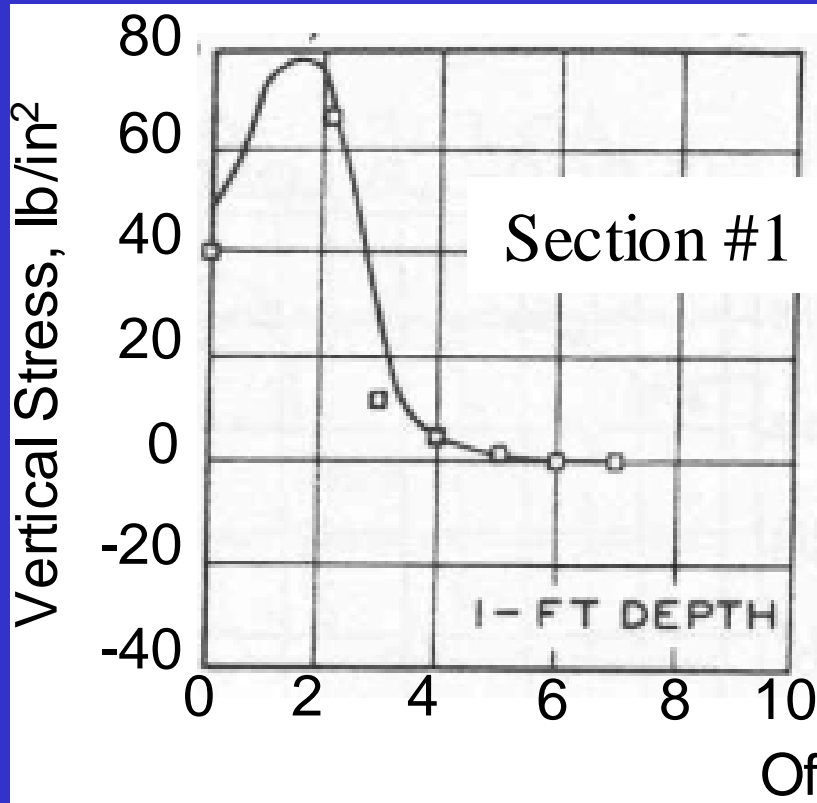
SUPERPOSITION Studies

USCOE Study 1973 (Examples...)



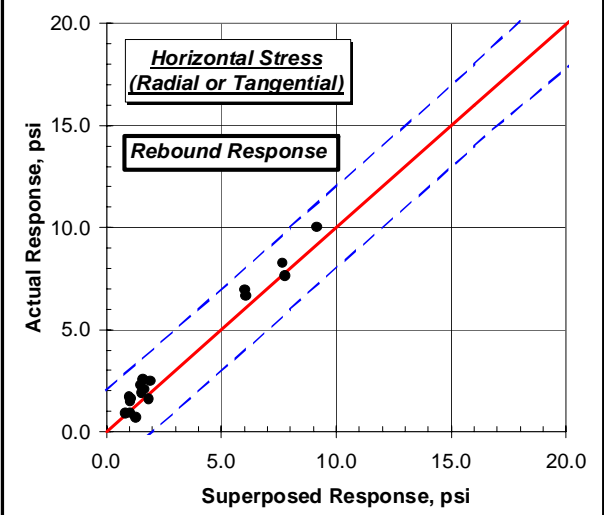
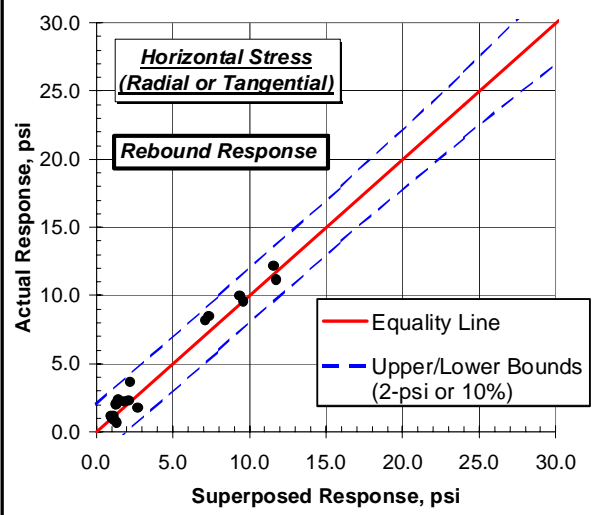
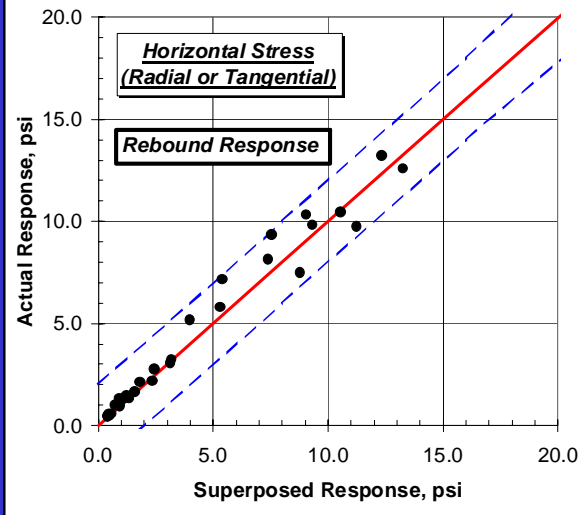
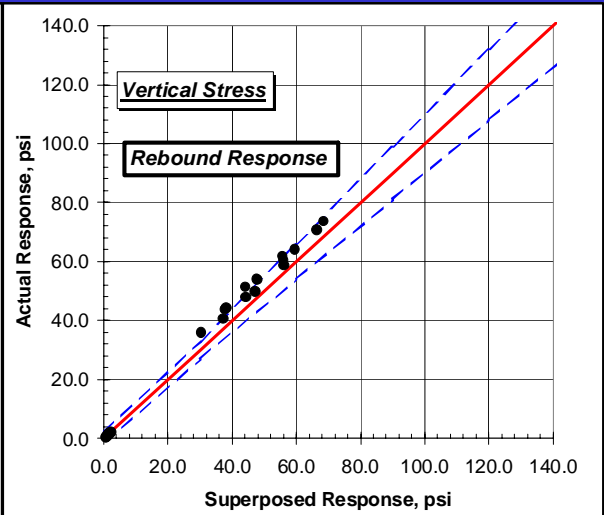
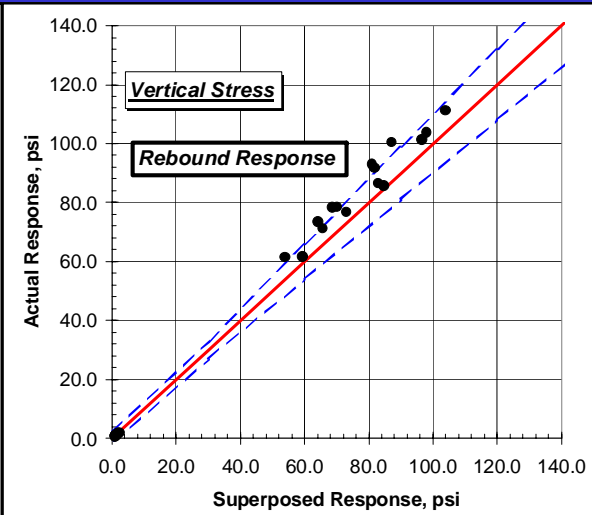
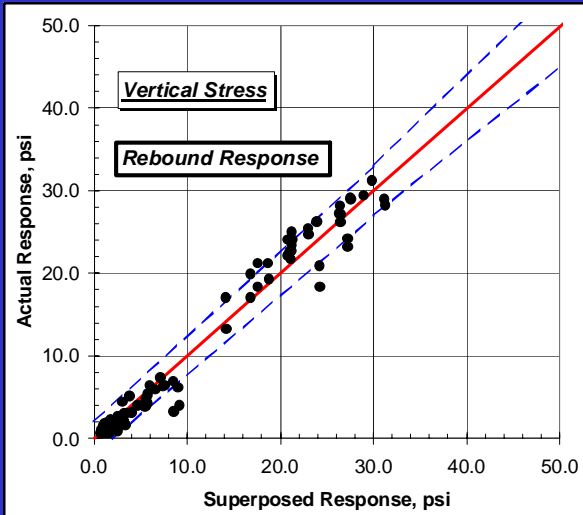
SUPERPOSITION Studies

USCOE Study 1973 (Examples...)



FAA NAPTF Study 2001 – Uof IL

FAA Airport Technology Transfer Conference - 2002



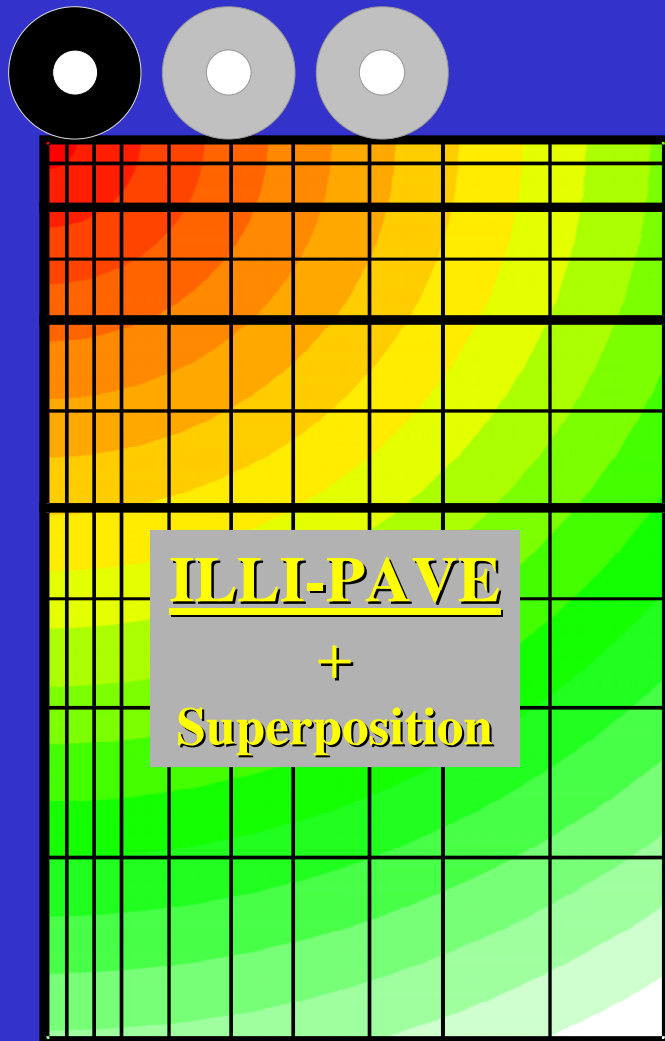
MFC Section

HFS Section

HFC Section

SOLUTION FOR MULTIPLE WHEELS

ILLI-PAVE + Superposition



$$\sigma_{xx} = (\sigma_{rr} \cdot \cos^2 \alpha) + (\sigma_{tt} \cdot \sin^2 \alpha)$$

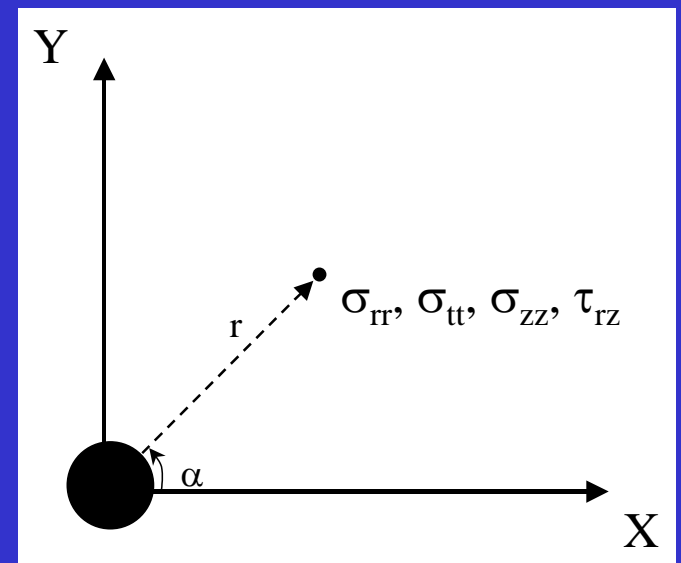
$$\sigma_{yy} = (\sigma_{rr} \cdot \sin^2 \alpha) + (\sigma_{tt} \cdot \cos^2 \alpha)$$

$$\sigma_{zz} = \sigma_{zz}$$

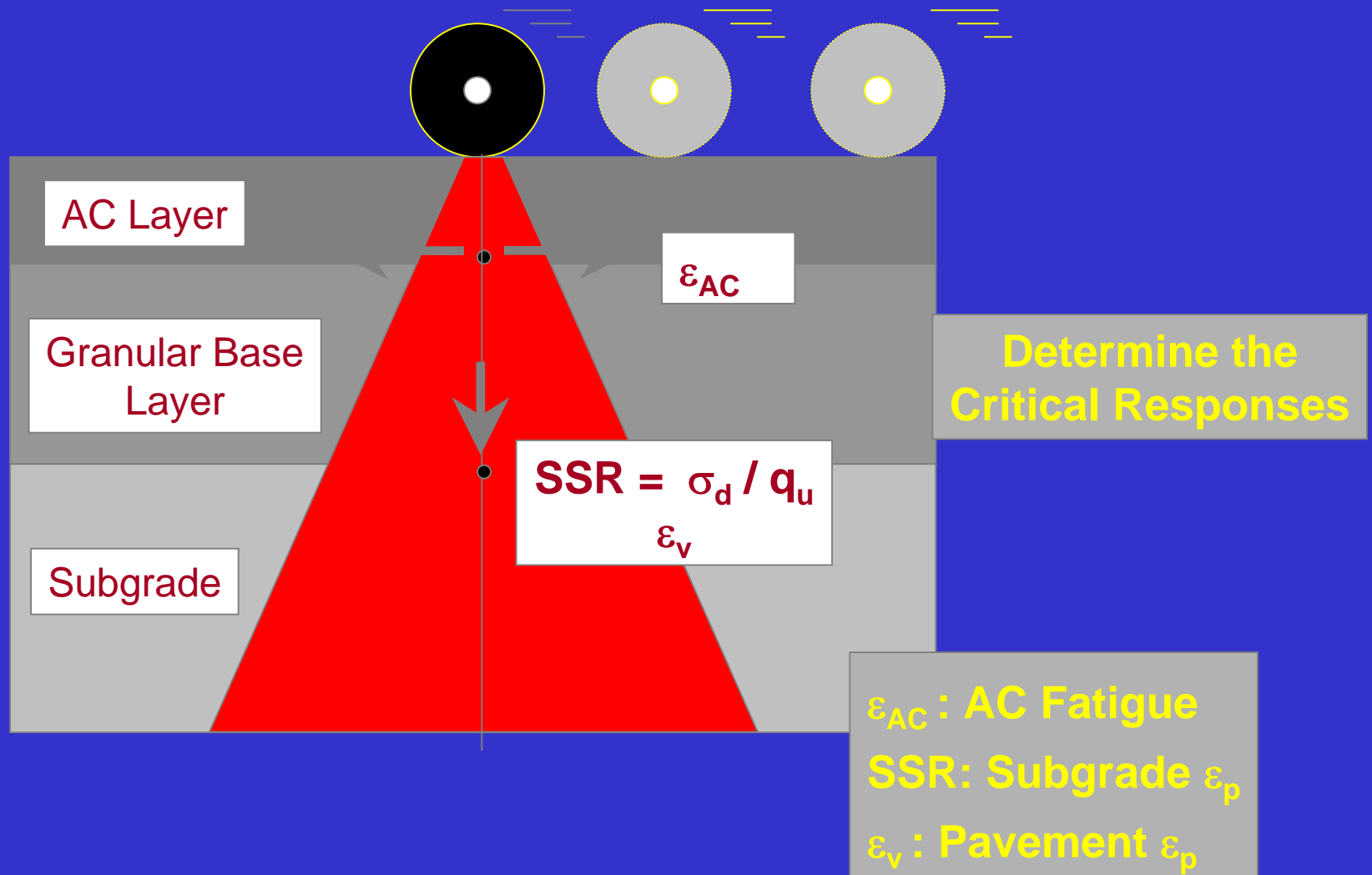
$$\tau_{xy} = (\sigma_{rr} - \sigma_{tt}) \cdot \sin \alpha \cdot \cos \alpha$$

$$\tau_{yz} = \tau_{rz} \cdot \sin \alpha$$

$$\tau_{xz} = \tau_{rz} \cdot \cos \alpha$$



Mechanistic-Empirical Approach



CONCEPTS FOR DEVELOPING
A M-E BASED ACN PROCEDURE
FOR NEW GENERATION AIRCRAFT

2006 ISAP

Quebec City, Canada

Thompson & Gomez-Ramirez

(U of IL)

