Presented By:
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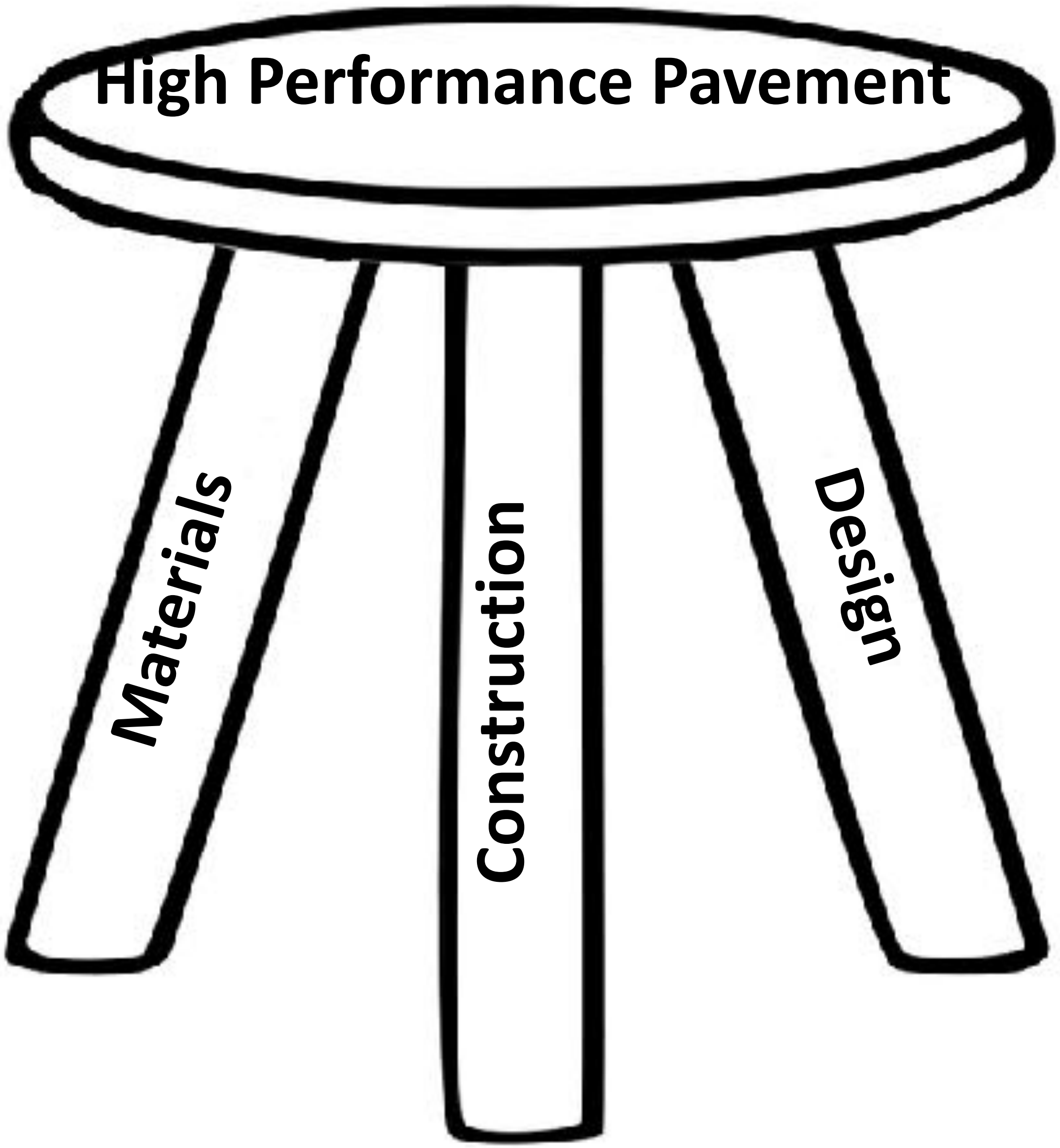
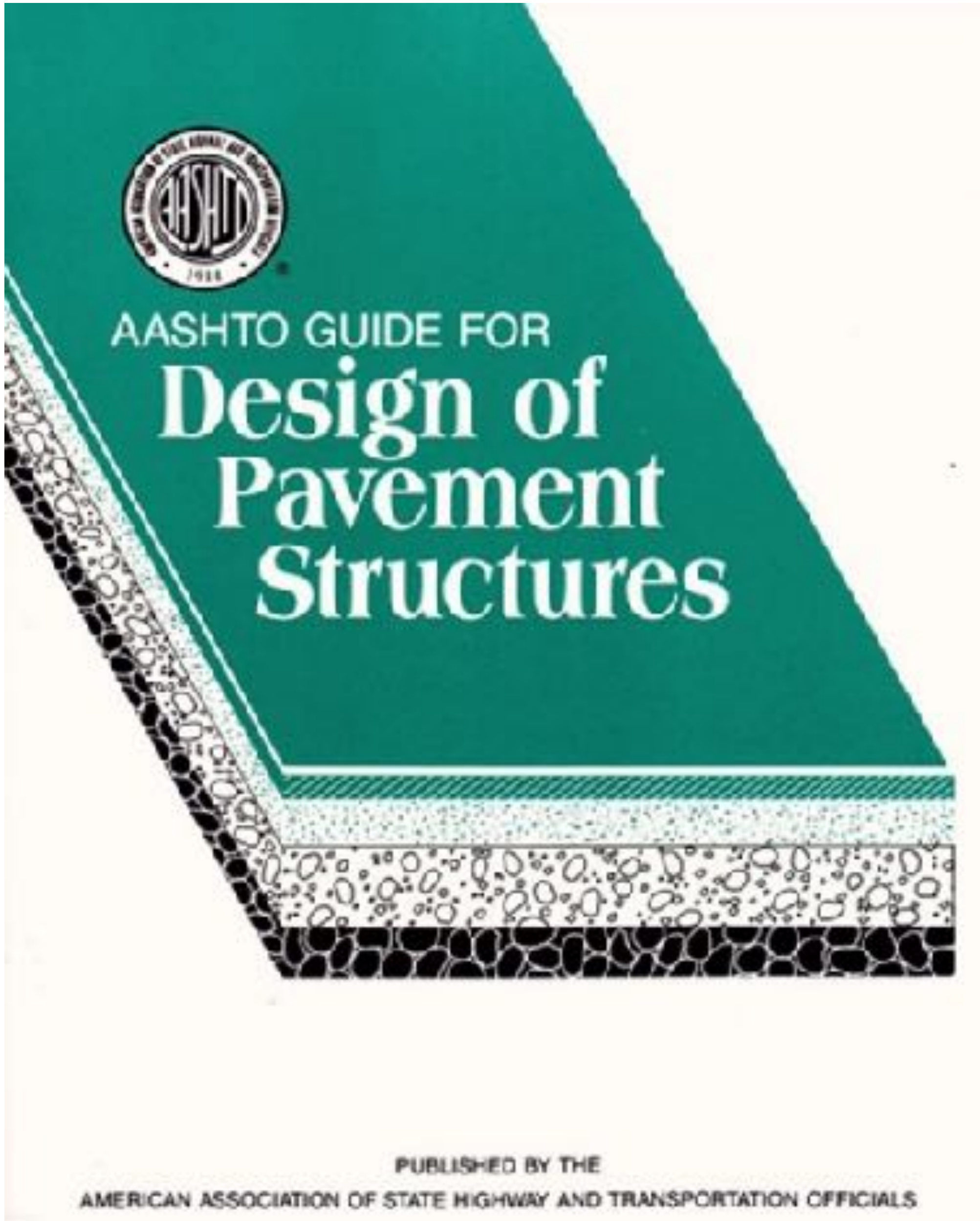
October 18, 2017

FALLING WEIGHT DEFLECTOMETER

Practical◆Cost effective⧫Innovative uses


High Performance Pavement
Materials
Construction
Design

GRI


AASHTO GUIDE FOR
Design of Pavement Structures
PUBLISHED BY THE
AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

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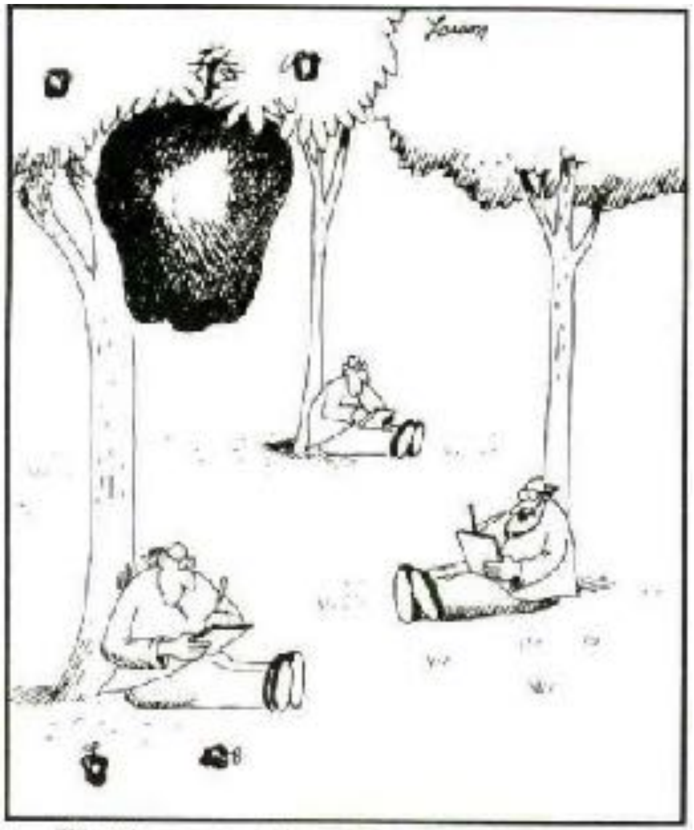
KUAB
Shell

What is a Falling Weight Deflectometer (FWD)?

