2002 Pavement Design

Federal Highway Administration

June 2001

Thomas P. Harman

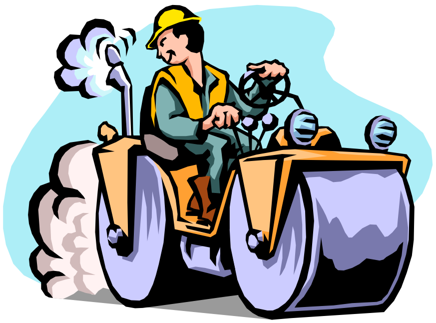
Asphalt Team Leader

Predicting Pavement Performance

- Pavements are designed to fail

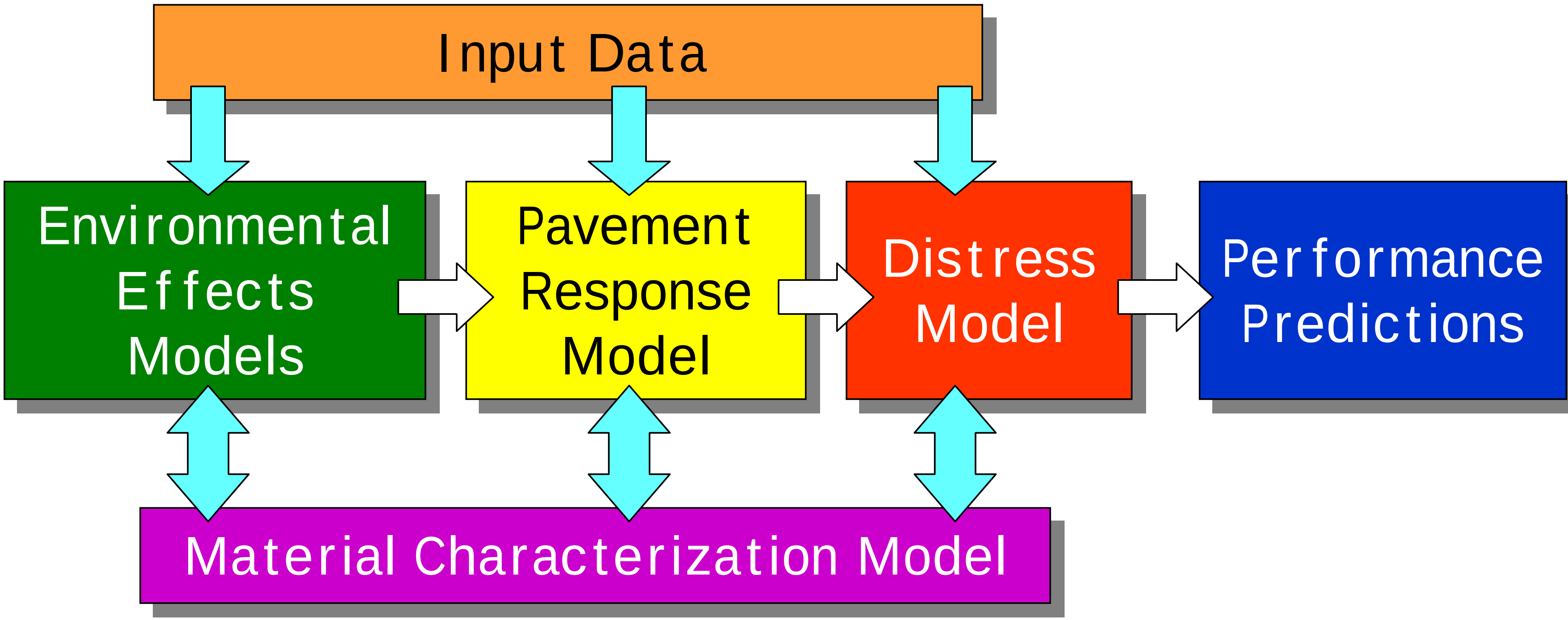
- But how do they perform?

Defining Performance



- Structural vs. functional
  - Structural: load carrying capacity
  - Functional: ride quality and safety
- Associated failures
  - Load: caused by traffic
  - Non-load: caused by climate, materials, and construction