Gervais & Roginski

(Boeing)

AIRCRAFT	WHEEL LOAD (KIPS)	PRESSURE (psi)
A-340	65.3	228
A-380*	62	197
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B-767-400	55.8	215
B-777-300ER*	57.9	218
B-747-400 (REF)	51.1	200

* DUAL-TRIDEM

ICAO Subgrade	"Representative" CBR	Q_U (psi)	E_{Ri} (ksi)
A	15	68	21
B	10	45	15
C	6	27	9
D	3	14	5

ICAO SUBGRADES

$$C = Q_U/2$$

$$\text{PHI} = 0^\circ$$

GRANULAR LAYERS

$$T_{\text{GRAN}} = \text{BASE} + \text{SUBBASE}$$

$$M_R \text{ (psi)} = 5,000 (\text{THETA})^{0.5}$$

$$C = 0$$

$$\text{PHI} = 45^\circ$$

ICAO SUBGRADE	AC (INCHES)	GRANULAR (INCHES)
D (CBR-3)	5	50-100
D (CBR-3)	7.5 & 10	40-100
C (CBR-6)	5	30-70
C (CBR-6)	5	20-70
B (CBR-10)	5	20-60
B (CBR-10)	7.5 -10	15-60
A (CBR-15)	5	15-50
A (CBR-15)	7.5 - 10	10 -50

PAVEMENT PARAMETERS

SINGLE WHEEL RESPONSES

- * Surface Def. (0-72 ins)
 - * AC Surface Strain
 - * AC Base Strain
- * GB Dev. Stress (top/middle)
 - * Subgrade Dev. Stress
(Top / 1&2 Radii)
- * Subgrade Vertical Strain
(Top / 1&2 Radii)

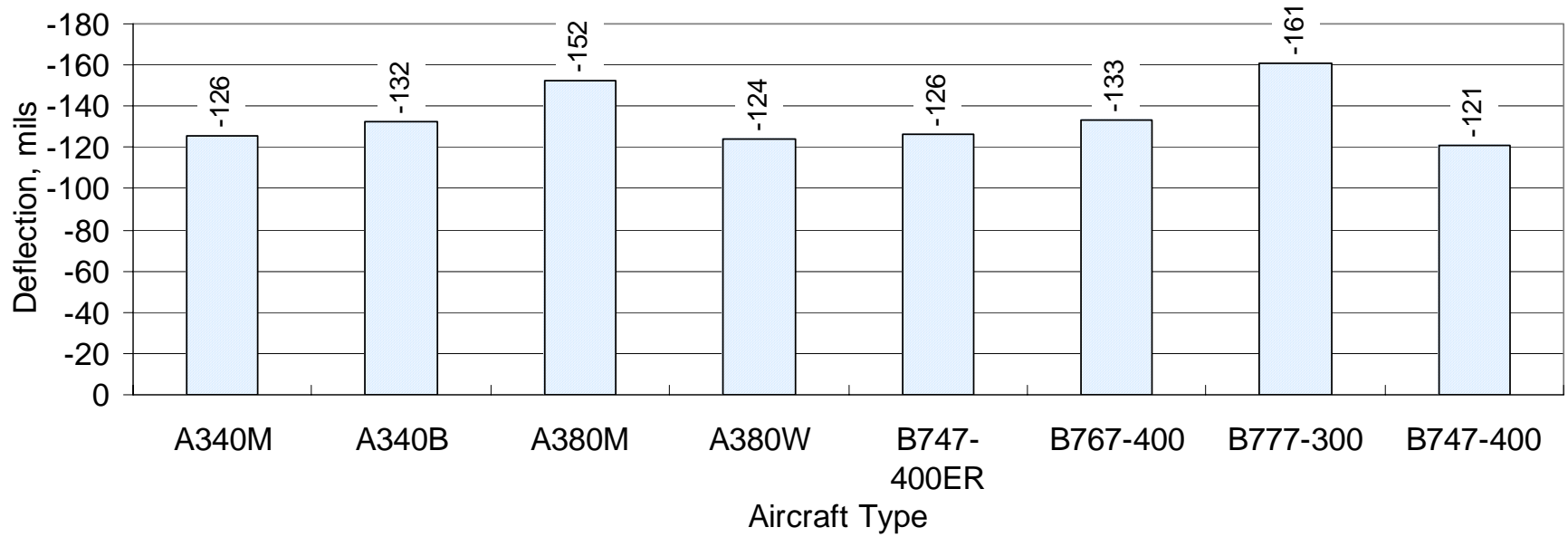
MULTIPLE WHEEL RESPONSES

(GRID: 1/4 Dual & 1/4 Axle)

- * Max. Surface Def.
- * Max. AC Surface Strain
- * Max. AC Base Strain
- * Max. GB Dev. Stress (top/middle)
 - * Max. Subgrade Dev. Stress
(Top / 1&2 Radii)
- * Max. Subgrade Vertical Strain
(Top / 1&2 Radii)

ILLIPAVE Analysis Results

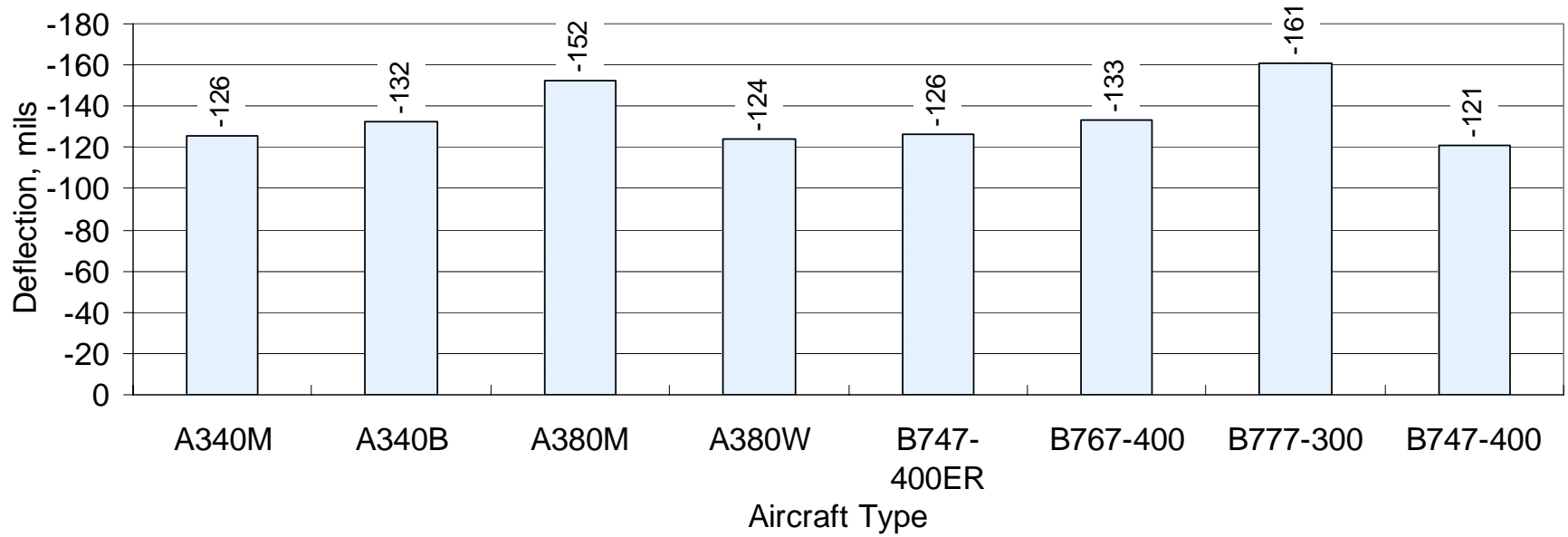
AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi



□ MLG--Surface DMax

ILLIPAVE Analysis Results

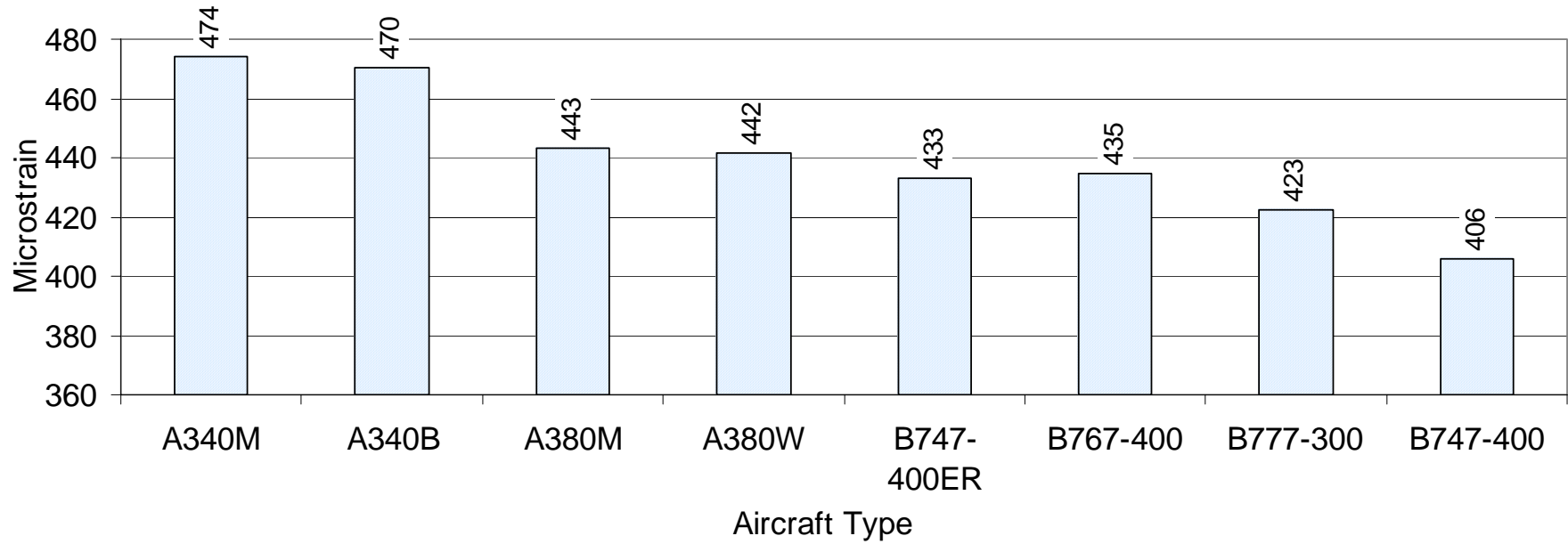
AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi



□ MLG--Surface DMax

ILLIPAVE Analysis Results

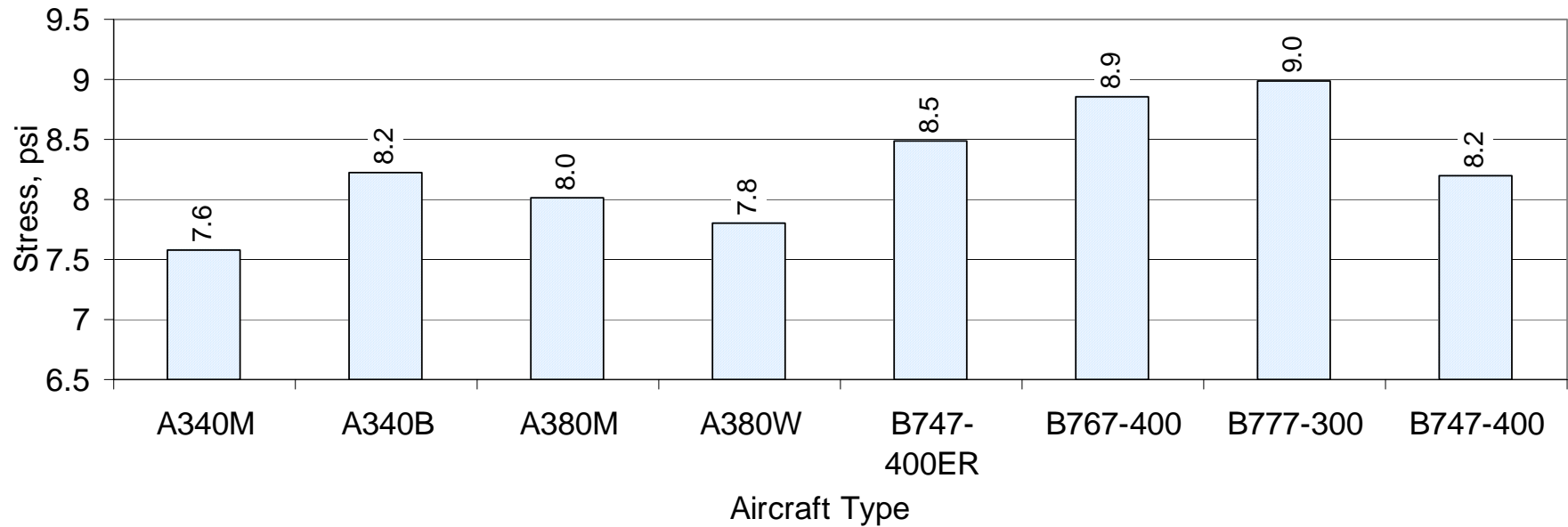
AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi



MLG--Max AC Surface Strain

ILLIPAVE Analysis Results

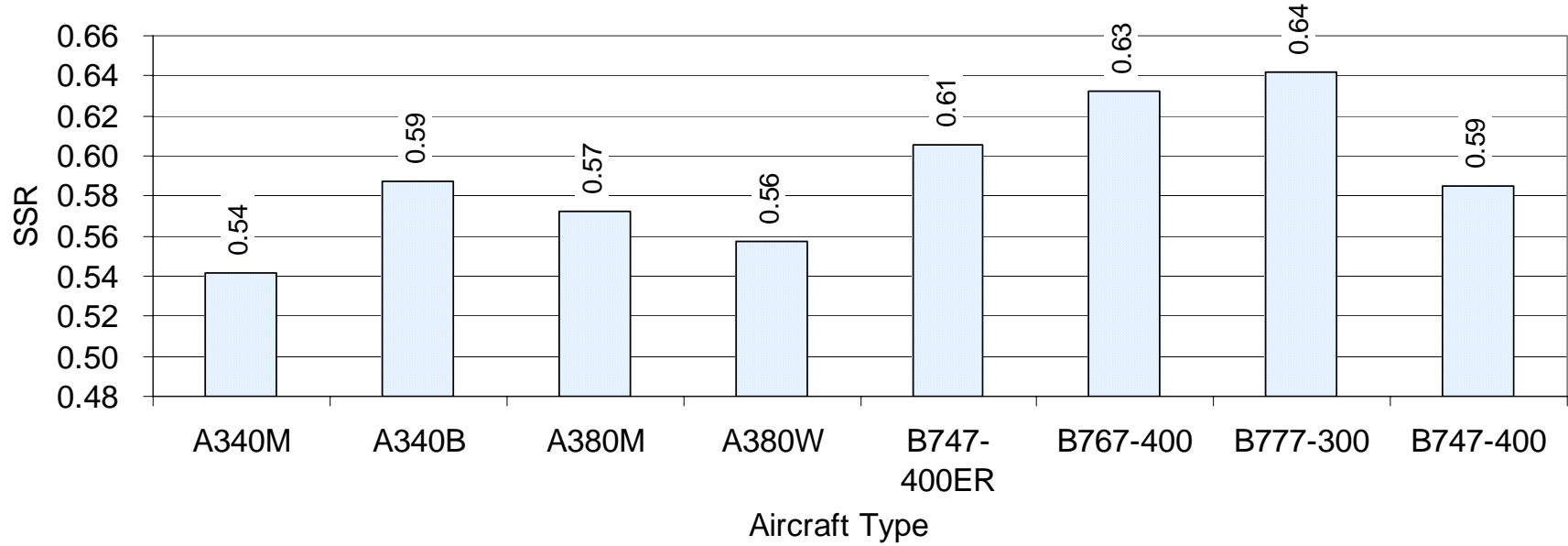
AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi



MLG--Deviator Stress @ Top of Subgrade Layer

ILLIPAVE Analysis Results

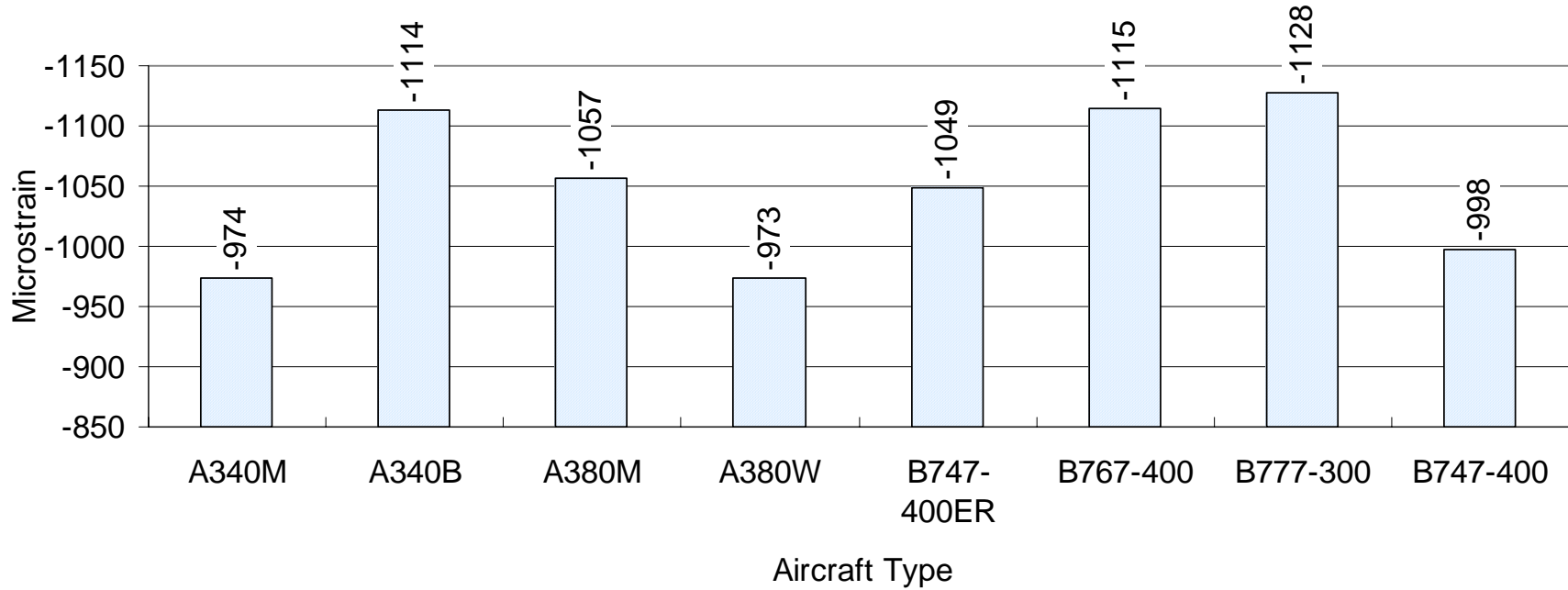
AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi



MLG--Subgrade Stress Ratio (SSR)

ILLIPAVE Analysis Results

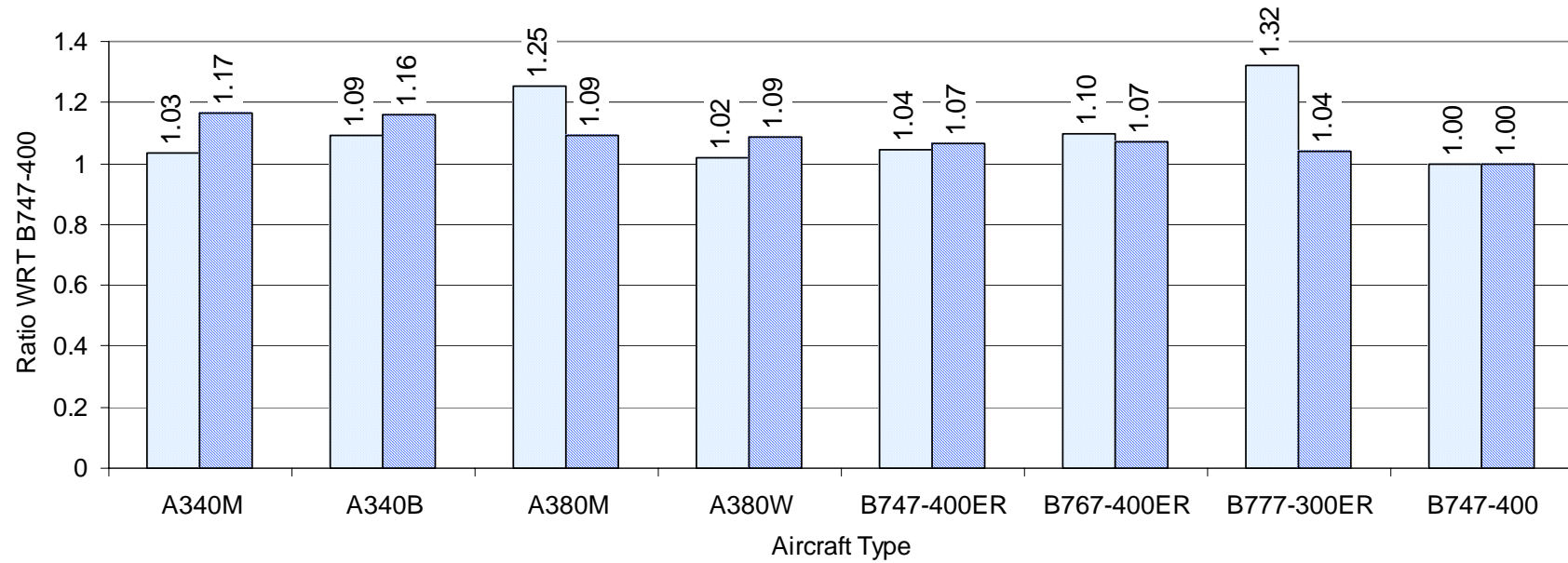
AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi



□ MLG--Vertical Strain @ Top of Subgrade Layer

ILLIPAVE Analysis Results

AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi

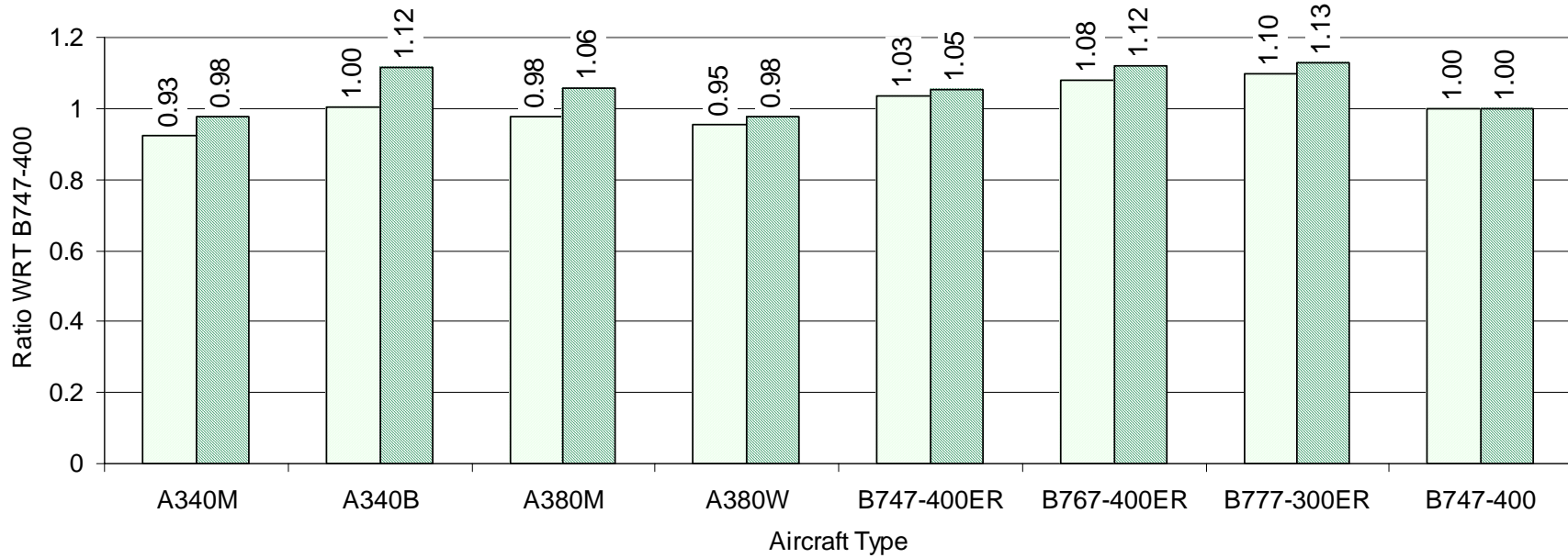


MLG--Surface DMax

MLG--Max AC Surface Strain

ILLIPAVE Analysis Results

AC Surface Thickness: 10-in -- Modulus: 500-ksi
GB Thickness: 40-in -- SG Eri: 5-ksi



- MLG--Deviator Stress @ Top of Subgrade Layer
- ▨ MLG--Vertical Strain @ Top of Subgrade Layer

TRANSFER FUNCTIONS
(RESPONSES – DISTRESS)

CRITICAL FACTORS!!!

FLEXIBLE PAVEMENT DISTRESSES

- **HMA FATIGUE**
- **RUTTING:**
 - + **HMA (MATL. SELECTION / MIX DESIGN)**
 - + **GRANULAR BASE/SUBBASE**
 - + **SUBGRADE**

SUBGRADE TRANSFER FUNCTIONS

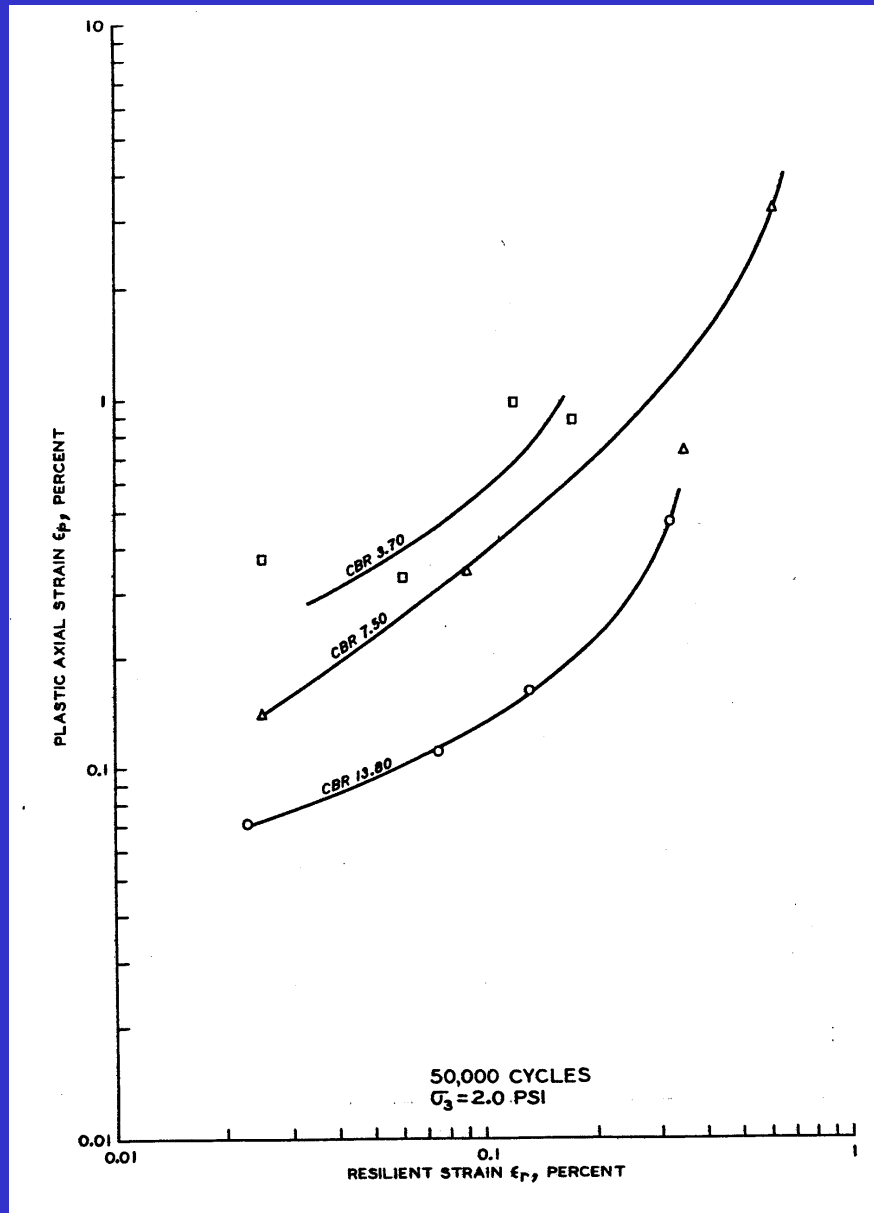
- SUBGRADE VERTICAL STRAIN
- SUBGRADE STRESS RATIO (SSR)
(SSR= DEV STRESS / Q_U)

VERTICAL STRAIN CRITERIA ϵ

$$\epsilon = L (1/N)^m$$

AGENCY	L	m	RD (INS)
AI	$1.05 \cdot 10^{-2}$	0.223	0.5
SHELL			
50%	$2.8 \cdot 10^{-2}$	0.25	
85%	$2.1 \cdot 10^{-2}$	0.25	
95%	$1.8 \cdot 10^{-2}$	0.25	
TRL/1132 (85%)	$1.5 \cdot 10^{-2}$	0.253	0.4

WES / TOWNSEND & CHISOLM / 1976



Vicksburg
"BUCKSHOT CLAY"
(CH)

Transfer Functions: Subgrade Rutting- *Vertical Strain Design Criteria*



COE / FAA LEDFAA

FAA SUBGRADE STRAIN CRITERIA (Revised)

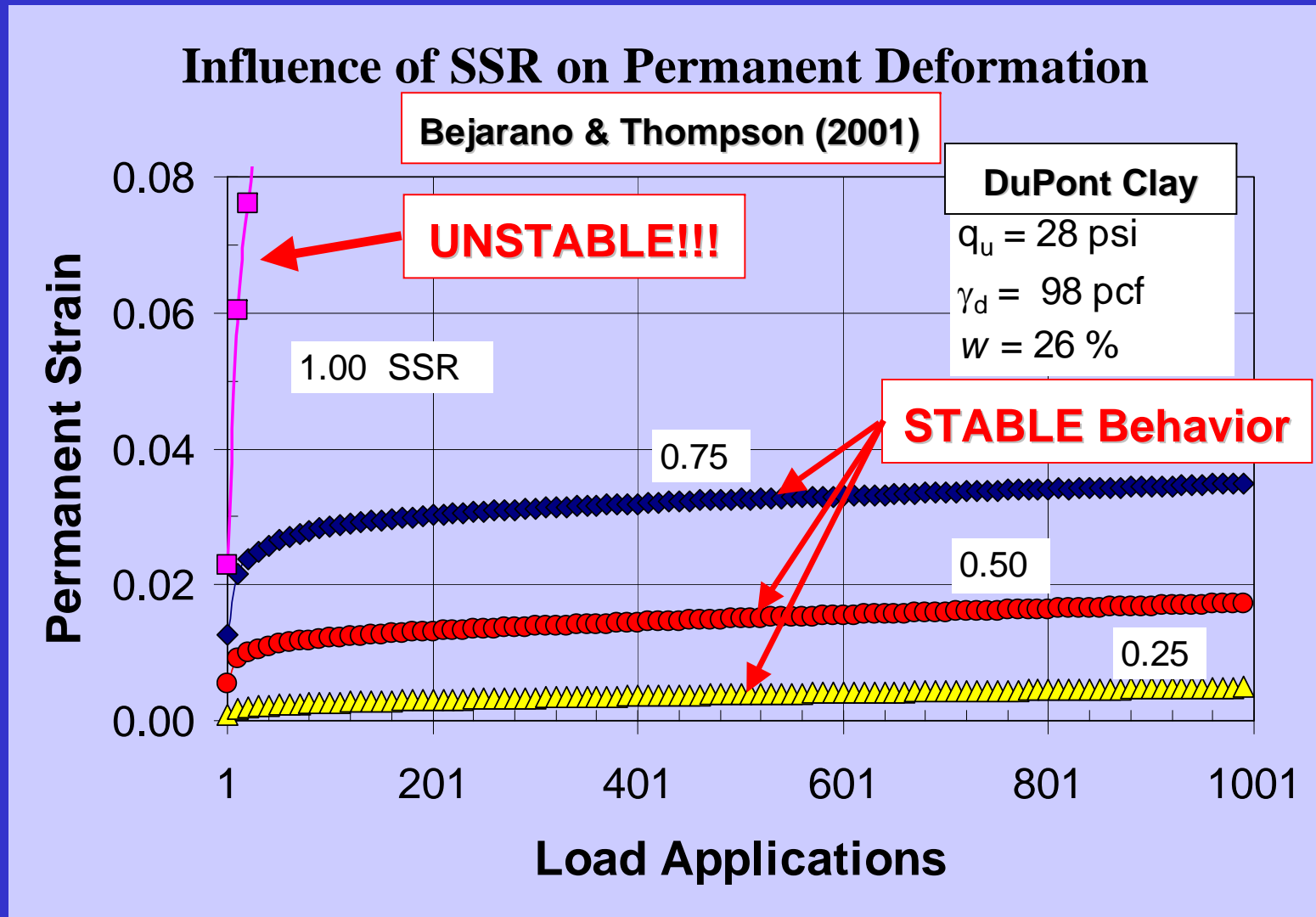
$$**C = (0.004 / \varepsilon_v)^{8.1} \quad \text{Coverages} < 12,100**$$