- Non-destructive pavement loading device
- Imparts a load impulse to the pavement structure
- Simulates a moving wheel load
- Measures deflections at the pavement surface


"Nothing yet. ... How about you, Newton?"

$$F = \sqrt{2Mghk}$$

Where:

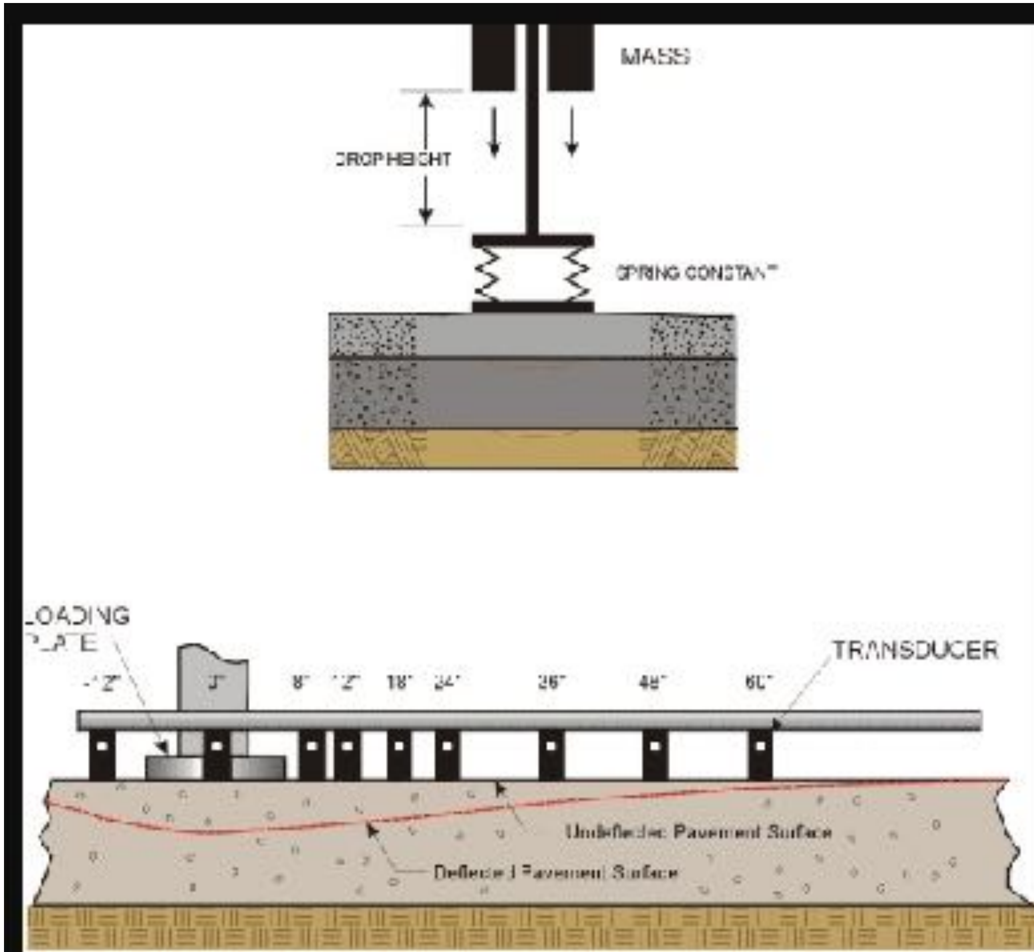
M = mass of the falling weight;
g = acceleration of gravity;
h = drop height;
K = spring constant.

There are 3 possible ways to change the force:

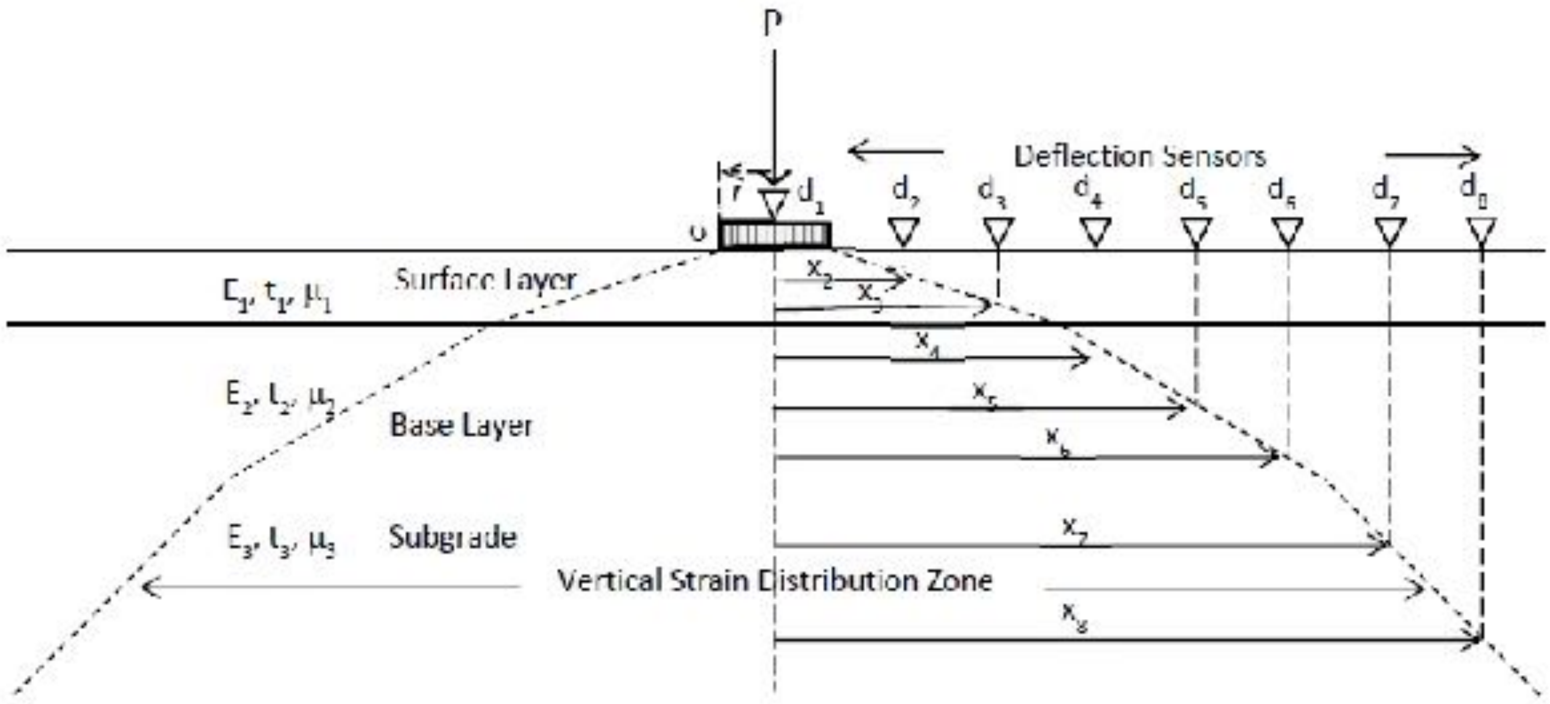
a) change the mass of the falling weight
b) change the drop height
c) change the spring constant

Only alternative "b" is feasible for the FWD (although alternative "a" is used at times).

Note that force is measured by the load cell and not calculated using the above equation.


MASS
SPRING CONSTANT
LOADING PLATE
TRANSDUCER
8"
18"
Undeflected Pavement Surface
Deflected Pavement Surface

FWD Concept


P
Deflection Sensors
r
d1
d2
d3
d4
d5
d6
d7
d8
o
Surface Layer
E1, t1, μ1
x2
x3
x4
x5
x6
E2, t2, μ2
Base Layer
E3, t3, μ3
Subgrade
x7
Vertical Strain Distribution Zone
x8

What is the FWD used for?

- Estimate the structural capacity of the pavement
  - Overlay and Inlay Analysis
  - Analysis of remaining life and allowable traffic loading
  - Estimate of the subgrade & pavement layer elastic moduli values
  - Provides the ability to evaluate rehabilitation alternatives
- Evaluate the uniformity of support and identification of weak areas

- Detection of voids beneath rigid pavements
- Measurement of joint efficiency in rigid pavements

FWD Components

- Load Cell
- LVDT or Geophones
  - Deflection measurement
- Infrared temperature gages
  - Air temperature
  - Pavement surface temperature
- Electronic distance measurement
- Power source
- Control/data acquisition unit