Performance Modeling



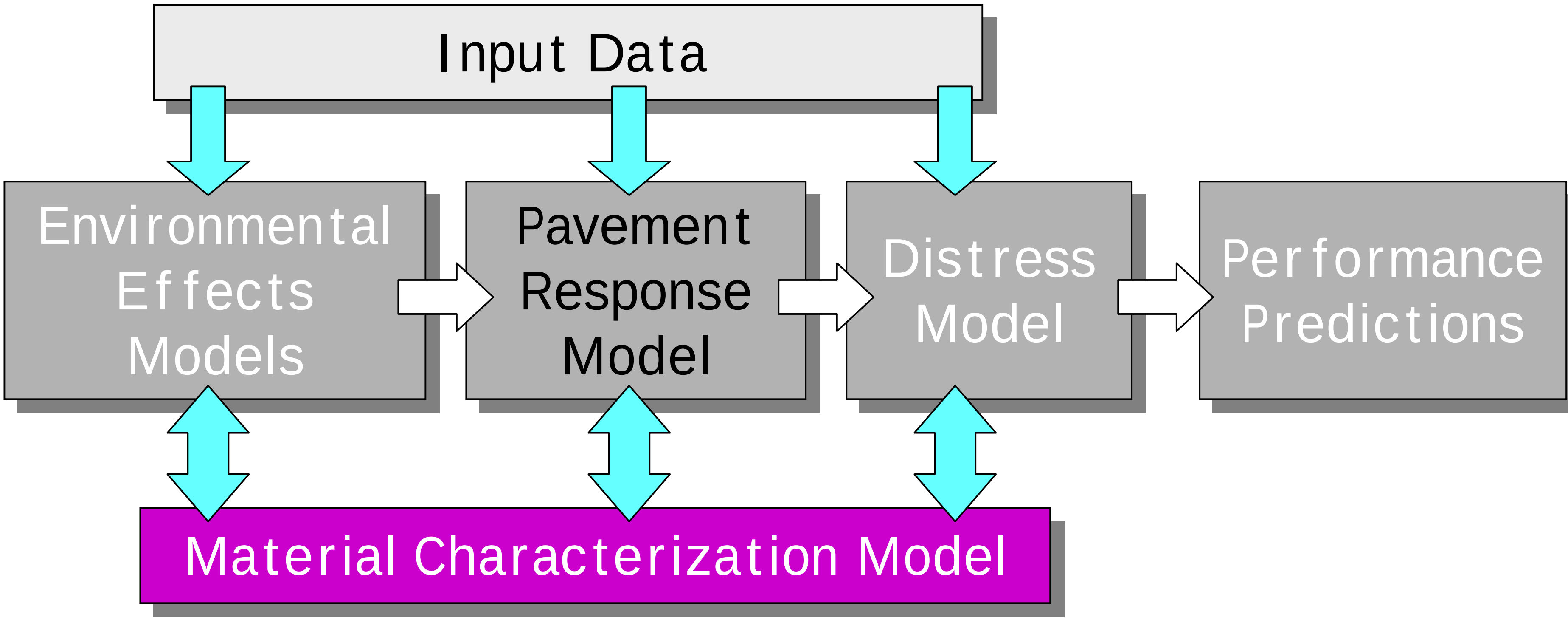
Our Project

- State of Confusion
- 10 mile section
- 36 feet wide

Our Project

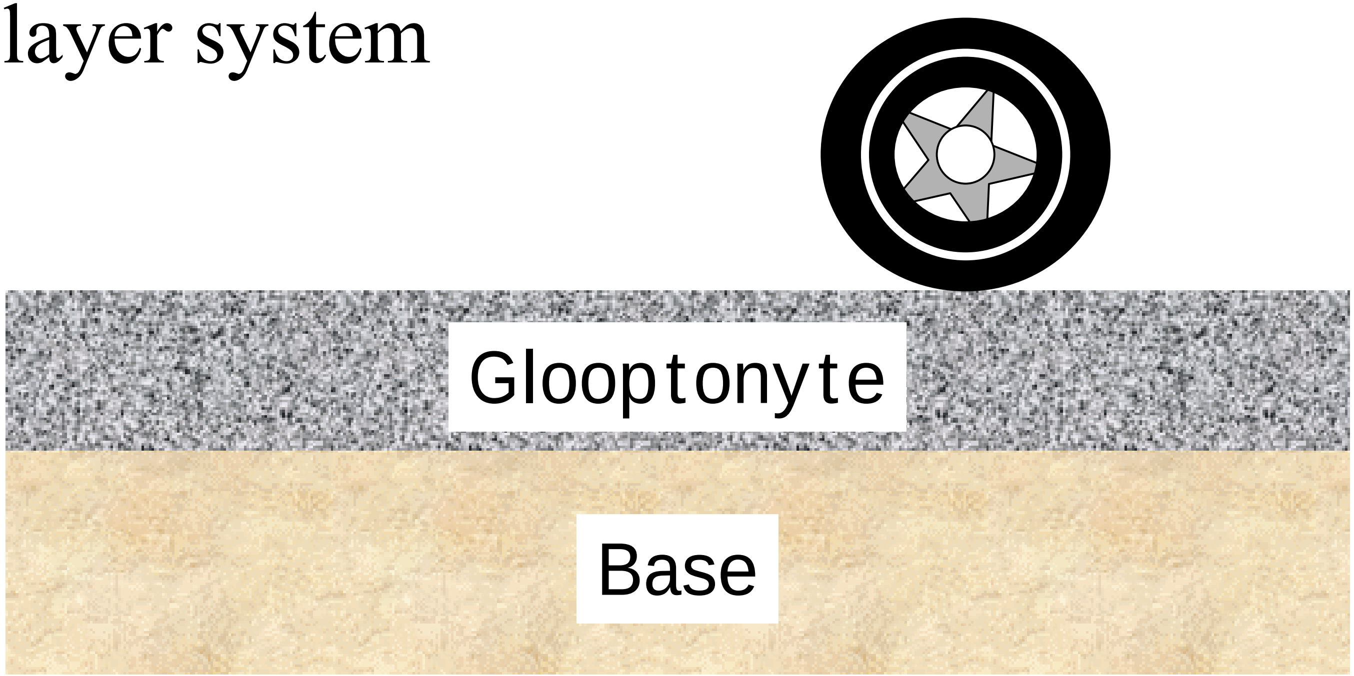
- Materials
- Environment
- Traffic
- Modeling
- Performance Prediction