$$**C = (0.002428 / \varepsilon_v)^{14.21} \quad \text{Coverages} > 12,100**$$

C - Coverages

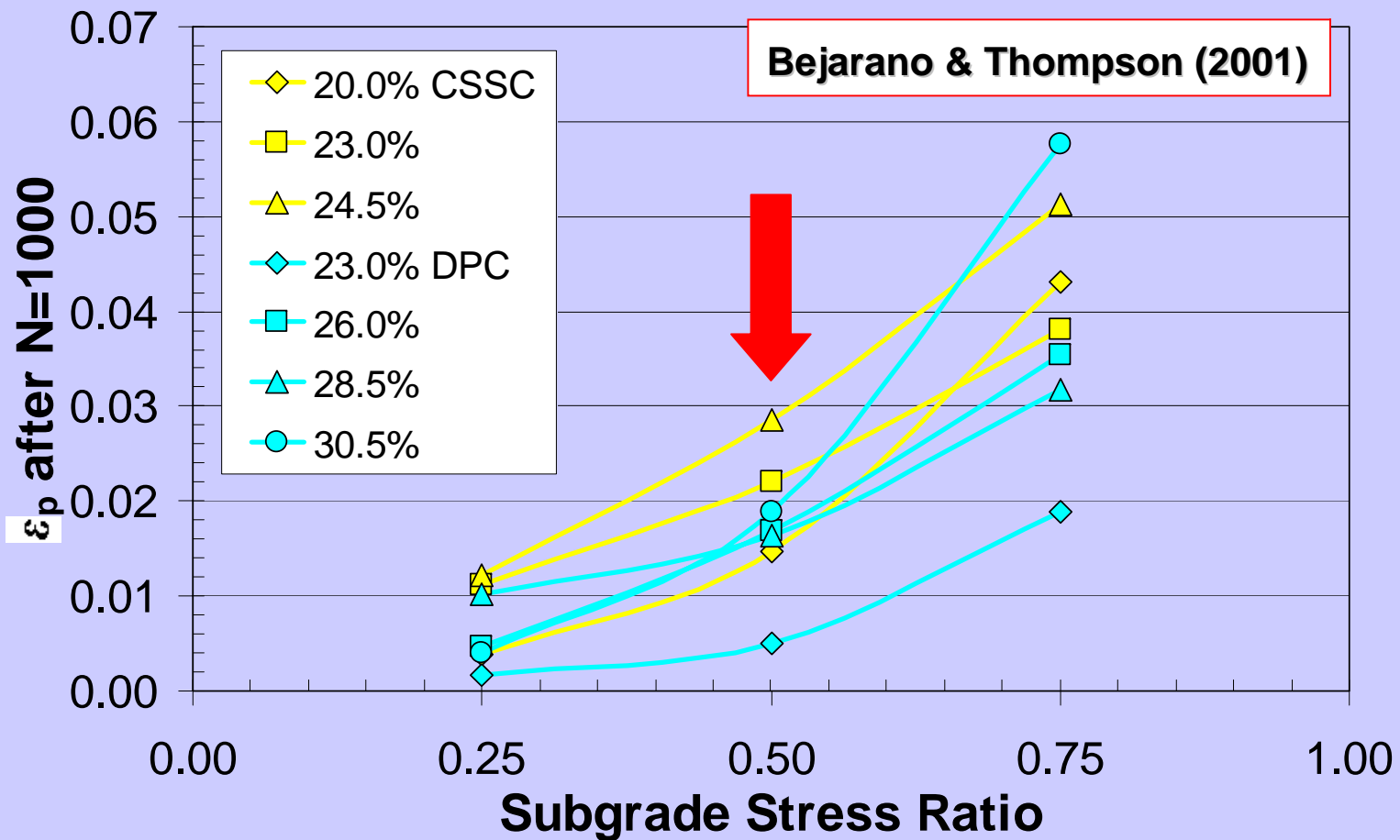
ε_v - Subgrade Vertical Compressive Strain

Transfer Functions: Subgrade Rutting-SSR



Transfer Functions: Subgrade Rutting-SSR

Permanent Deformation vs. SSR



SUBGRADE RUTTING ALGORITHM

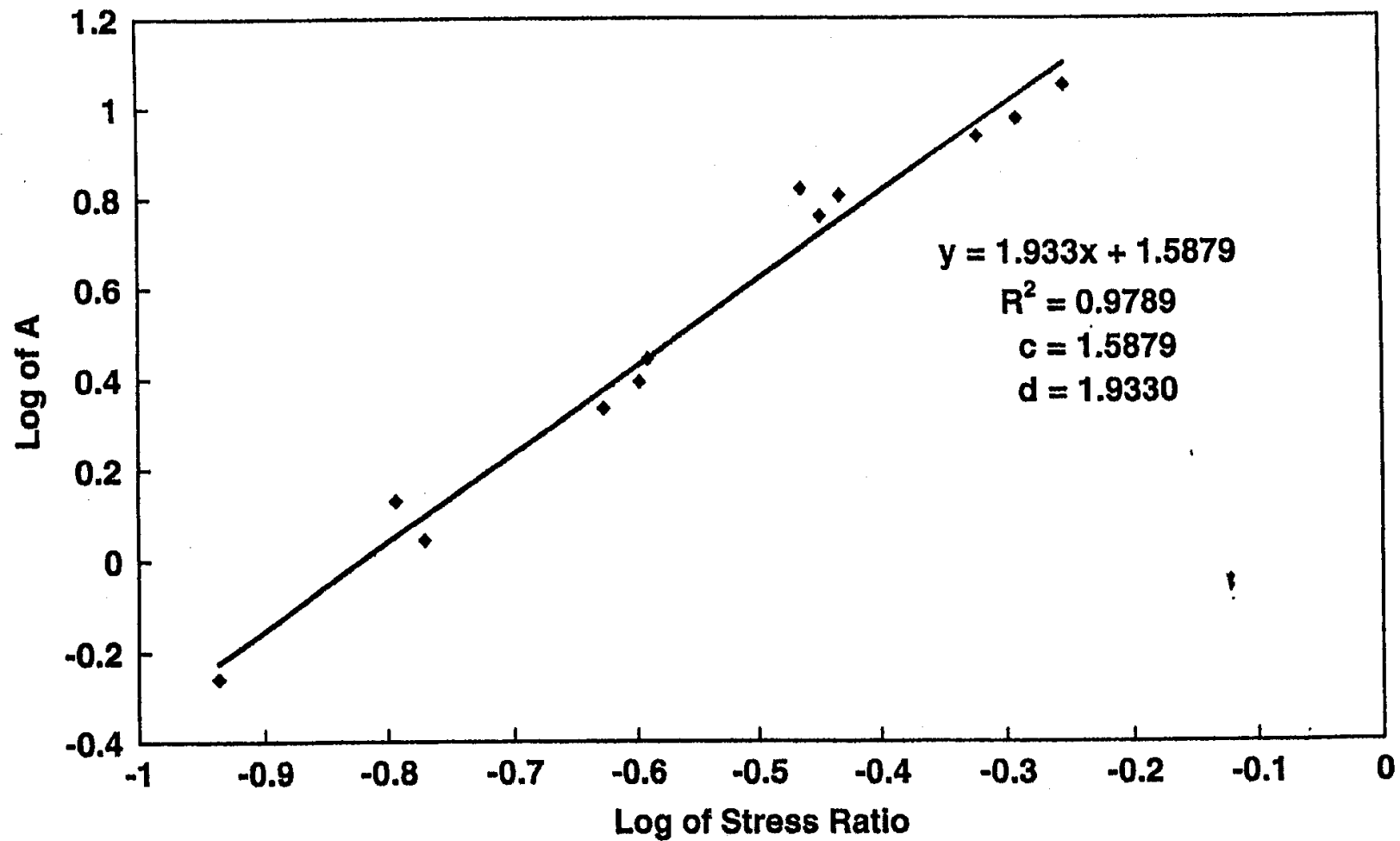
$$\text{LOG } \varepsilon_p = A + b (\text{LOG } N)$$

$$\varepsilon_p = AN^b$$

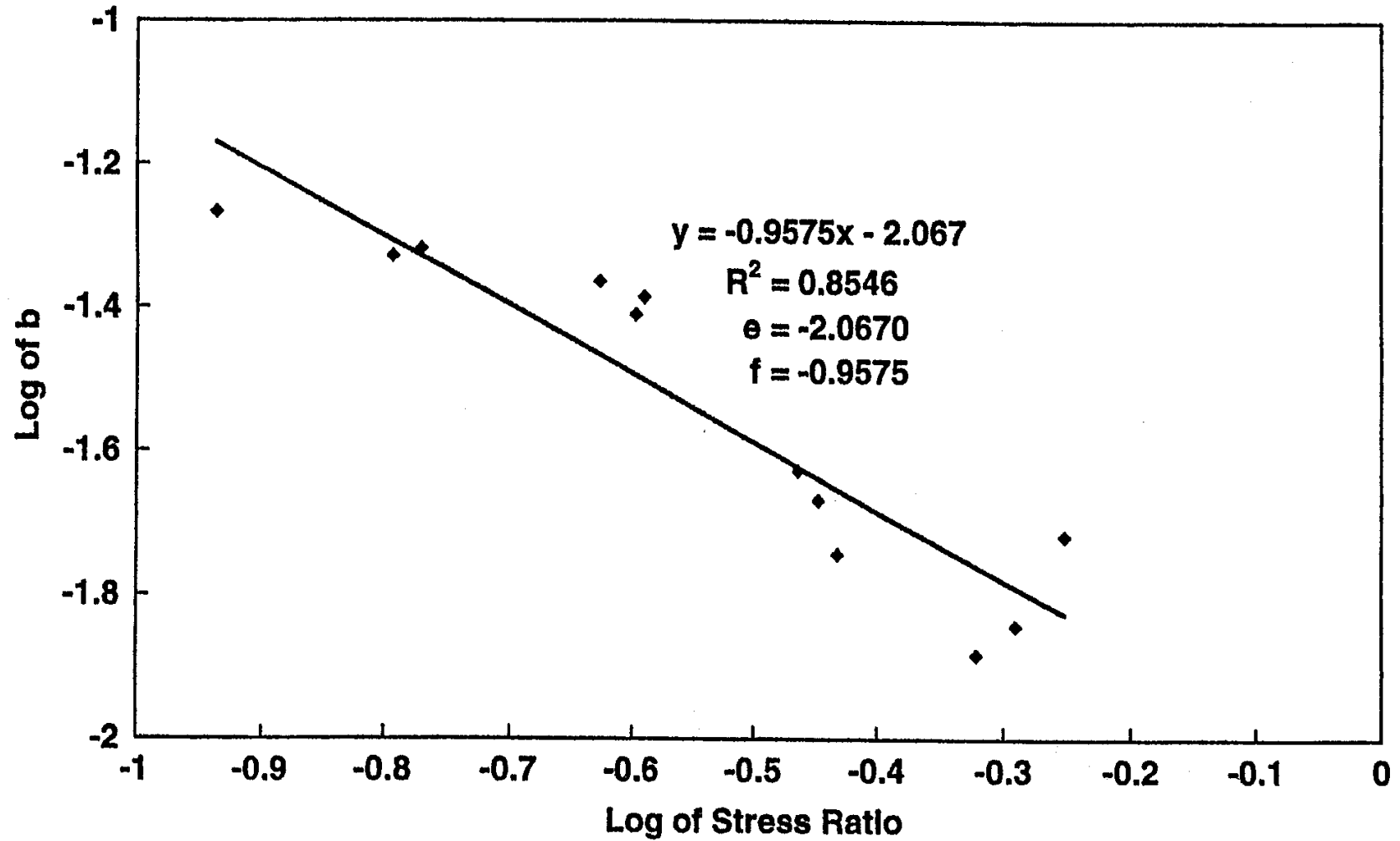
**“Development of a Simplified M-E Design
Procedure for Low-Volume Flexible Roads”**

**Zhao & Dennis
University of Arkansas
TRR # 1989 – Vol. 1**

Subgrade Stress Ratio (SSR) / A



Subgrade Stress Ratio (SSR) / b



Transfer Functions: Subgrade Rutting-SSR

SSR General Guidelines

<i>Damage Potential...</i>	Low/Acceptable	Limited	High
<i>SSR...</i>	0.5 / 0.6	0.6 to 0.75	> 0.75

GRANULAR LAYER RUTTING

- * COE – NOT A CRITERION
- * FAA / LEDFAA - NOT A CRITERION

**INDIRECT ACCOMODATION:
MINIMUM HMA SURFACE THICKNESS
STABILIZED BASE - > 100 KIPS**

GRANULAR BASE

- Minimum HMA Surface Thickness
FAA
4-5 ins. / Critical
3-4 ins. / Noncritical
(Base CBR - 80)
 - S. African “F”

South African Mechanistic Approach

Material Shear Strength / Shear Stress

$$F = [\sigma_3 * \phi_{\text{term}} + c_{\text{term}}] / [\sigma_1 - \sigma_3]$$

where:

$$\phi_{\text{term}} = [\tan^2(45 + \phi/2) - 1]$$

$$c_{\text{term}} = 2 * C * \tan(45 + \phi/2)$$

ϕ - friction angle, degrees

C - cohesion, psi

GRANULAR BASE RATIO

FOR $\text{PHI} = 45^\circ$ & $C = 0$

$$F = \text{DEV. STRESS} / 4.8 * \text{SIG}^3$$

DECREASED "F": MORE RUTTING

HMA FATIGUE (TRADITIONAL)

HMA FATIGUE CRACKING



LEDFAA – HMA FATIGUE

$$\text{LOG } C = 2.68 - (5 * \text{LOG } \varepsilon) - (2.665 * \text{LOG } E_{\text{HMA}})$$

C – COVERAGES TO FAILURE

ε - HMA STRAIN @ BOTTOM OF P401 HMA SURFACE

E_{HMA} – HMA MODULUS (200 ksi)

Heukelom & Klomp – AAPT (1964)