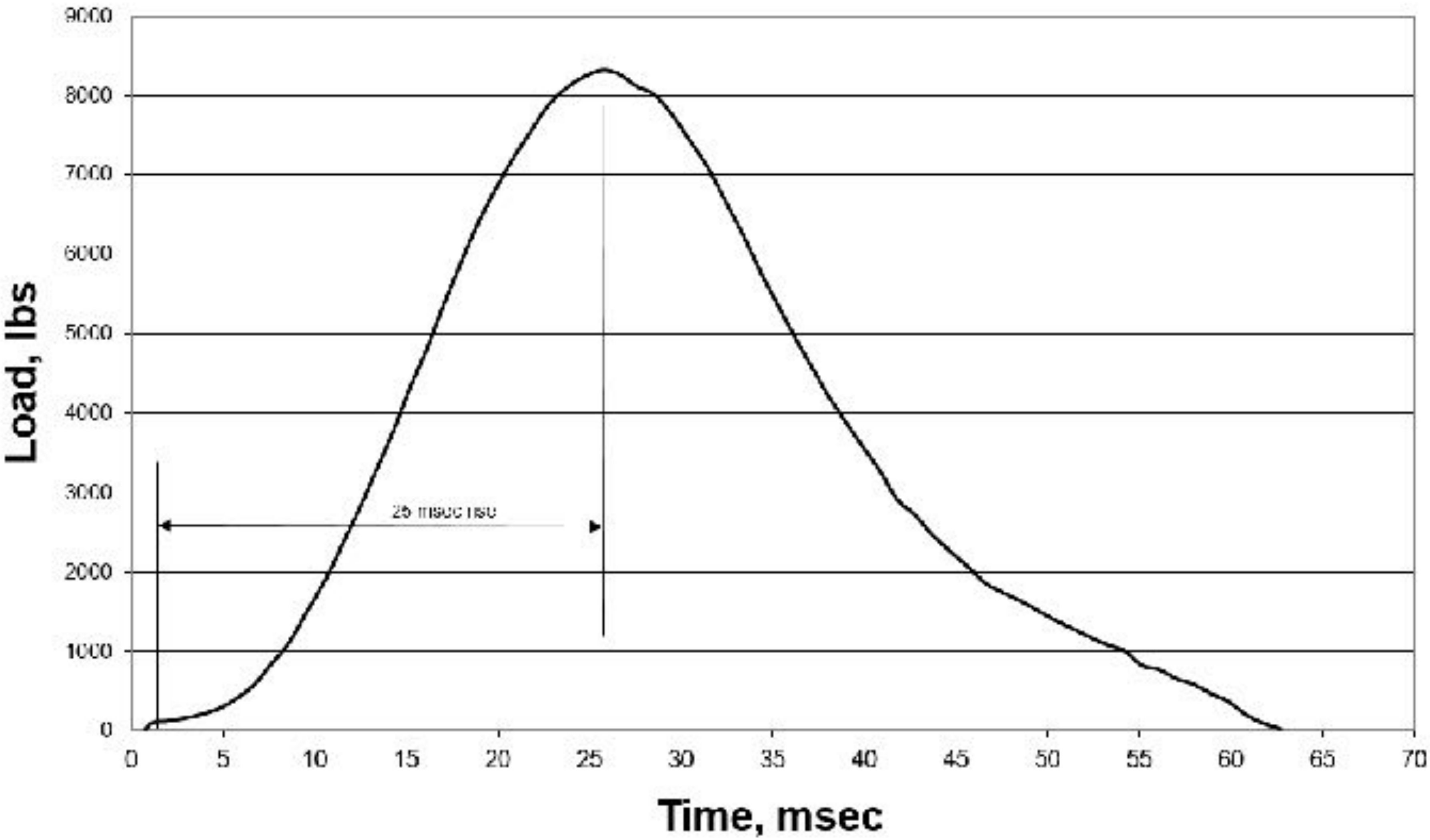
Advantages of FWD Testing

- Non-destructive test
- Wide coverage since testing can occur quickly
  - Typically 1 to 2 minutes per test
  - Can easily test different pavement conditions (for example difference between the inner and outer wheel path)
- Data compiled and viewed in real-time
- Gives an accurate assessment of the in situ properties of the pavement structure and subgrade

Limitations of FWD Testing

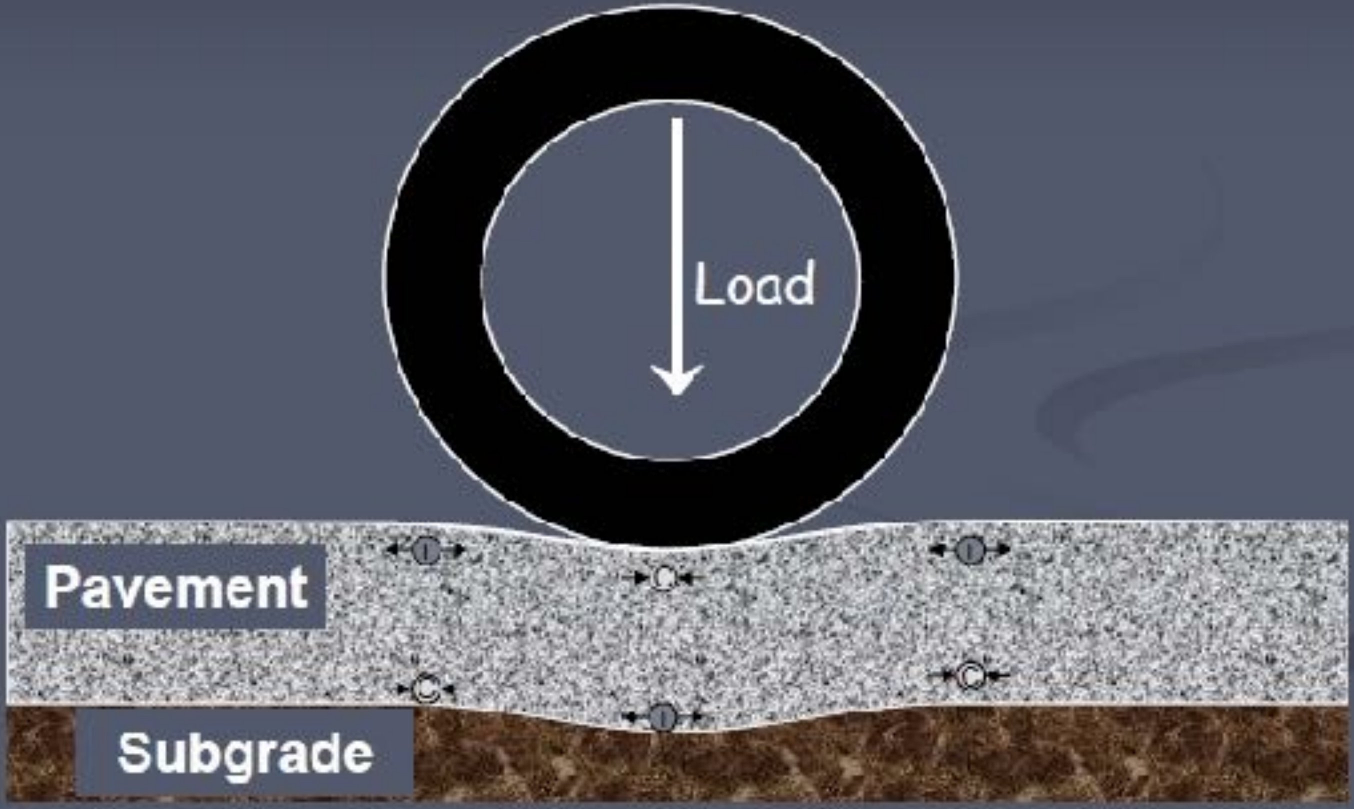
- The impact load must be adjusted to match the dynamic load of a heavy vehicle
- Analysis and interpretation of the results requires engineering judgement

FWD Load Pulse



Pavement Deflection

Pavement Deflection



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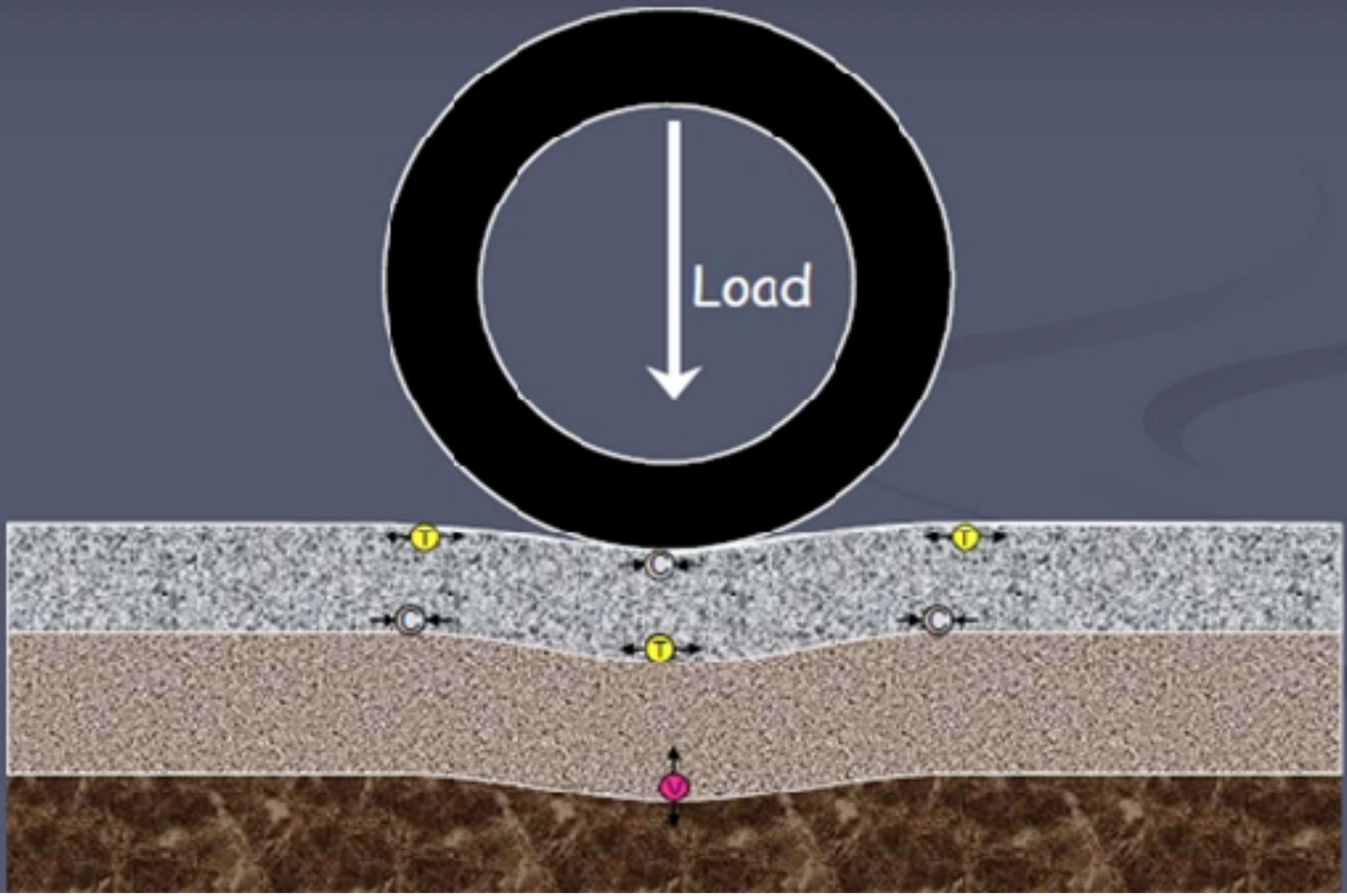
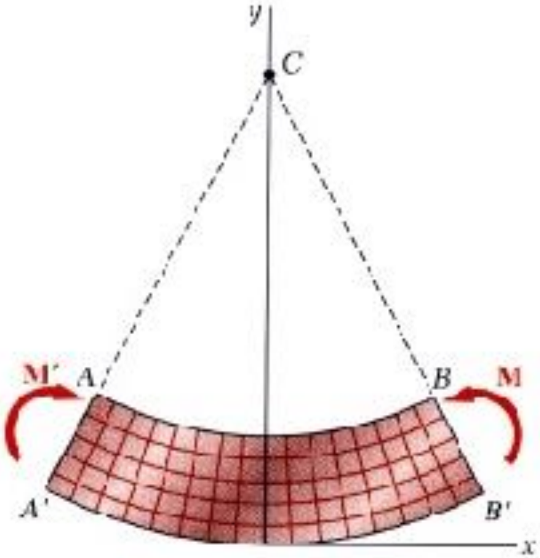
Locations of Critical Strains