Material Characterization



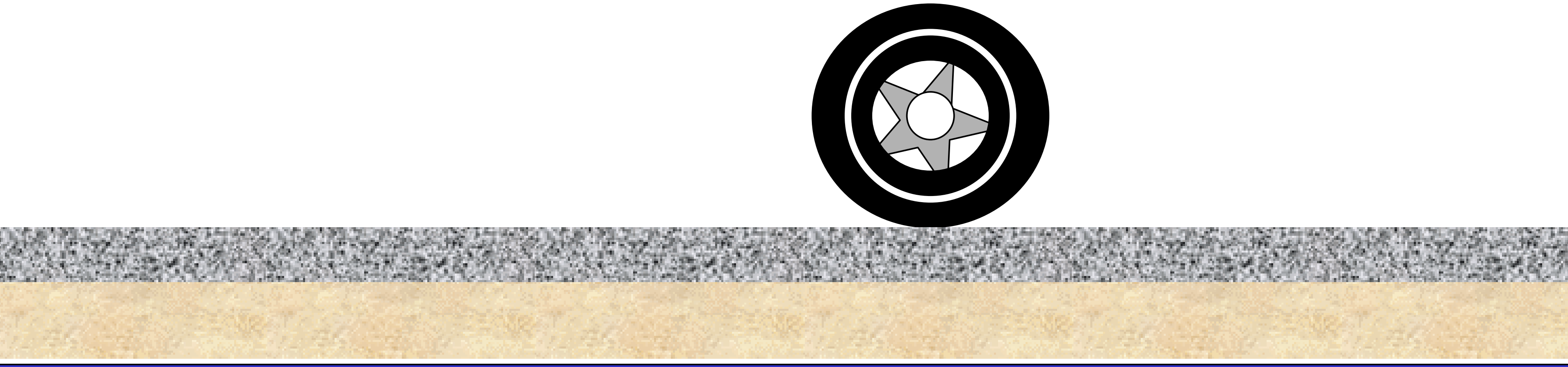
Materials

- 2 layer system



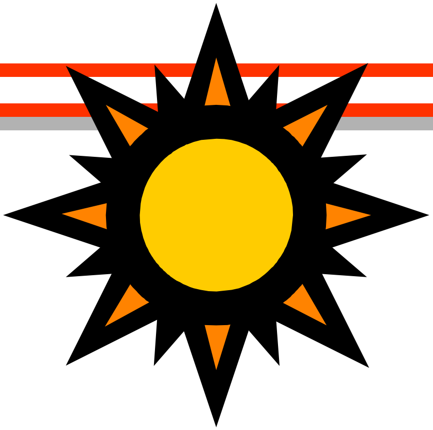
Materials Characterization

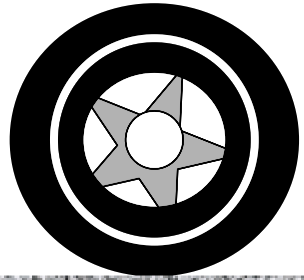
- Response to. . .
  Load



Materials Characterization

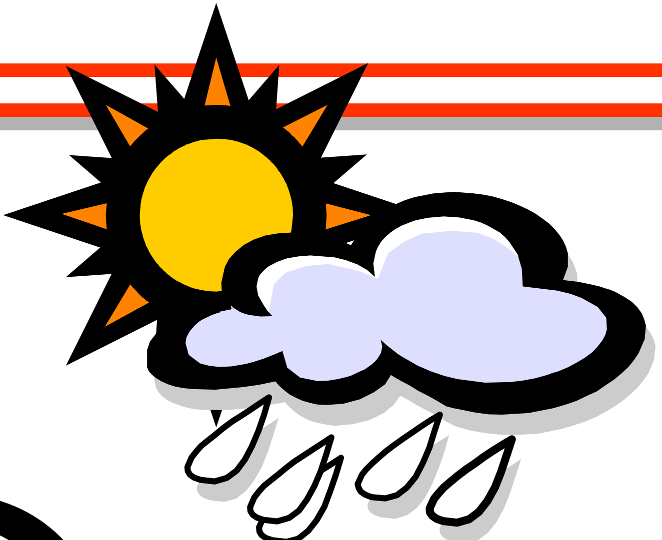
- Response to. . .
  Load,