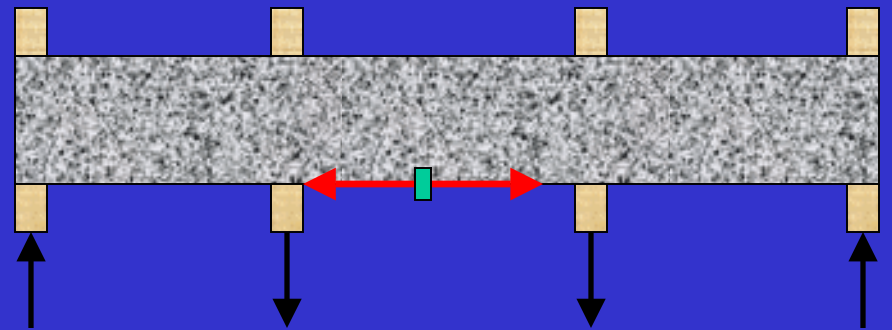
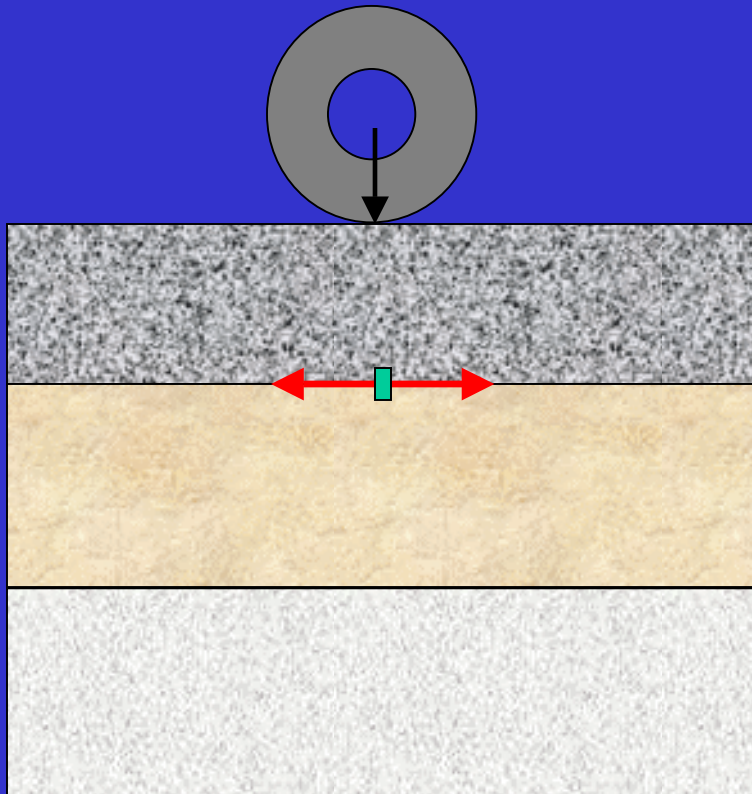
AASHTO TP 8-94

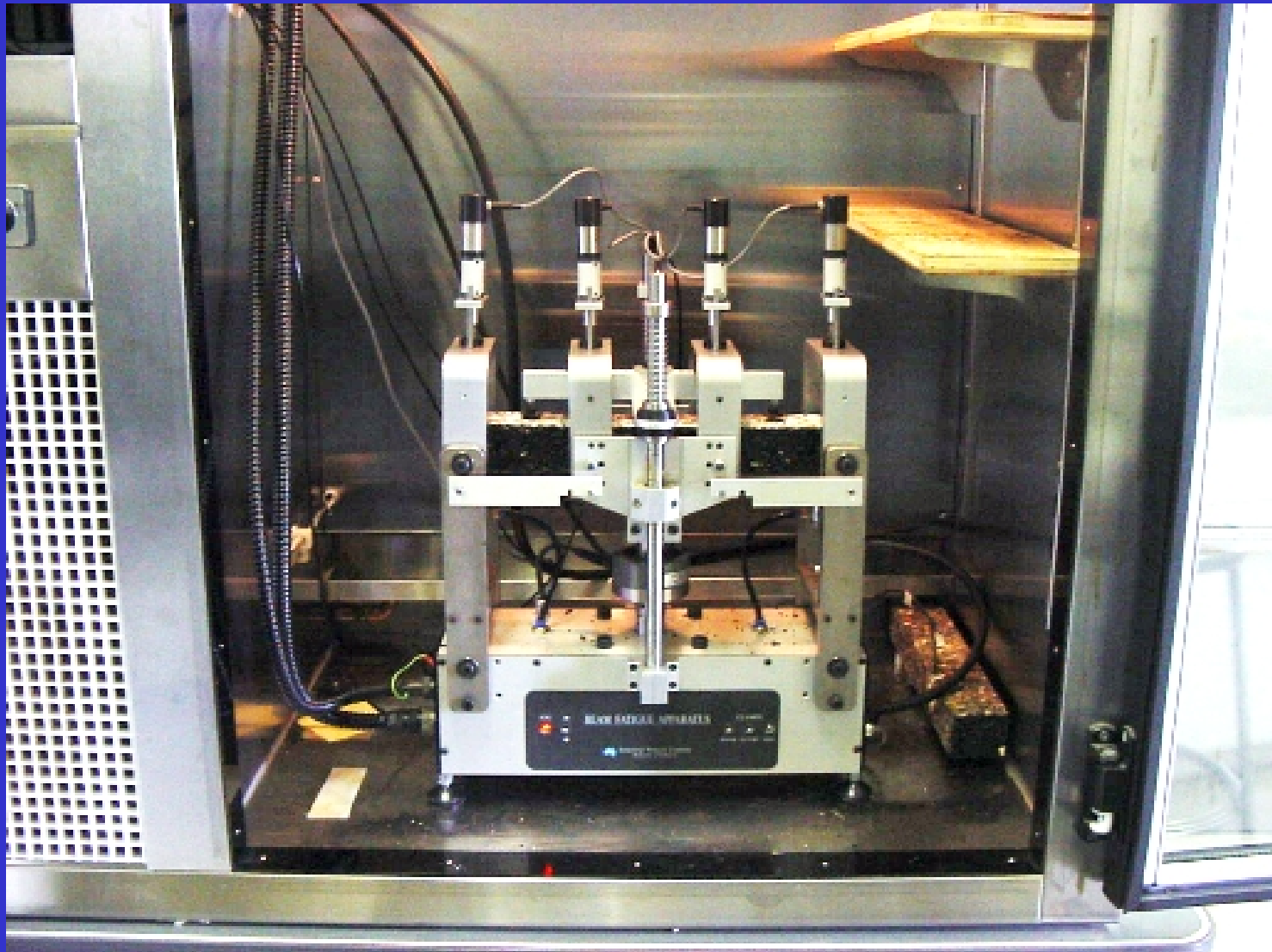
Standard Test Method for Determination of
the Fatigue Life of Compacted HMA
Subjected to Repeated Flexural Bending