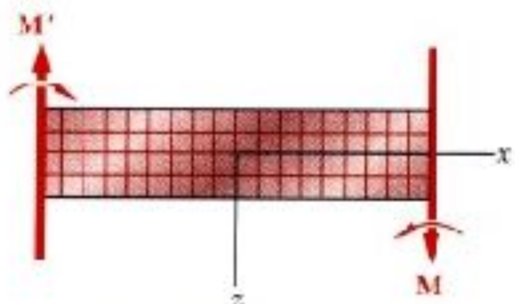


MECHANICS OF MATERIALS

Bending Deformations



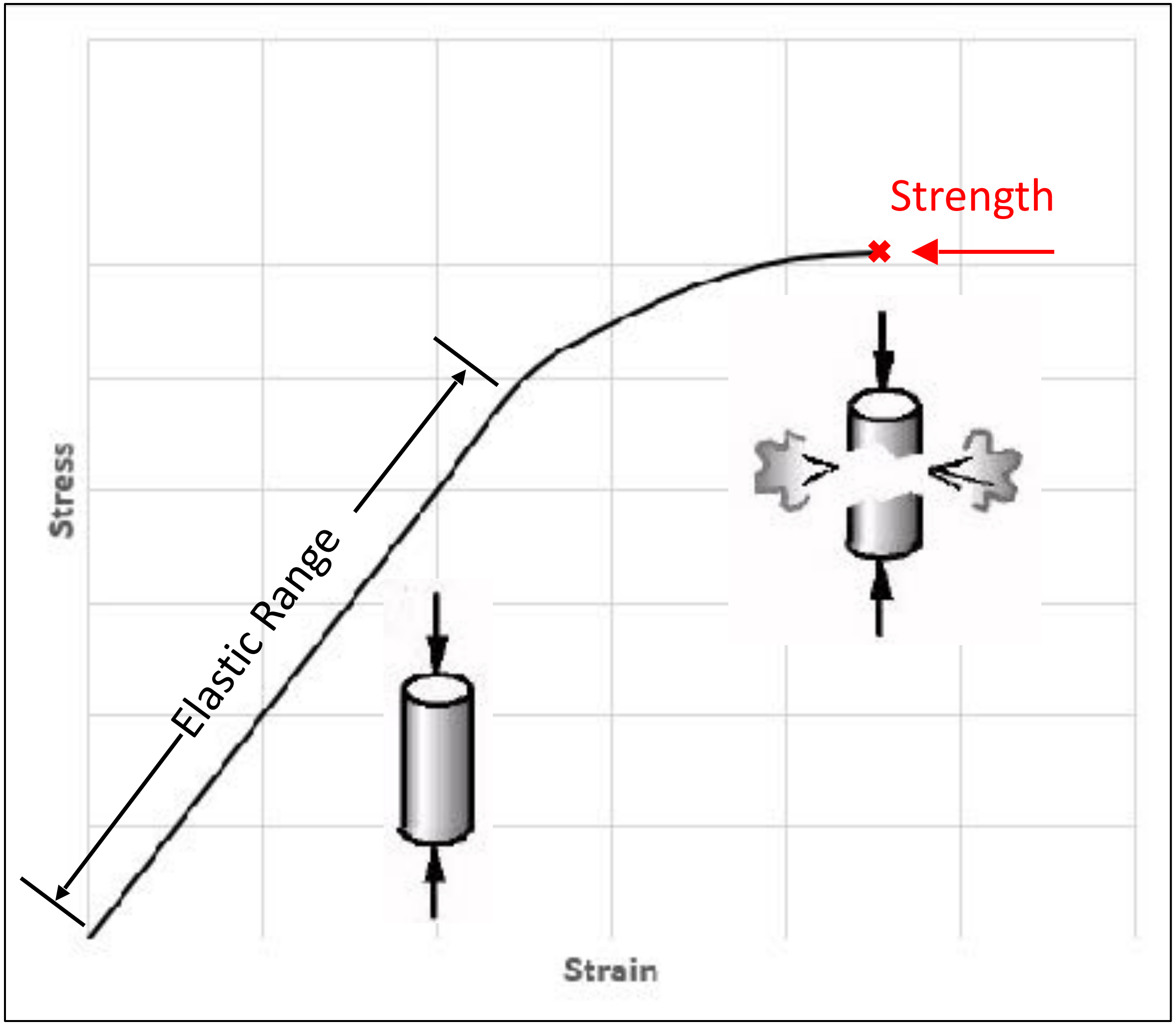
(a) Longitudinal, vertical section (plane of symmetry)



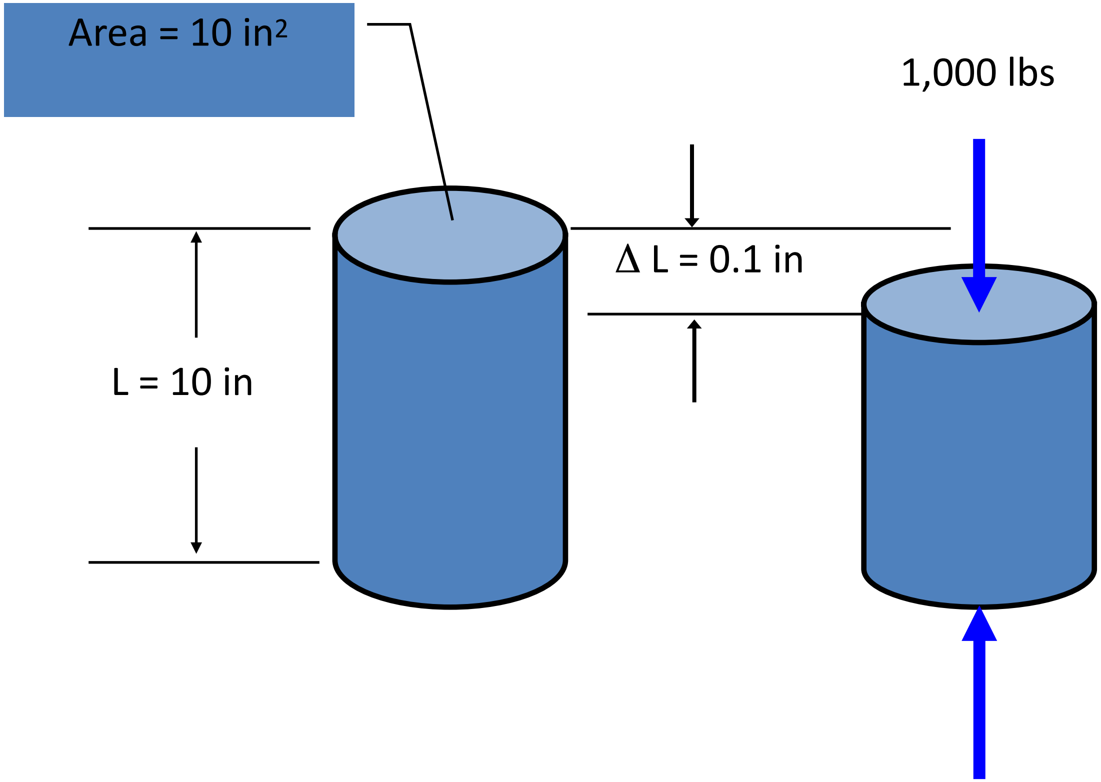
(b) Longitudinal, horizontal section

Beam with a plane of symmetry in pure bending:

- member remains symmetric
- bends uniformly to form a circular arc
- cross-sectional plane passes through arc center and remains planar
- length of top decreases and length of bottom increases
- a *neutral surface* must exist that is parallel to the upper and lower surfaces and for which the length does not change
- stresses and strains are negative (compressive) above the neutral plane and positive (tension) below it