  Temperature

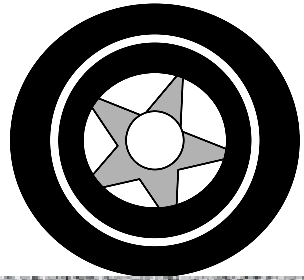




Materials Characterization

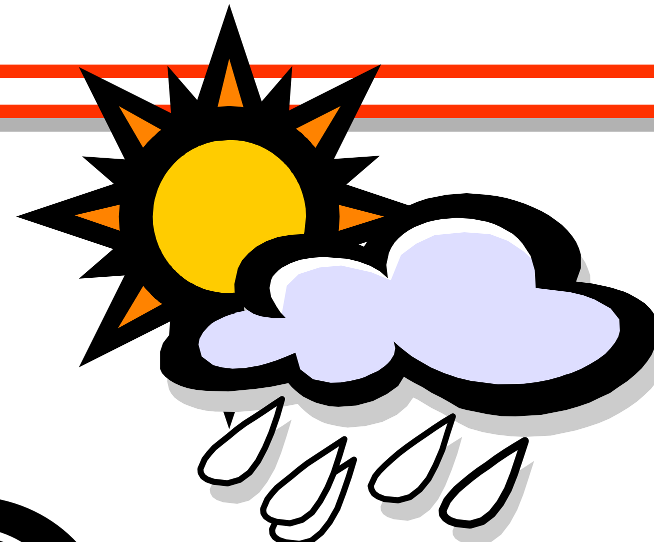
- Response to Load, Temperature, Moisture

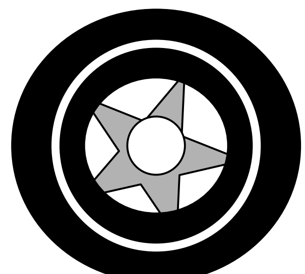




Materials Characterization

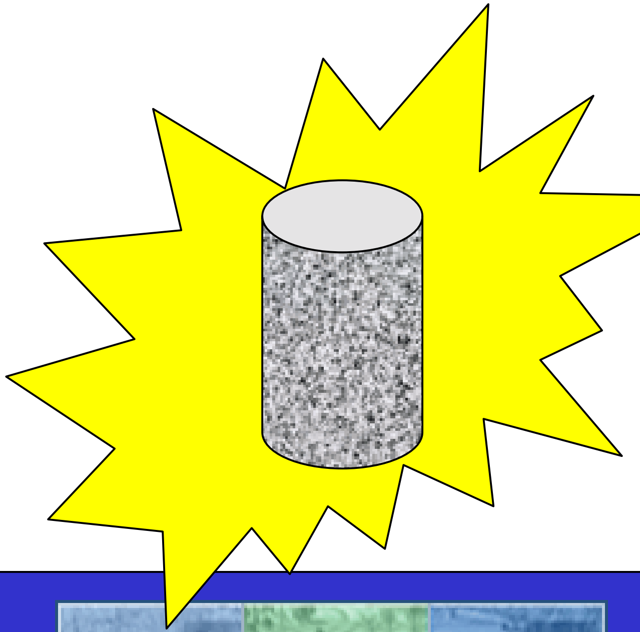
- Response to Load, Temperature, Moisture, & Time.