FATIGUE DESIGN

- Tensile Strain at Bottom of Asphalt
- Tensile Strain in Flexural Beam Test

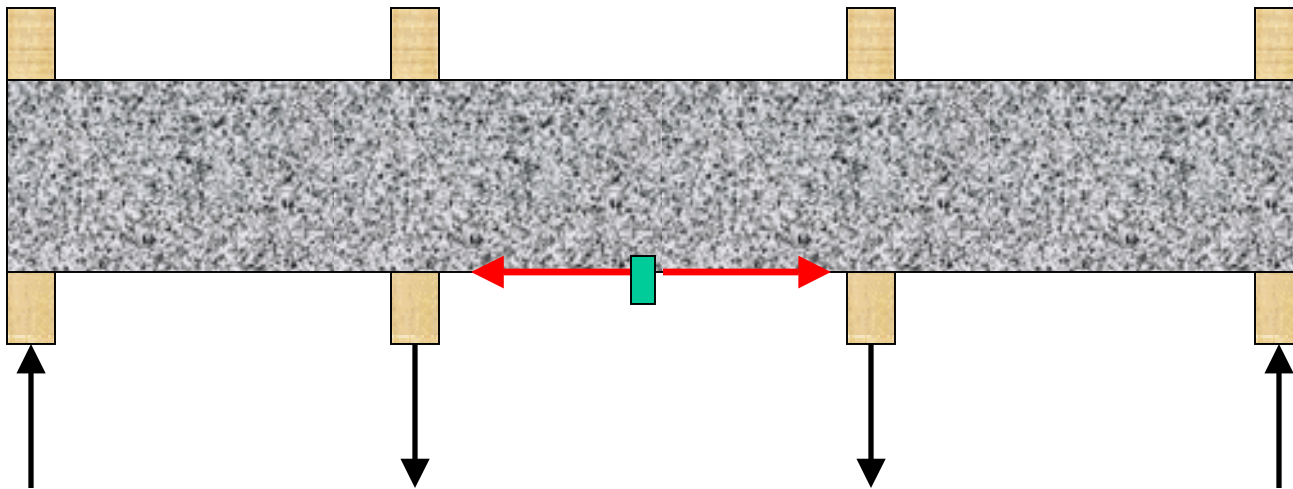
Other Configurations





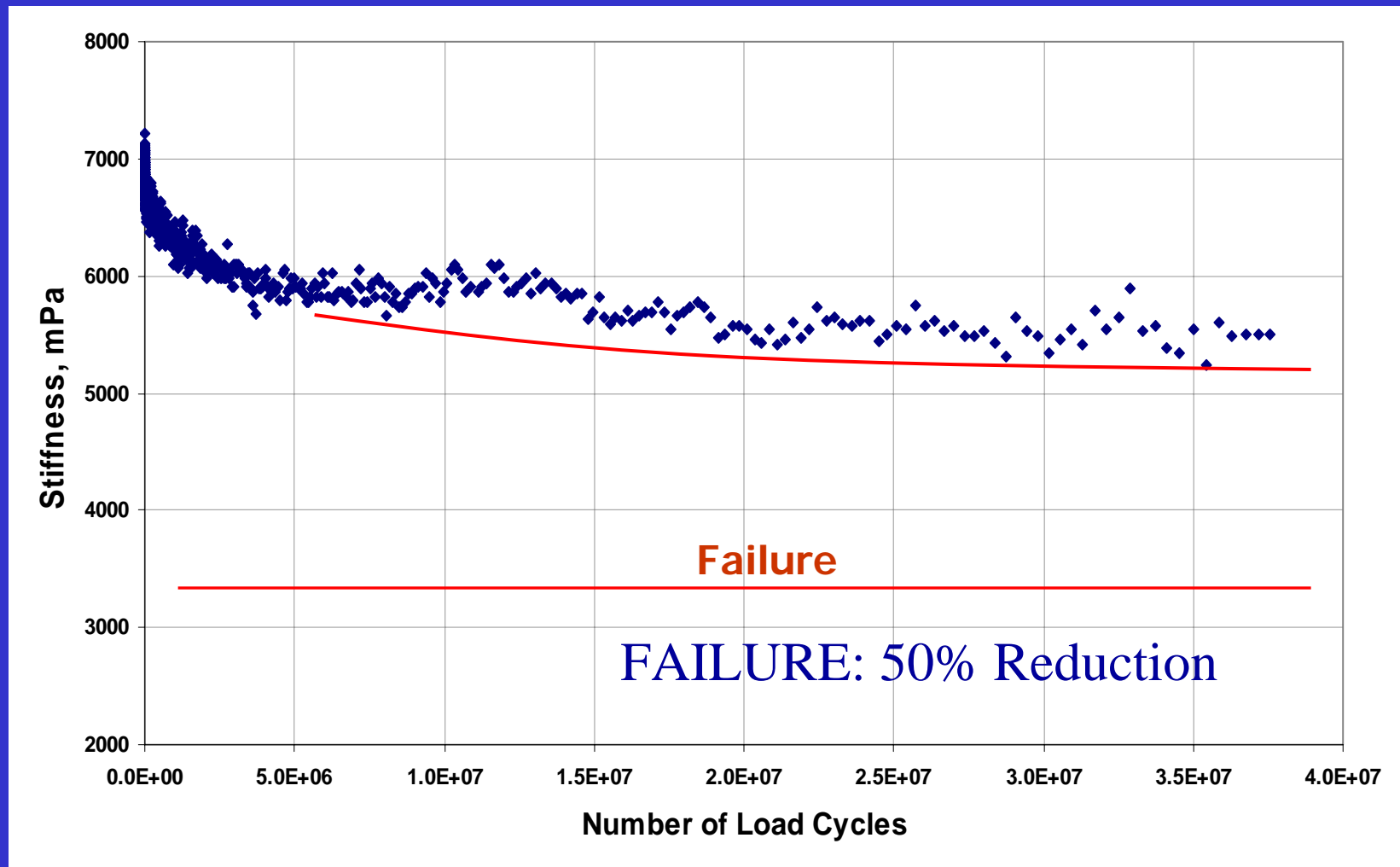
FATIGUE TESTING

- Tensile Strain in Flexural Beam Test
 - Other Configurations

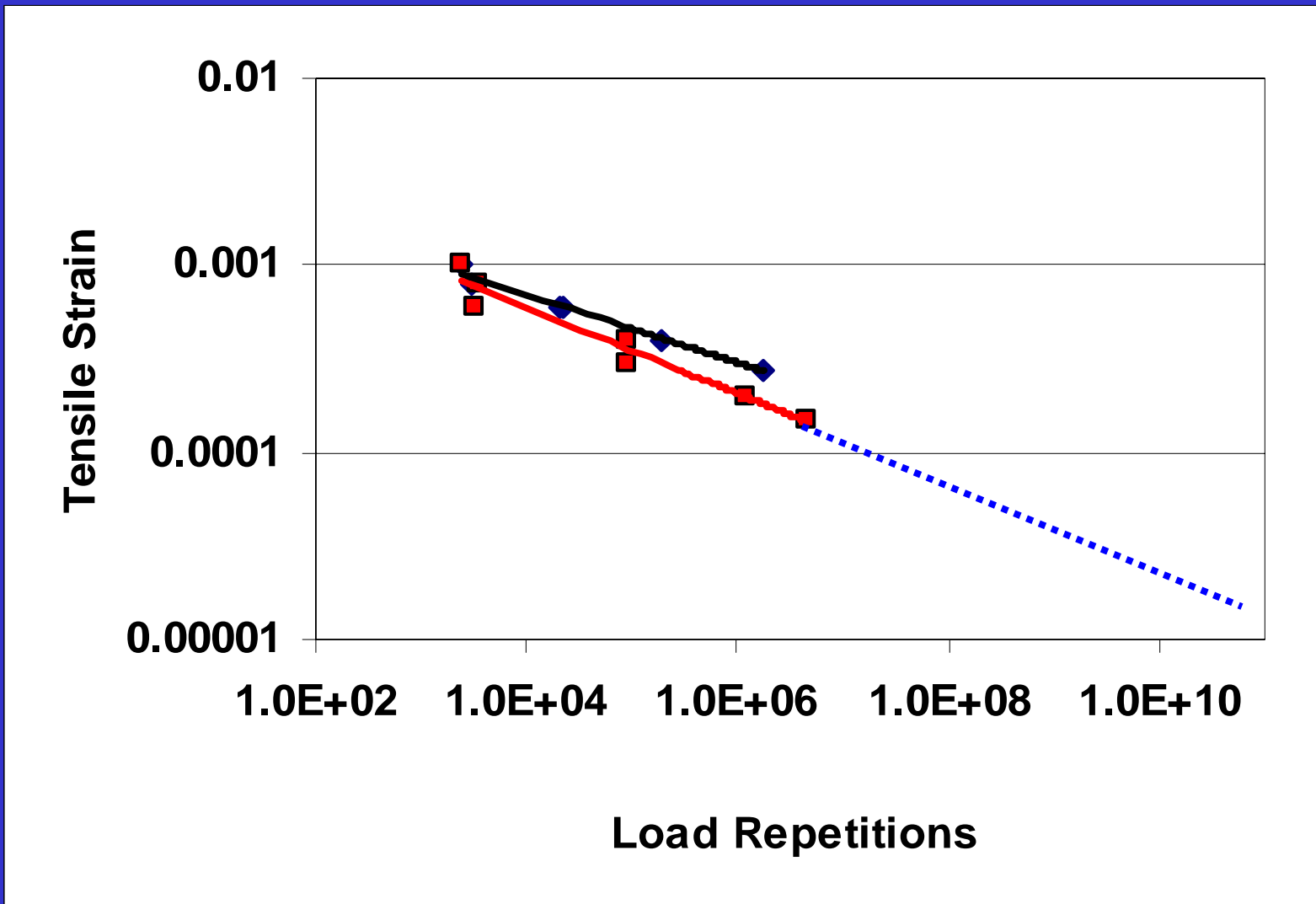


- 10 Hz Haversine Load, 20° C, Controlled Strain

STIFFNESS CURVE



LABORATORY ALGORITHM

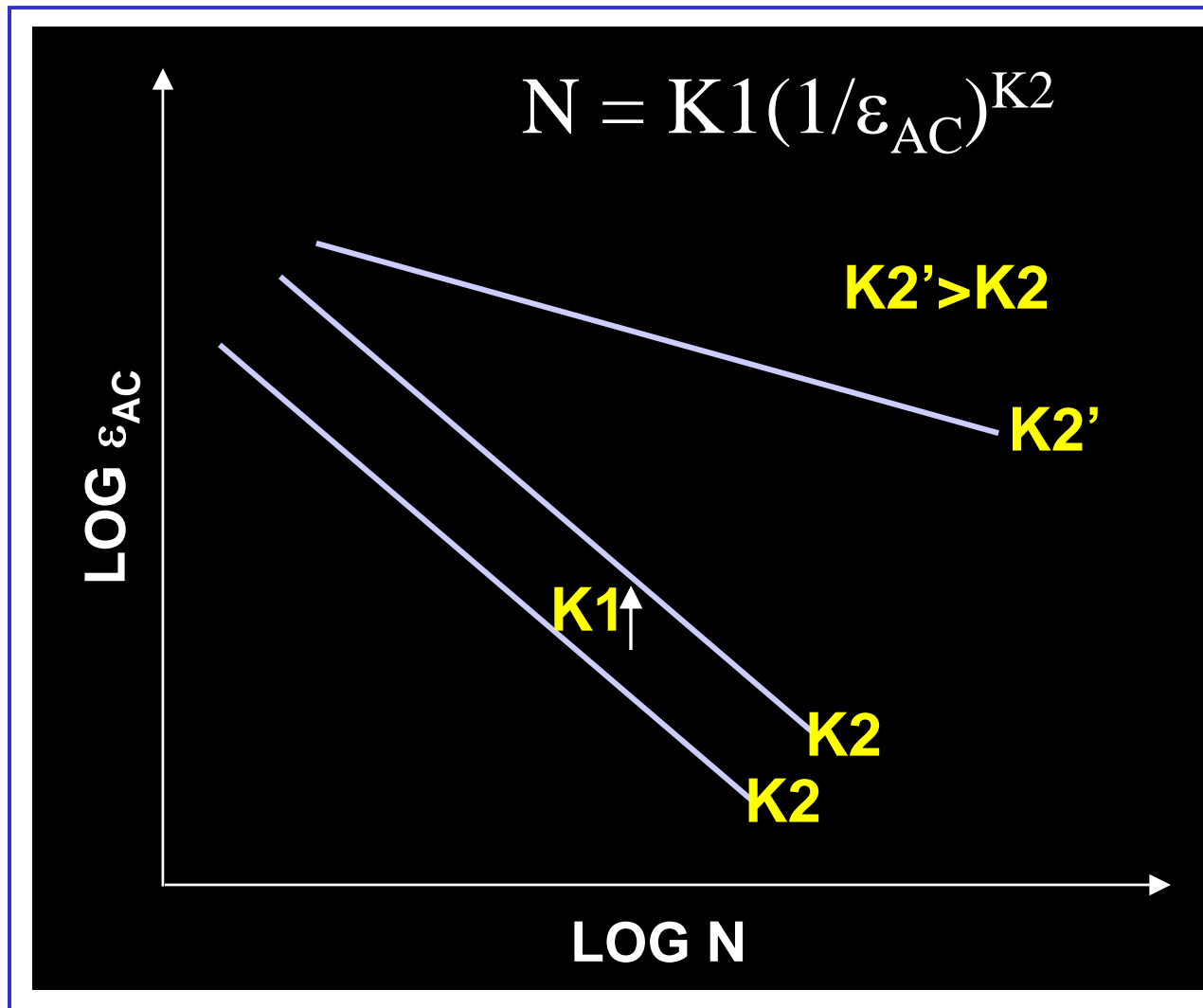


FATIGUE ALGORITHMS

$$N_f = K1(1/\varepsilon)^{K2}$$

$$N_f = K1 (1/\varepsilon)^{K2} (1/E^*)^{K3}$$

AC FATIGUE



HMA FATIGUE @ UIUC
Carpenter - Ghuzlan - Shen

IDOT HMA FATIGUE DATA SUMMARY 84 MIXES

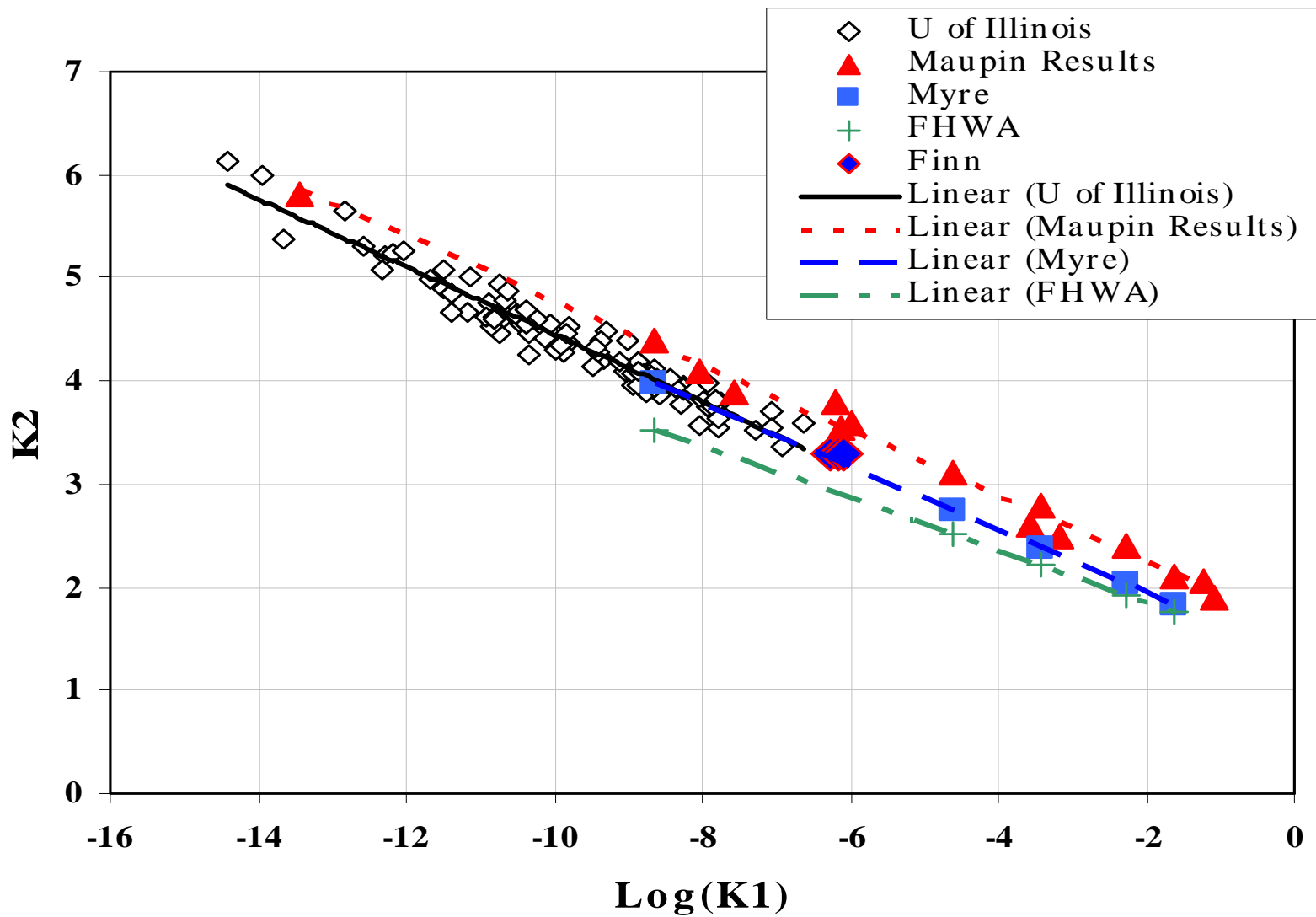
$$N = K1 (1/\varepsilon)^{K2}$$

Minimum K2: 3.5

90% K2: 4.0

Average K2: 4.5

OTHER STUDIES



K – n RELATIONS

Myre / Norway NTH (1992)

$$\text{LOG } K1 = (1.332 - K2) / 0.306$$

U of IL / IDOT HMA_s

Carpenter – et al

$$\text{LOG } K1 = (1.178 - K2) / 0.329$$

$$N = K1(1/HMA \text{ STRAIN})^{K2}$$

HMA STRAIN *	K2 3.0	K2 3.5	k2 4.0	K2 4.5
75	8.4 **	22.4	60.0	160.6
150	1.1	2.0	3.8	7.1
250	0.23	0.33	0.49	0.71

* Micro-strain

**Mreps

THERE IS

NO “UNIQUE”

HMA FATIGUE ALGORITHM !!!!

HMA ENDURANCE LIMIT

Monismith & McLean

**“Technology of Thick Lift Construction:
Structural Design Considerations”**

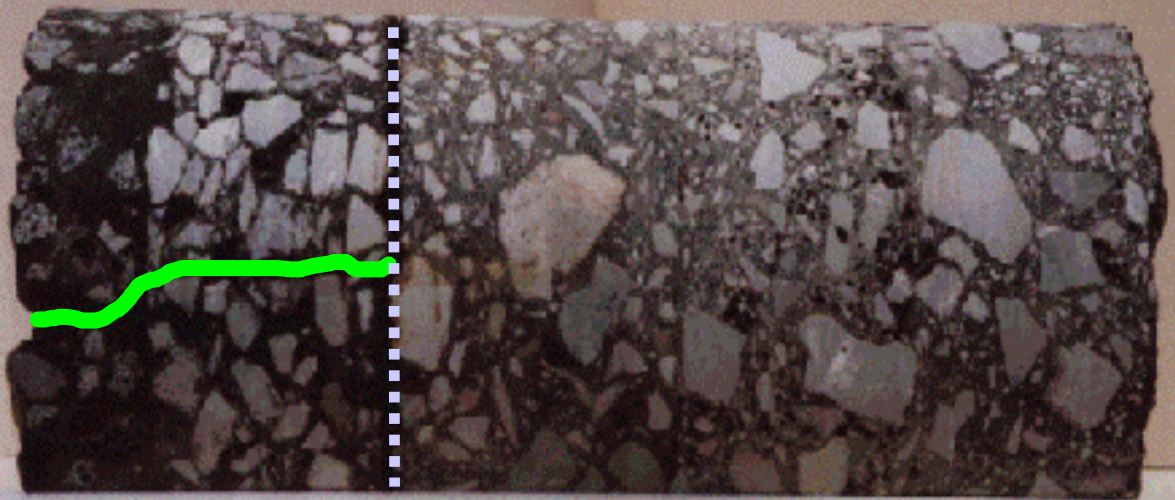
1972 AAPT Proceedings

70 Micro-Strain Endurance Limit!!

Michael Nunn
“Long-Life Flexible Pavements”
8th ISAP Conference
Seattle, WA - 1997