Strength
Elastic Range
Stress
Strain



Stress = 1000/10 = 100 psi

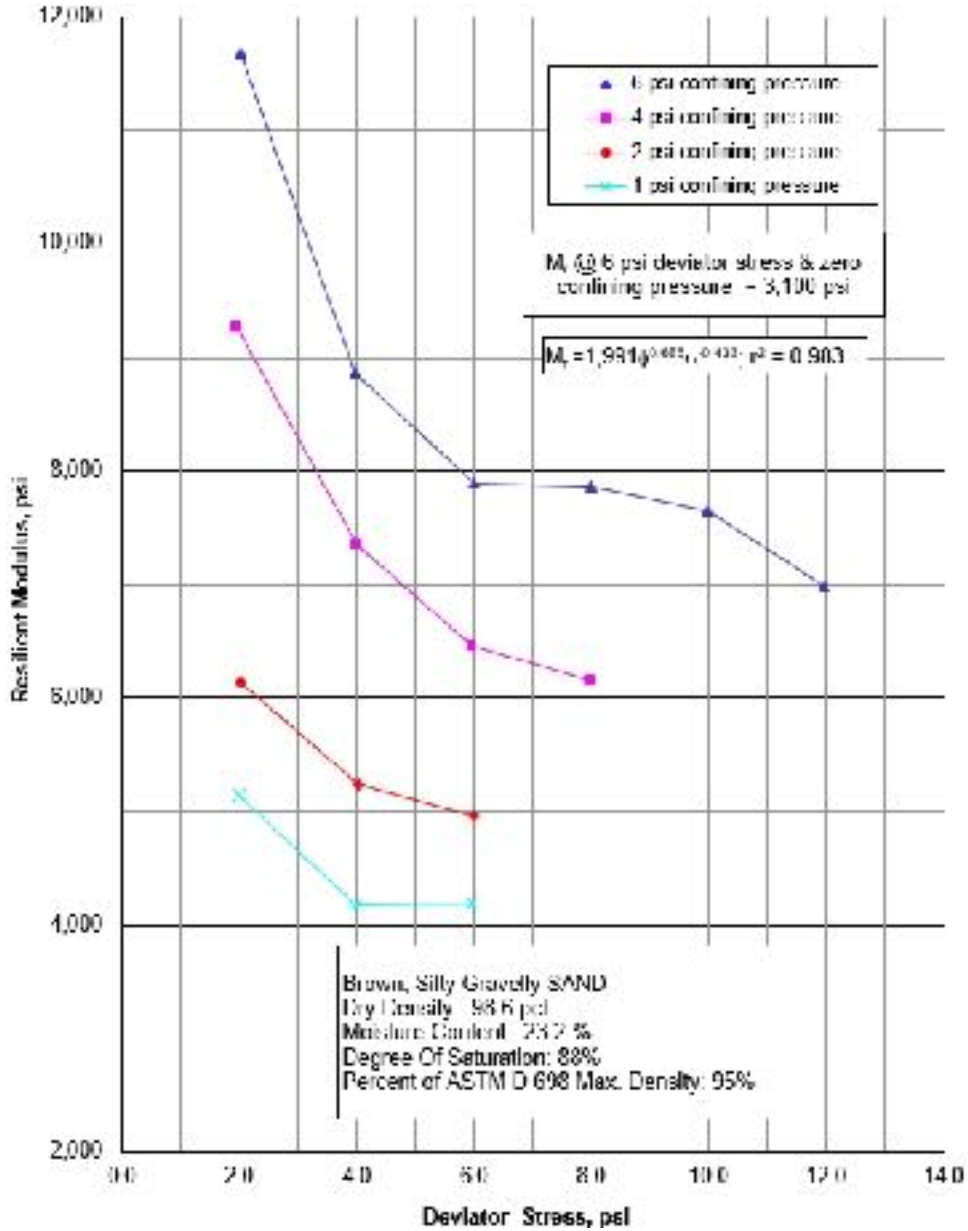
Strain = 0.1/10 = 0.01 in/in

M_r = Stress / Strain, psi

M_r = 100 / 0.01 = 10,000 psi

Triaxial Resilient Modulus Test Results - Figure 6

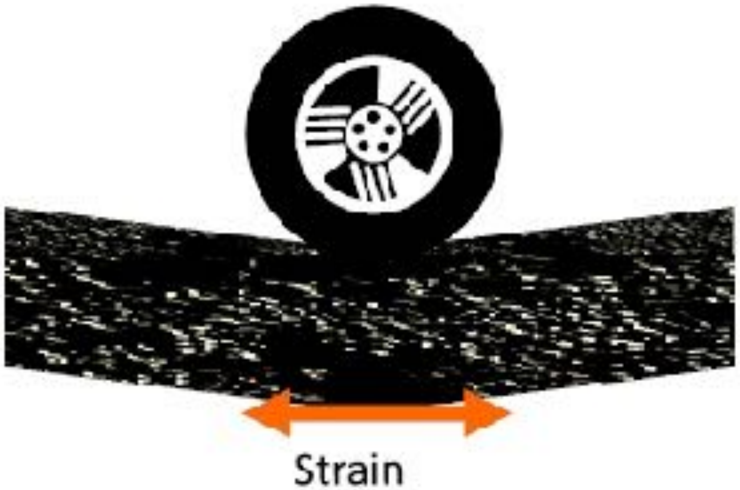
(Bulk sample from Boring B-3 compacted to 95% of standard Proctor)