TRL

M32 CORE

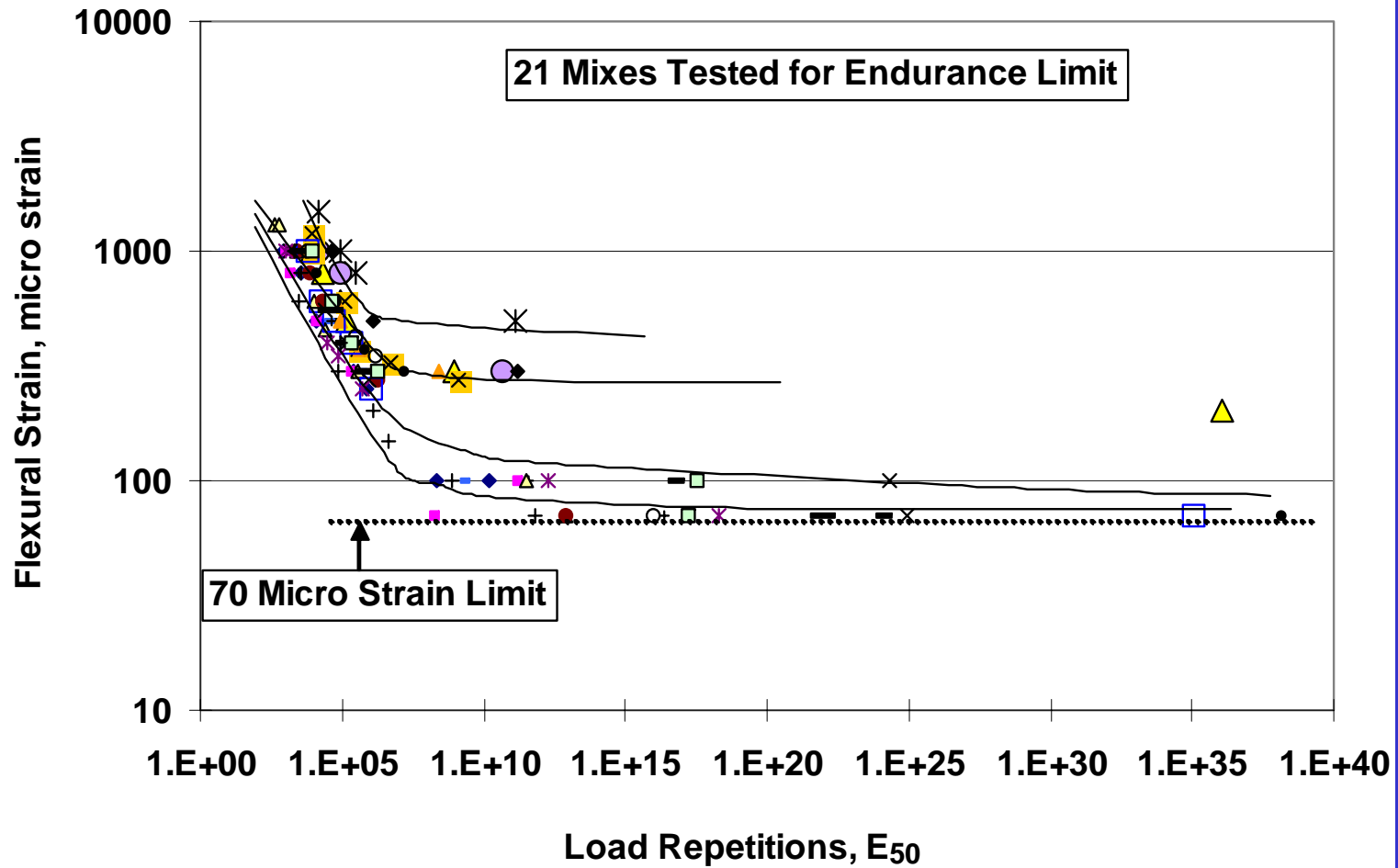


M32(s) 9

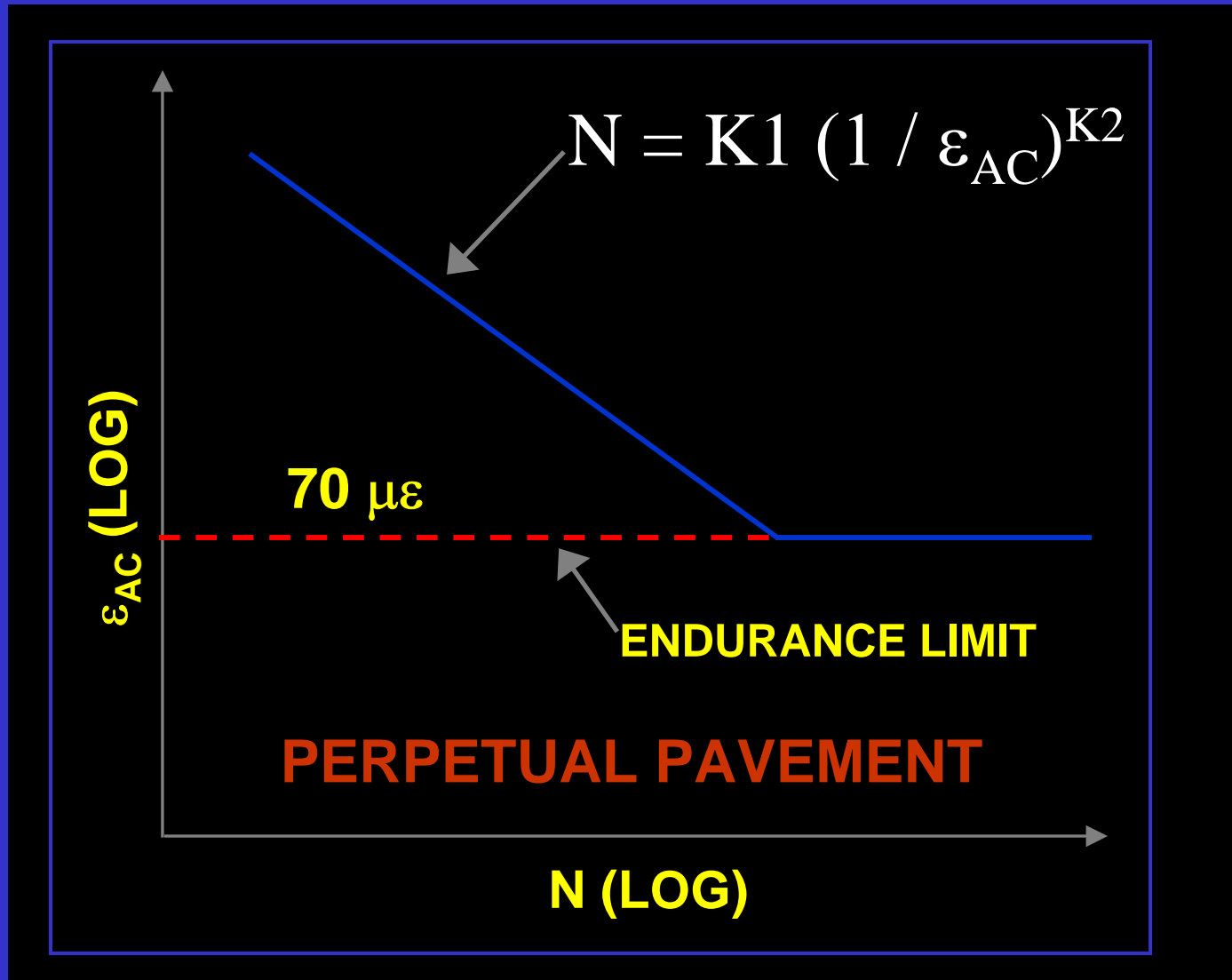


TRL

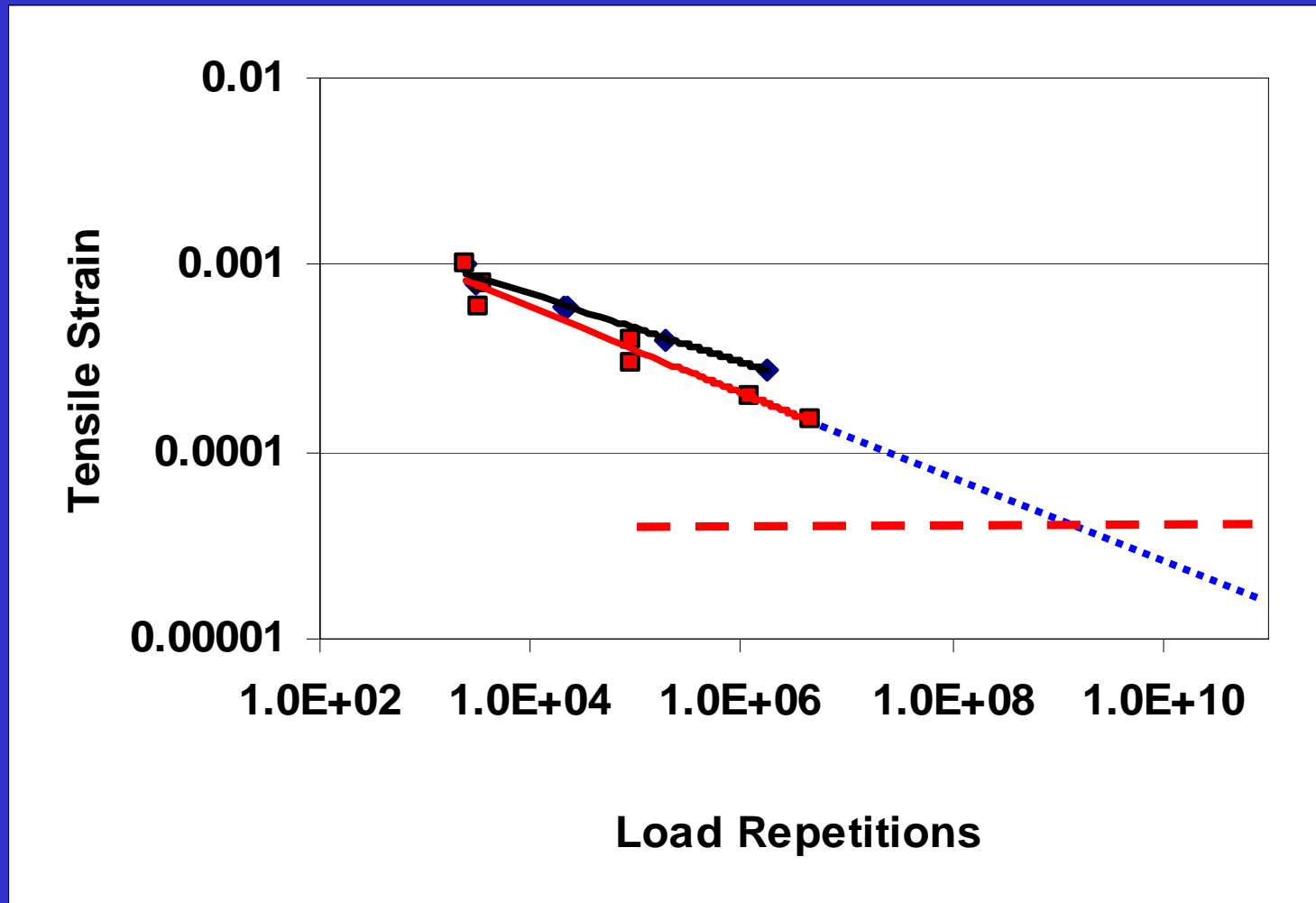
LOW STRAIN TESTING



HMA FATIGUE



FATIGUE ENDURANCE LIMIT



FATIGUE ENDURANCE LIMIT

- Damage and Healing Concepts and Test Data Support a Strain Limit Below Which Fatigue Damage Does Not Accumulate
- Strain Limit Is Not The Same for All HMAs.

FATIGUE ENDURANCE LIMIT IDOT DATA

NEVER < 70 micro-strain!!!

GENERALLY: 70 –100 micro-strain

MAY BE > 100 micro-strain

EFFECT OF REST PERIODS

**SMALL REST PERIODS BETWEEN
STRAIN REPETITIONS SIGNIFICANTLY
INCREASES HMA FATIGUE LIFE**

**IDOT HMA
5 SECONDS: 10 X**

OVERLOADING

- HMA CAN SUSTAIN “SPORADIC OVERLOADS” AND RETURN TO “ENDURANCE LIMIT” PERFORMANCE
- SUBSEQUENT HMA STRAIN REPETITIONS < ENDURANCE LIMIT:

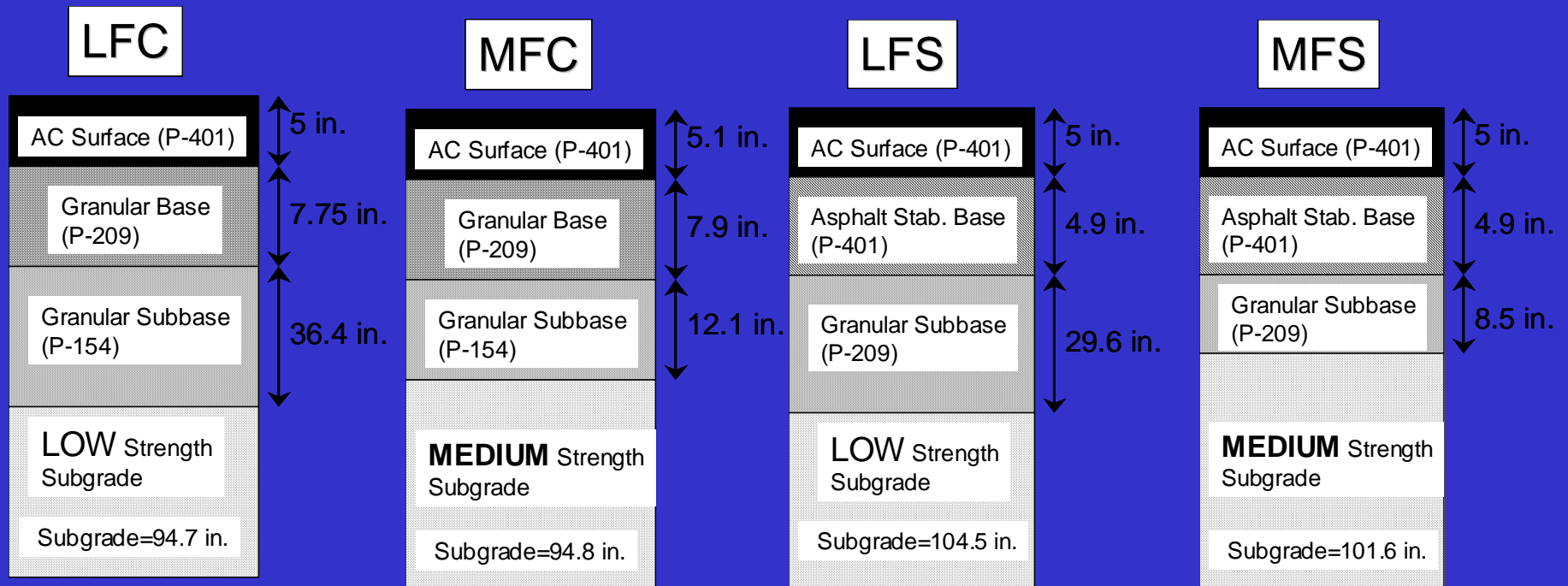
“DO NOT COUNT”

NAPTF – PAVEMENT RUTTING

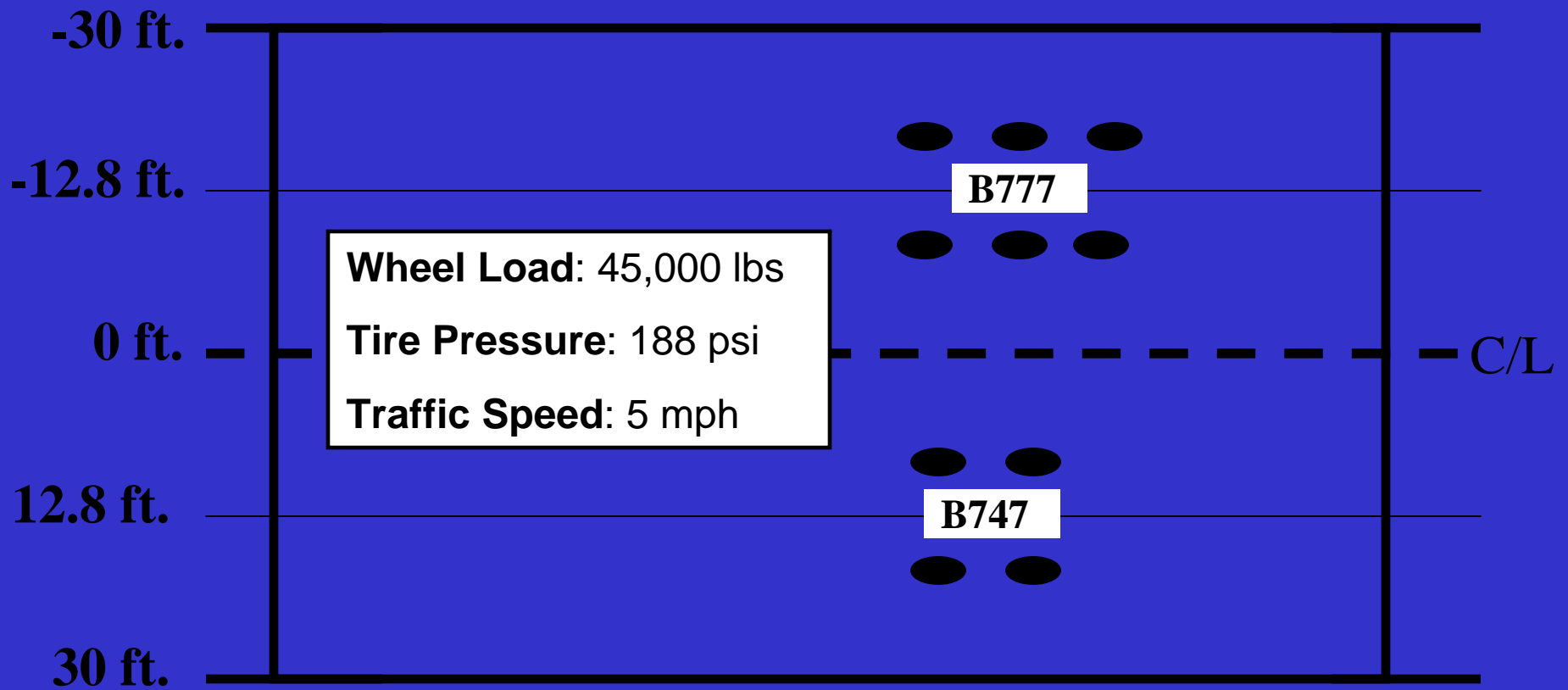
NAPTF TEST SECTIONS

75 FEET LONG
60 FEET WIDE

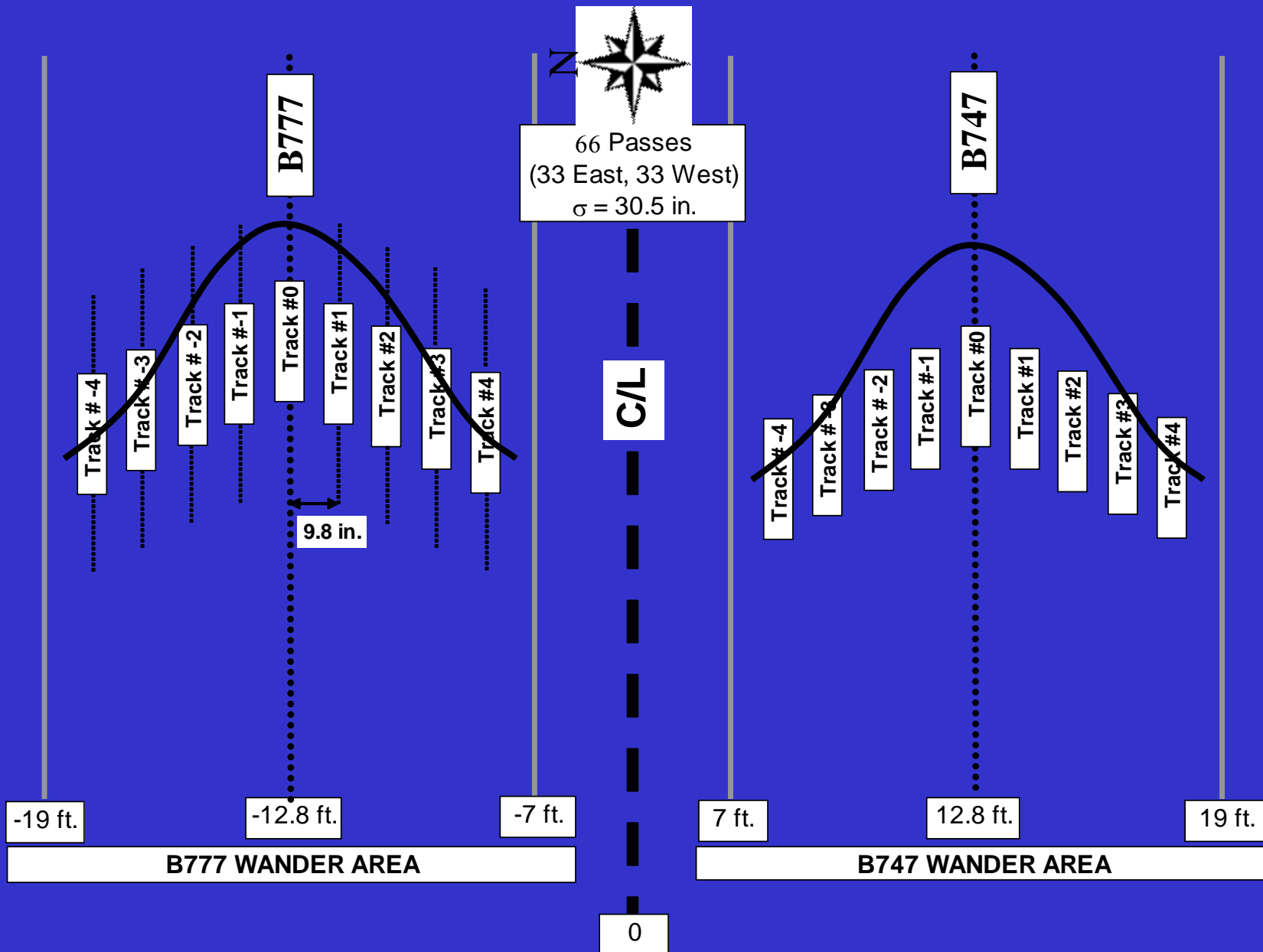
“As-Built” NAPTF Test Sections



NAPTF Traffic Test Program

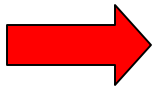


NAPTF Traffic Wander



NAPTF “Failure” Criteria

- “At least 1 inch surface upheaval adjacent to the traffic lane” (USCOE MWHGL tests)
- This is considered to reflect structural or shearing failure in the subgrade
- 1 inch surface upheaval may be accompanied by a 0.5-inch rut depth or rut depths in excess of 3 inches





UNIFIED FACILITIES CRITERIA (UFC)

O&M: PAVER ASPHALT SURFACED AIRFIELDS PAVEMENT CONDITION INDEX (PCI)

Table 15.1. Mean Rut Depth Criteria

Severity	All Pavement Sections
L	$\leq 1/4$ to $1/2$ inch (≤ 6.4 to 12.7 millimeters) (Figure 15.2. and Figure 15.3.)
M	$>1/2$ inch ≤ 1 inch (>12.7 to ≤ 25.4 millimeters) (Figures 15.4 and 15.5.)
H	>1 inch (>25.4 millimeters) (Figures 15.6. and 15.7.)