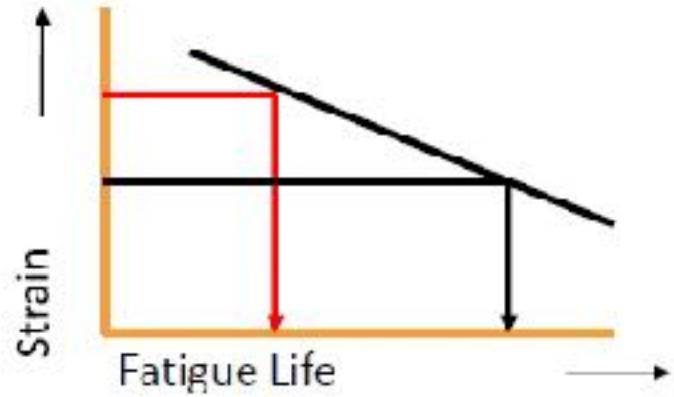


Fatigue Theory

High Strain = Short Life

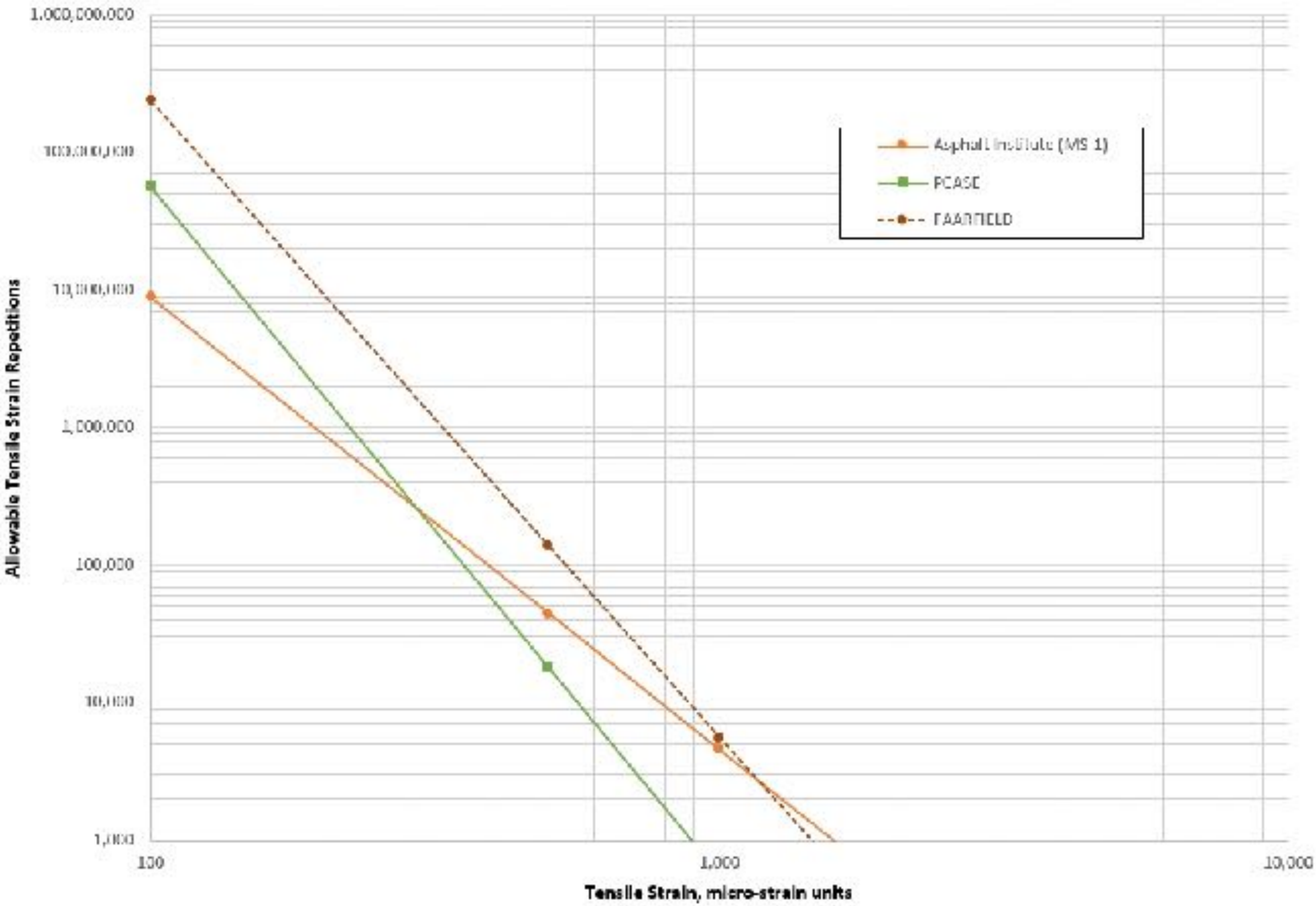
Low Strain = Long Life



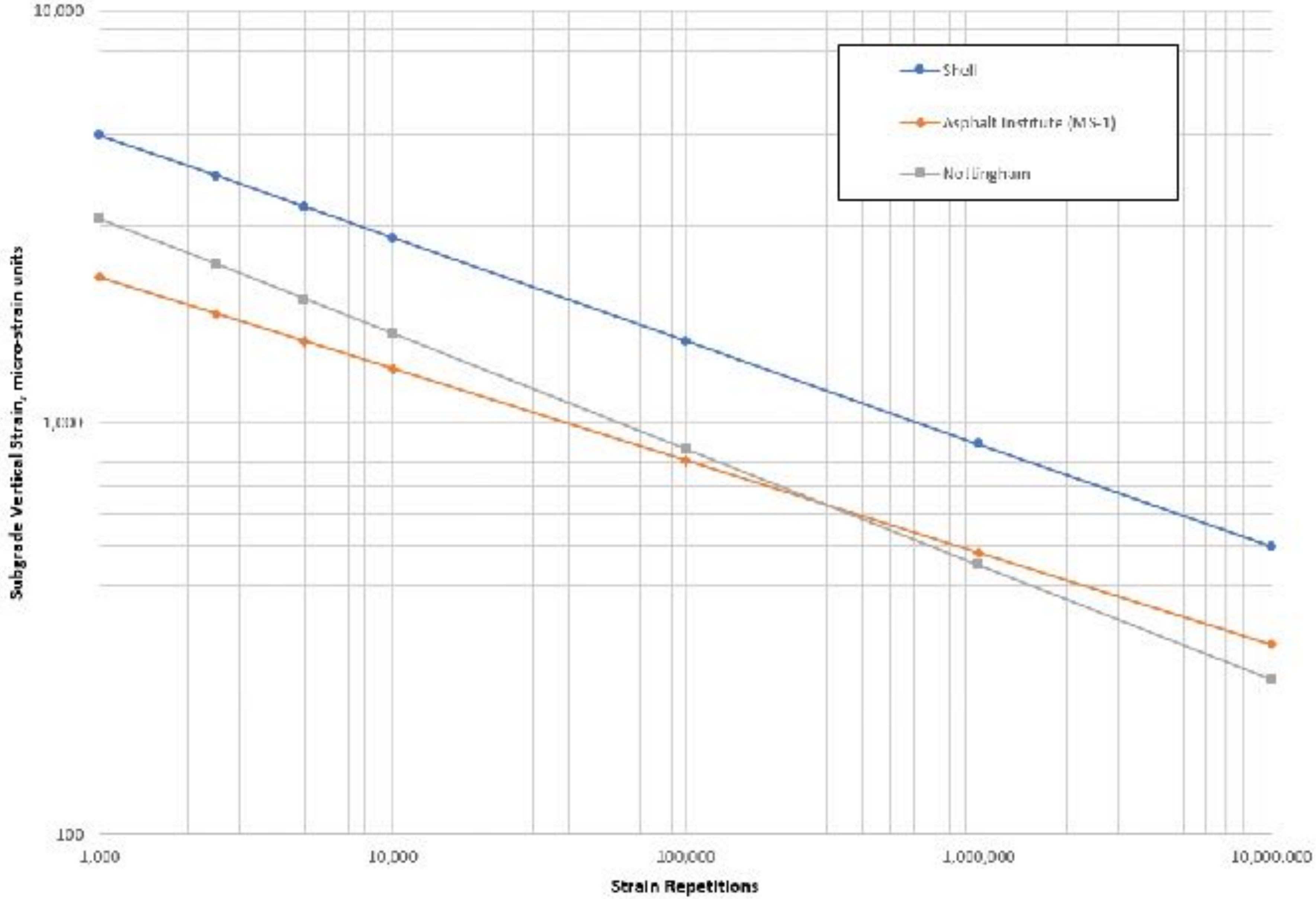


Extrapolations of loads from AASHO Road Test

Allowable Tensile Strain Repetitions Comparison



Allowable Subgrade Strain Comparison



Comparison of Allowable Asphalt Concrete Tensile Strain Repetitions Criteria for Given Strain Values

Asphalt Institute (MS-1) Tensile Strain Fatigue Criteria

Allowable tensile strain repetitions, N_f, based on NCHRP 291 fatigue relationship with failure defined as alligator cracking in 45% of wheelpath and with adjustment for effect of air voids per Asphalt Institute's Research Report No. 82-2, 8/82, as shown by the following equation:

$N_f = F_1 * Cm * F_2 * \varepsilon_t ^{F_3} * E_{ac} ^{F_4}$ Eq. 7

ε_t = tensile strain at bottom of AC layer, in/in (or m/m)

E_{ac} = dynamic elastic modulus of AC, psi

F_1 =	18.4	Shift factor for difference between laboratory repetitions to failure and field repetitions to failure (corresponding to 45% cracking in wheel paths of AASHO Test Track)
F_2 =	0.00432	regression constant
F_3 =	-3.291	regression constant
F_4 =	-0.854	regression constant

$C_m = 10^M$ factor to adjust laboratory fatigue life for effect of air voids and asphalt volume in asphalt concrete mix

$M = 4.84 * (V_b/(V_b+V_v) - 0.69)$, V_b = asphalt content, % by volume, V_v = volume voids, %

$V_b = P_{ac}/0.434$ =	11.5	computed from values below in allowable strain repetitions table
C_m =	0.469	computed from values below in allowable strain repetitions table

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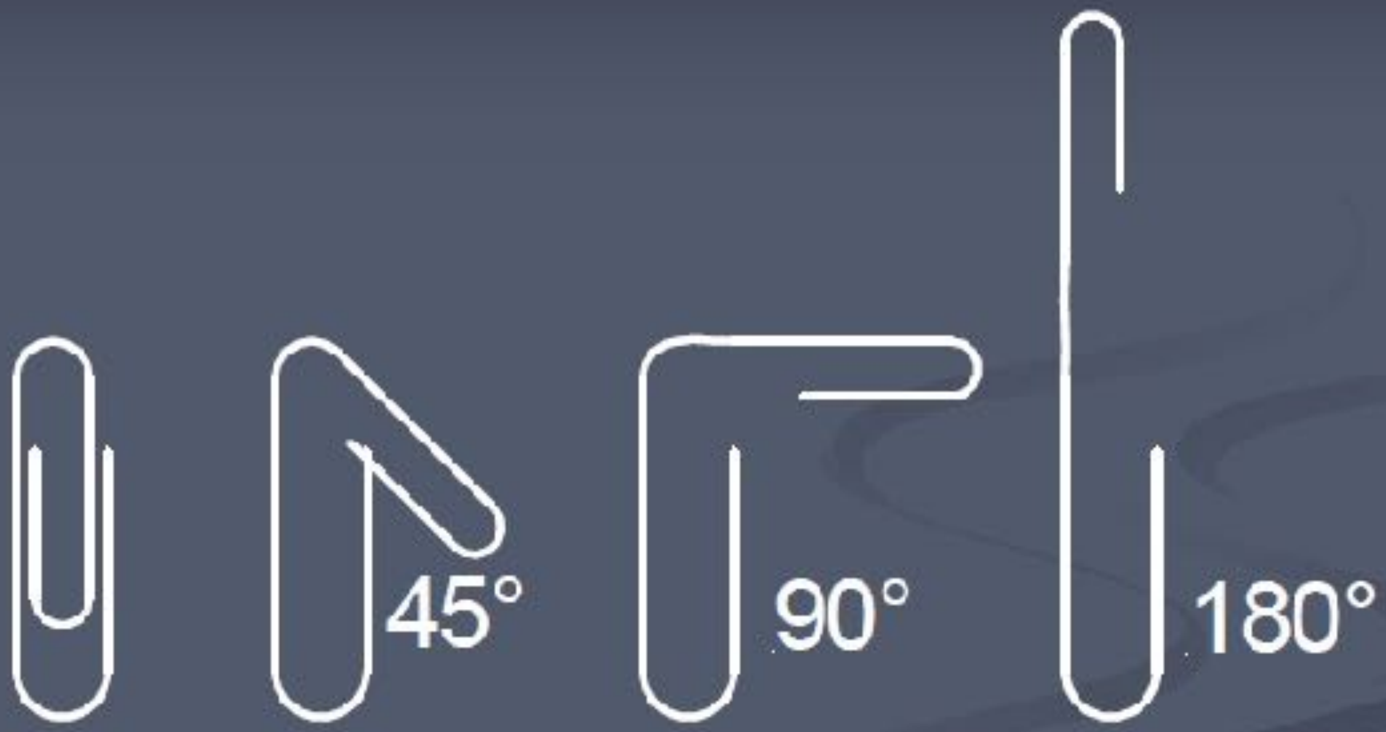
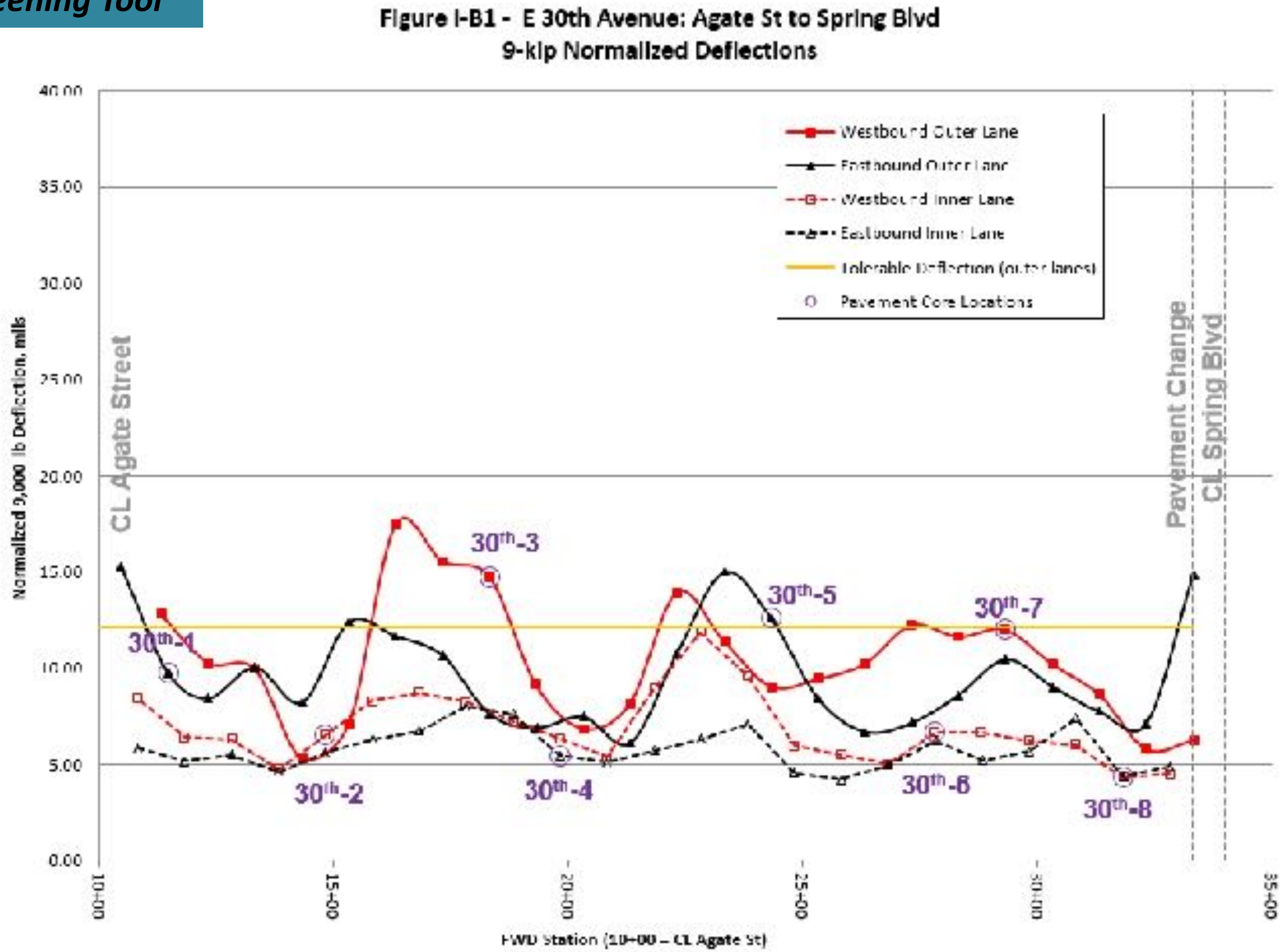
Pavement Fatigue



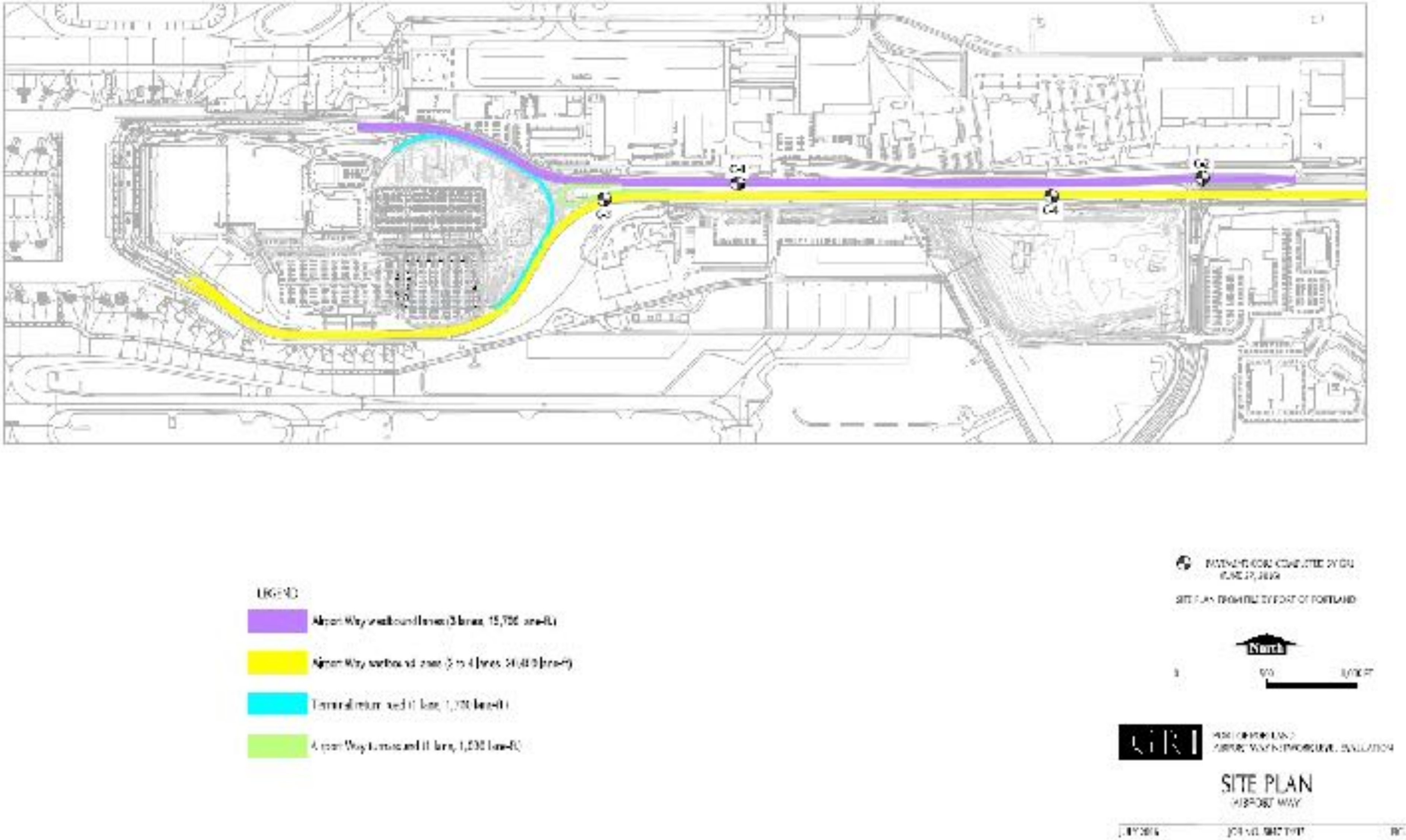
FWD 80/20 Rule

- Use of the FWD as a screening tool
- Network level evaluation

Screening Tool

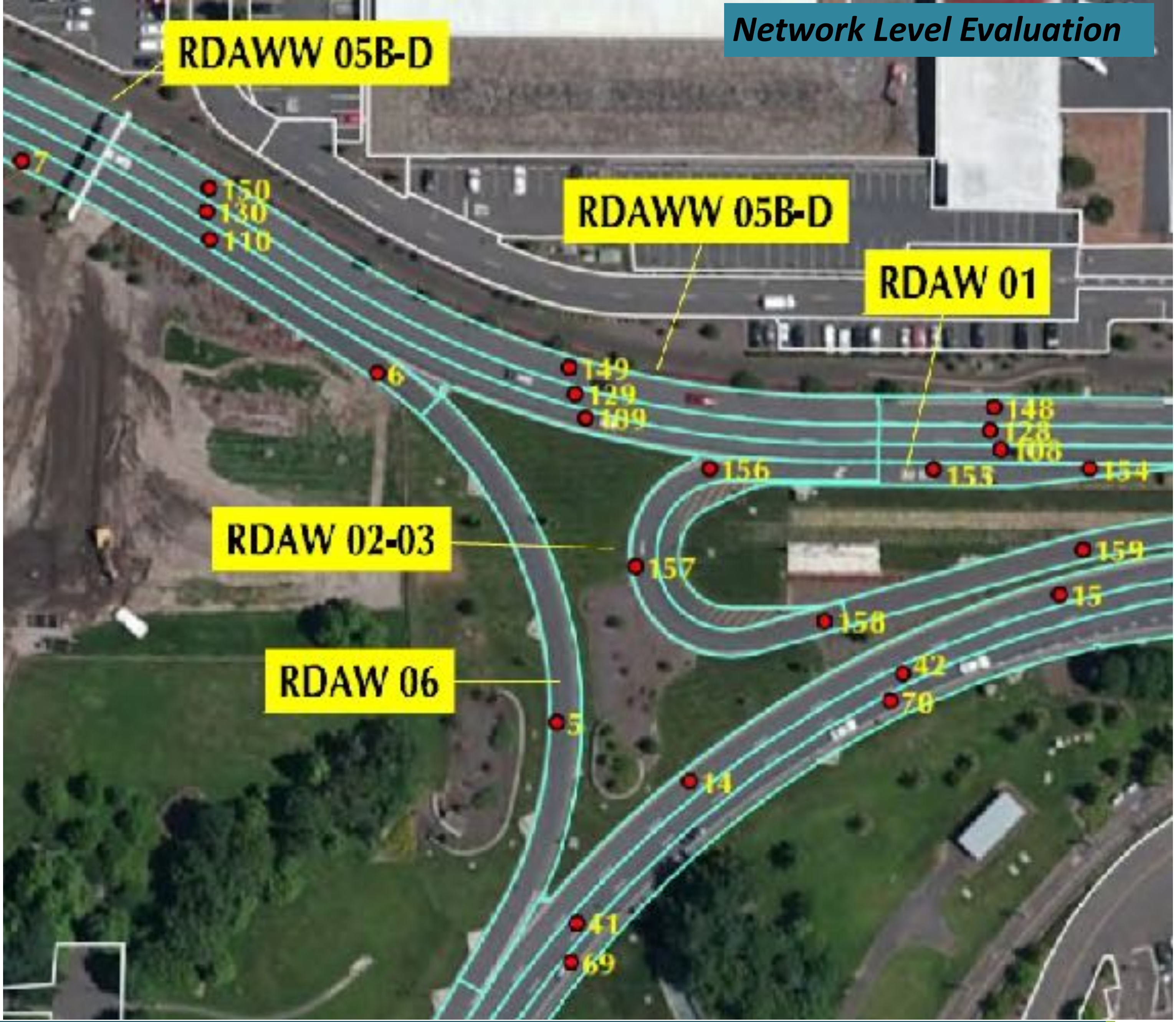


Network Level Evaluation



Network Level Evaluation

Network Level Evaluation



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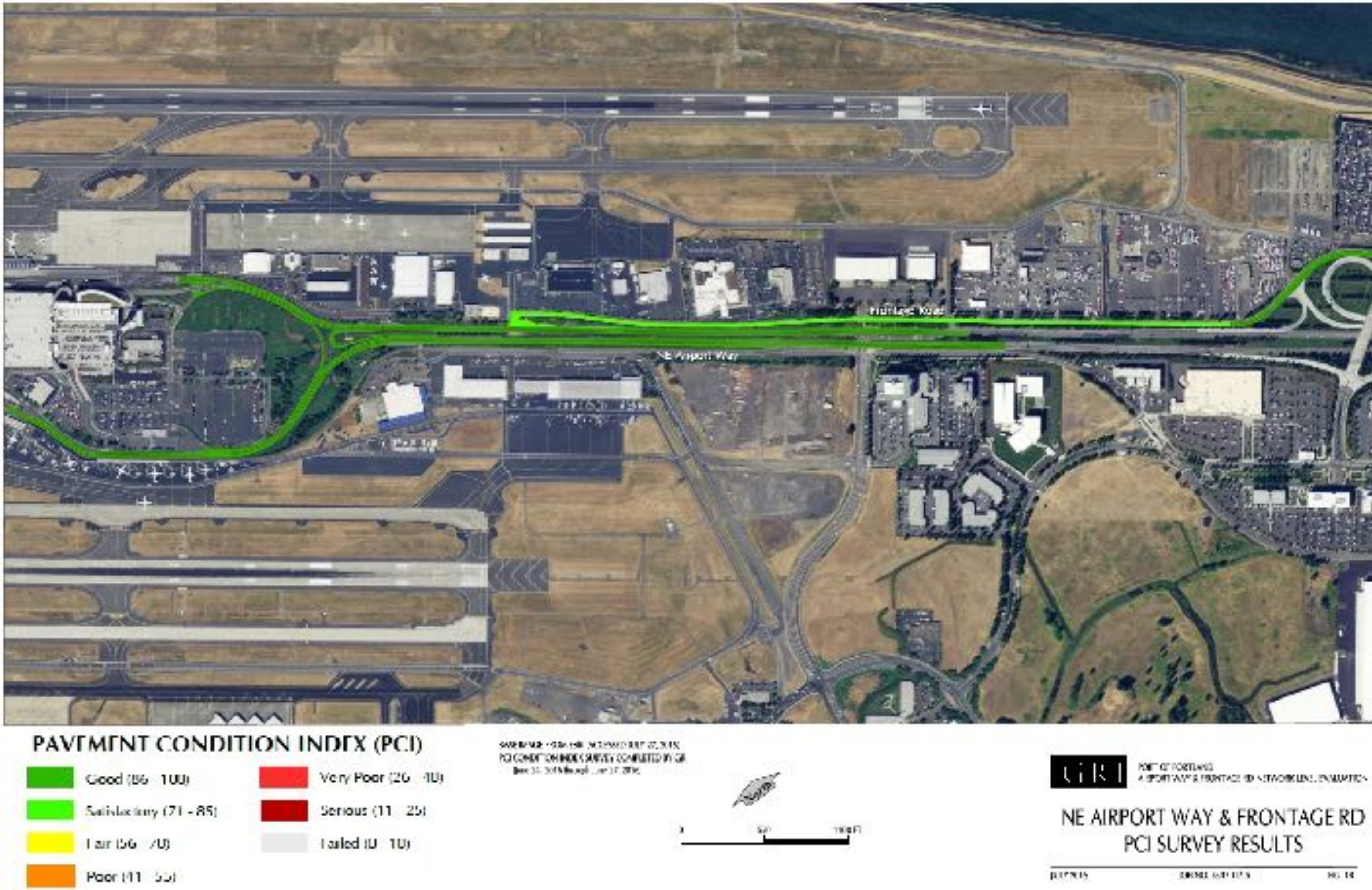
Network Level Evaluation