15.4. Options for Repair.

15.4.1. L. Do nothing.

15.4.2. M. Shallow,* partial- or full-depth patch; partial- or full-depth patch and overlay.

15.4.3. H. Shallow,* partial- or full-depth patch; partial- or full-depth patch and overlay.

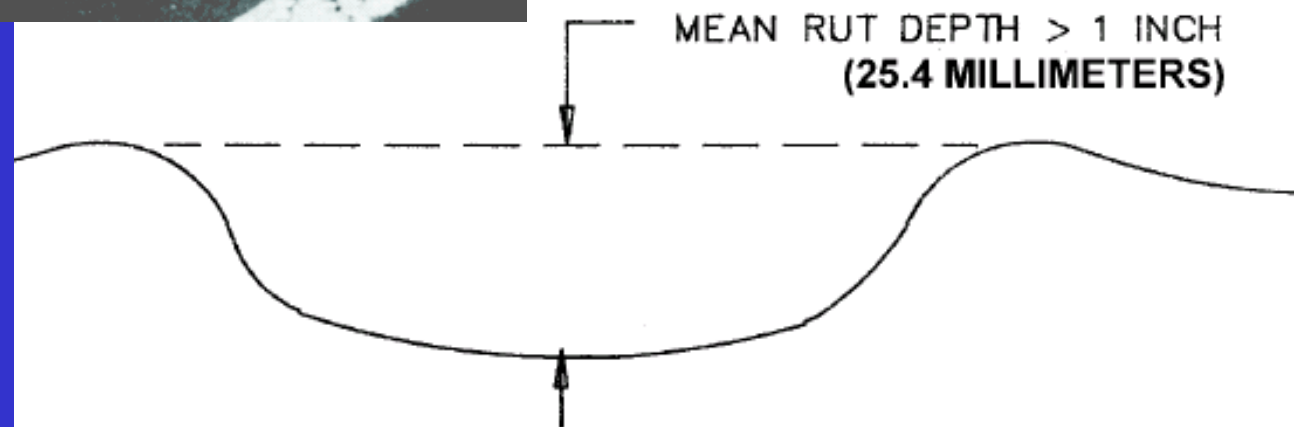
* Shallow patching will not be used on runways where FOD is of concern.



UNIFIED FACILITIES CRITERIA (UFC)



High Severity Rutting



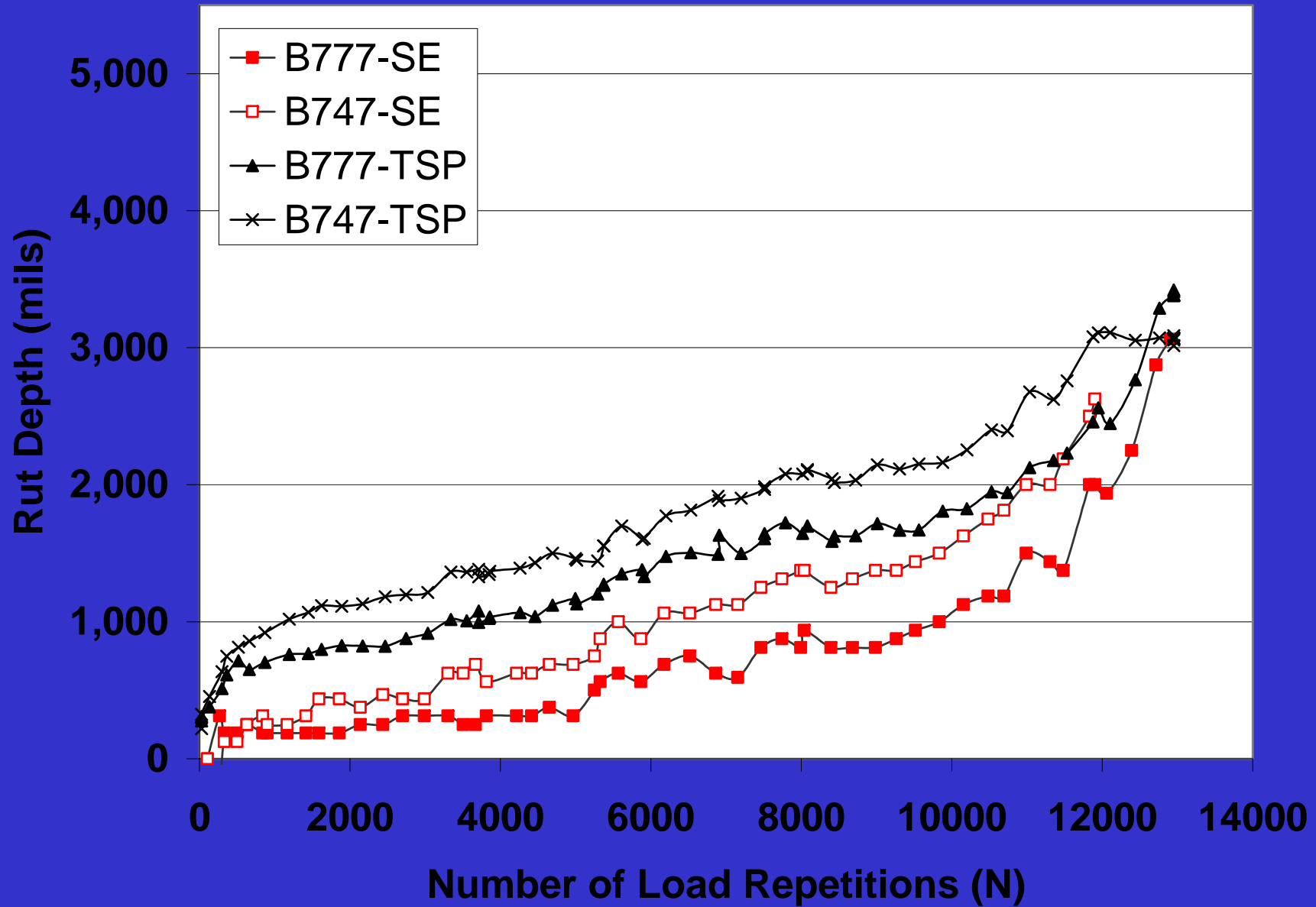
Number of Passes to “Failure”

NAPTF Test Section	45,000-lb Wheel Load	65,000-lb Wheel Load	Total
MFC	12,952 [*]	-	12,952
MFS	19,869 [*]	-	19,869
LFC	19,950	24,145	44,095 [*]
LFS	19,939	24,749	44,688 [*]
* - "Failure" achieved			

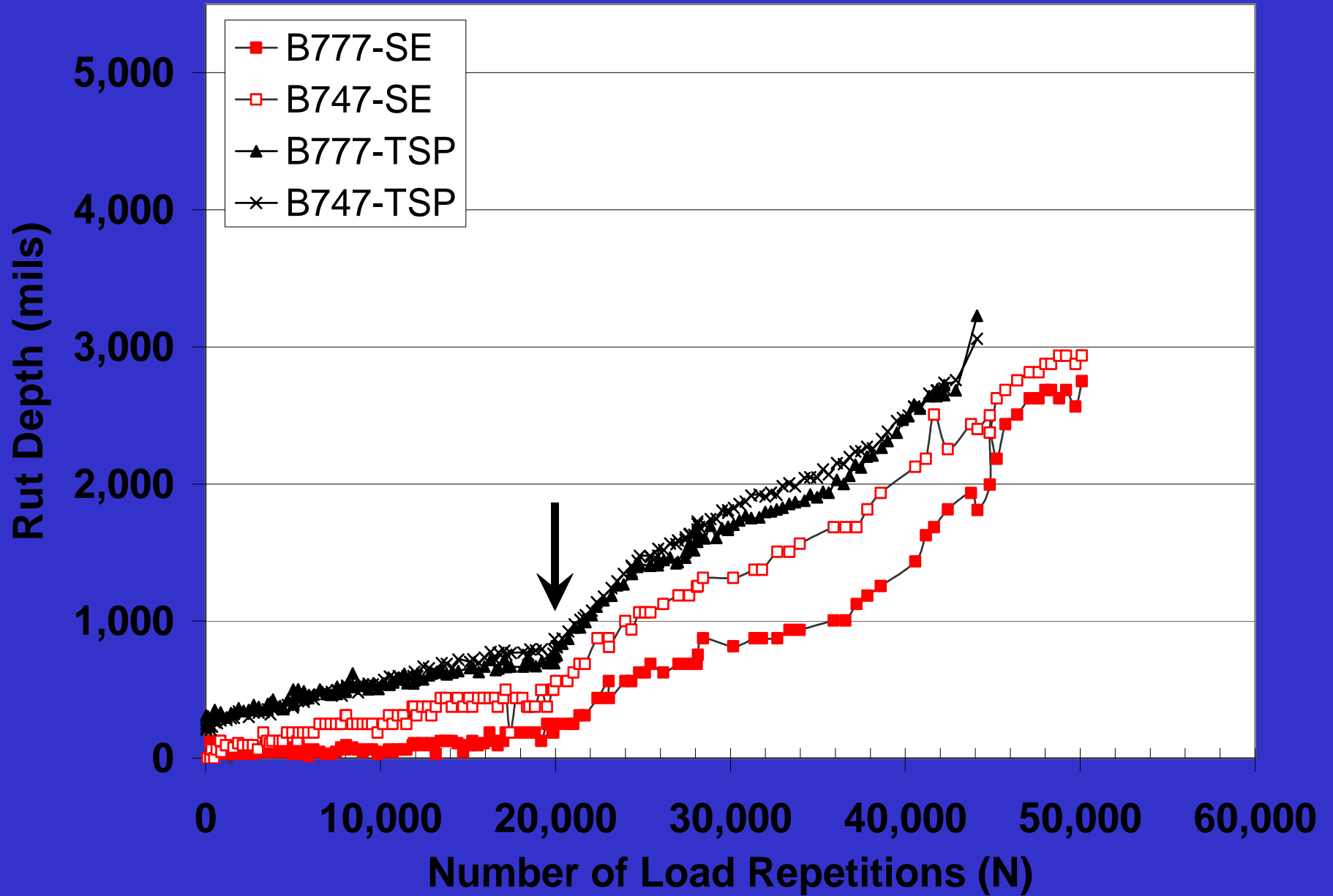
Max Rut Depths at “Failure”

NAPTF Test Section	RD under 45,000-lb Wheel Load (in.)		RD Under 65,000-lb Wheel Load (in.)		Total RD (in.)	
	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>
MFC	3.4	3.1	-	-	3.4	3.1
MFS	3.5	1.0	-	-	3.5	1.0
LFC	0.7	0.9	2.5	2.2	3.2	3.1
LFS	0.5	0.4	1.6	1.7	2.1	2.1

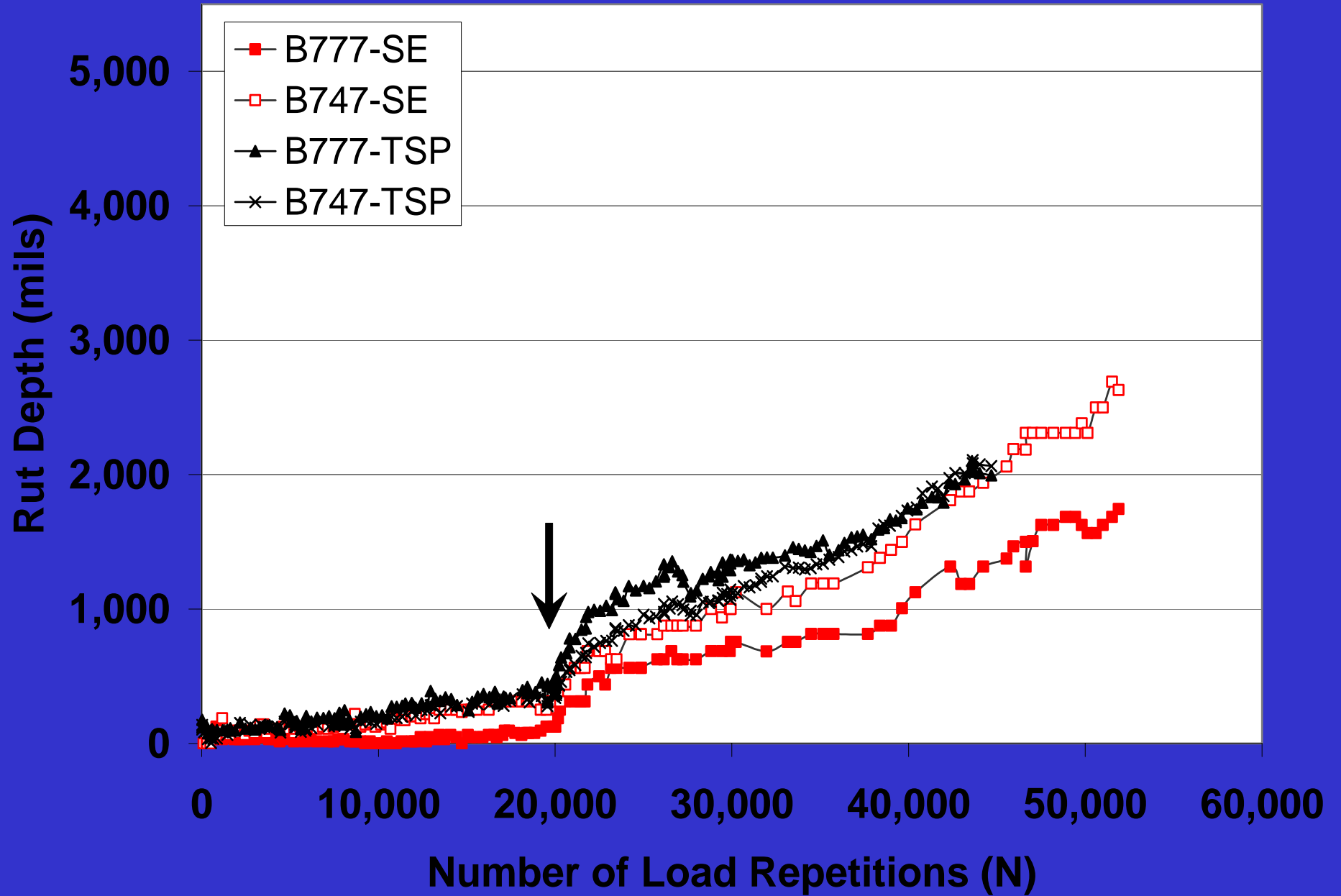
RD Vs N – MFC1



RD Vs N – LFC1



RD Vs N – LFS1



N to Reach Specific RD

Low Strength Sections

Rut Depth (mils)	LFC1		LFC2		LFS1		LFS2	
	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>
250	28	516	28	531	10,743	12,442	28	28
500	5,008	8,083	7,791	8,723	20,068	20,642	15,111	515
1000	21,612	21,414	21,084	22,759	22,888	26,153	21,488	21,488

Medium Strength Sections

Rut Depth (mils)	MFC1		MFC2		MFS1		MFS2	
	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>	<i>B777</i>	<i>B747</i>
250	28	28	28	28	-	28	28	5,295
500	299	133	133	133	-	10,529	5,373	7,513
1000	3,343	1,193	1,193	1,448	-	19,869	12,440	15,108

Conclusions

- Max RD at “failure” higher for conventional sections compared to stabilized sections
- More passes at higher wheel loads was required by L sections to reach “failure” compared to M sections
- N required by B777 and B747 gears to reach 1-inch RD were similar
- B777 RDs and B747 RDs do not differ significantly

M-E DESIGN TOOLS ARE:

“AVAILABLE”

AND

“TECHNOLOGICALLY ADEQUATE”

IT IS TIME TO:

“MOVE ON”