Network Level Evaluation

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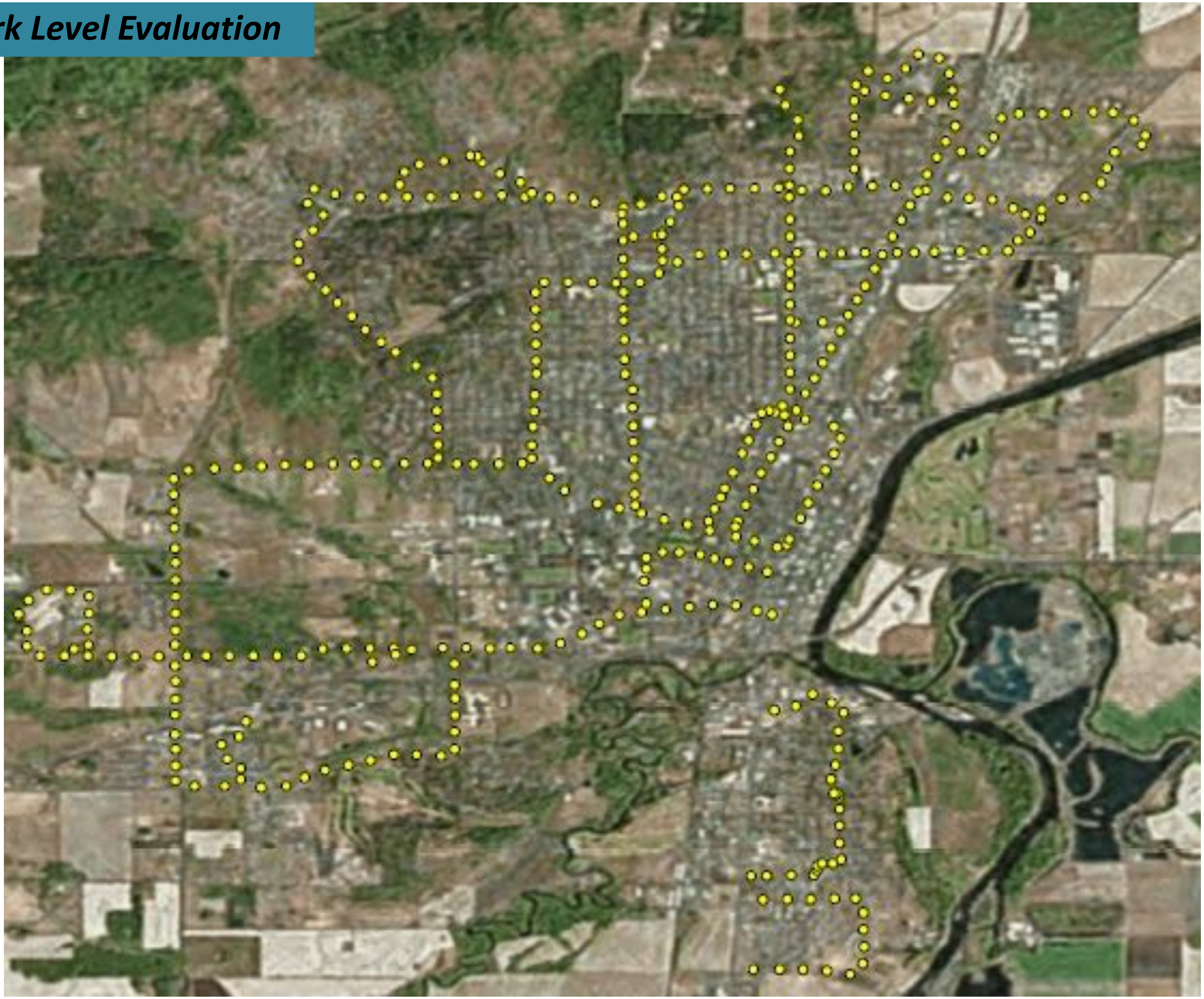
Network Level Evaluation

- Estimated Life: 20+ Years
- Estimated Life: 15-20 Years
- Estimated Life: 10-15 Years
- Estimated Life: 5-10 Years
- Estimated Life: < 5 Years

NE AIRPORT WAY & FRONTAGE RD
REMAINING PAVEMENT LIFE

Network Level Evaluation

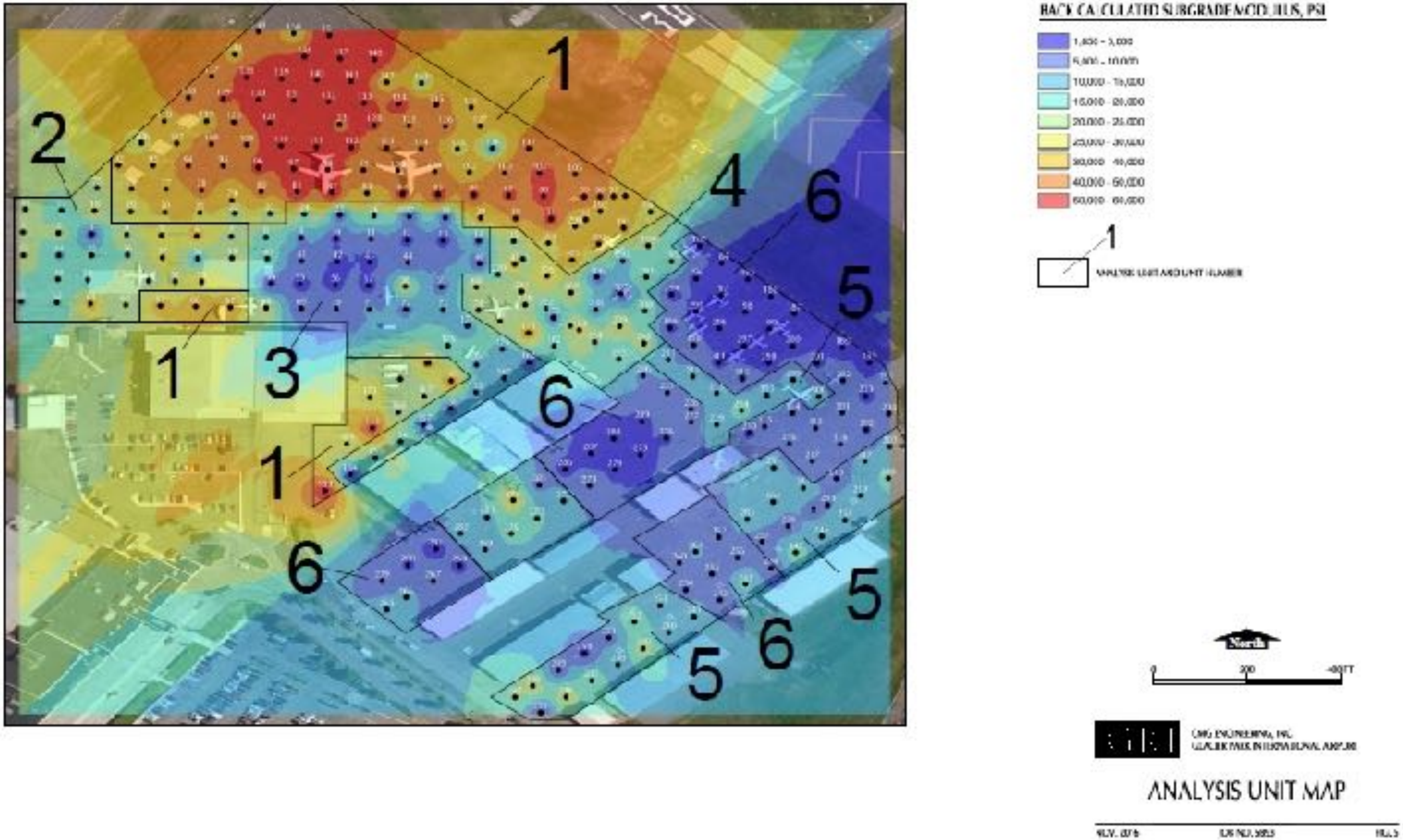
Network Level Evaluation



Network Level Evaluation

All Data	PCI	Overlay, in.		
	Category	Average	Average, non zero	85th Percentile
	Very Good	1.15	2.12	2.89
	Good	1.56	2.48	3.73
	Average	1.26	2.41	3.22
	Fair	2.59	3.83	5.78
	Poor	2.31	3.01	4.60
	Very Poor	2.22	2.40	4.60

Backcalculated Subgrade Modulus for Design



Questions ?