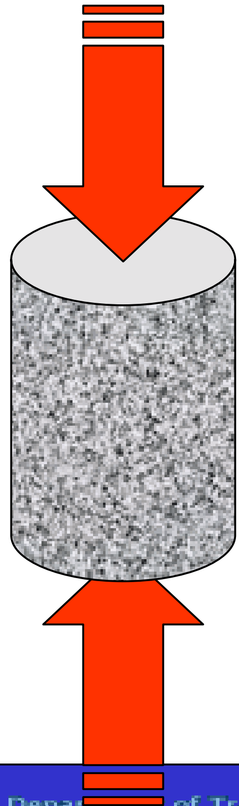


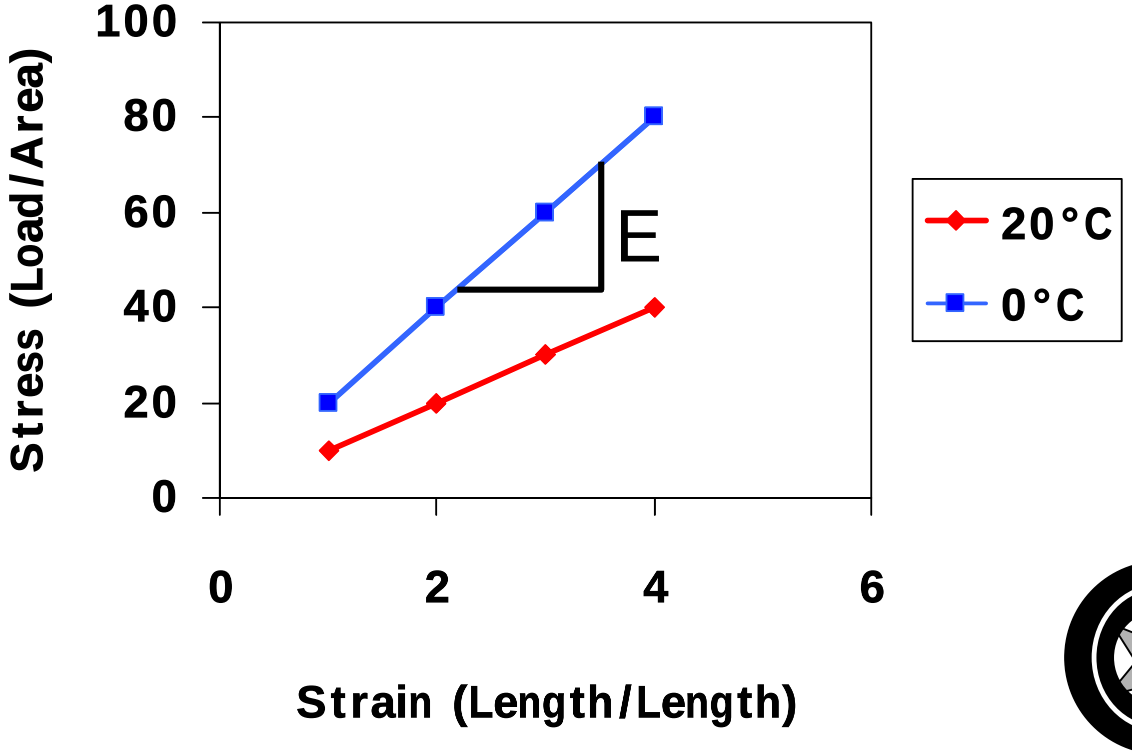
Glooptonyte

- All Glooptonyte is the same
- It is homogeneous, isotropic, and elastic
- It is <u>not</u> effected by moisture
- It is <u>not</u> effected by time



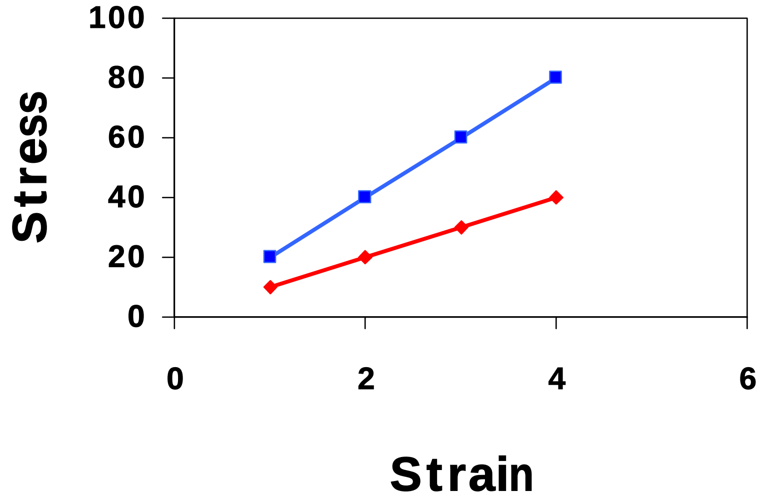
Glooptonyte



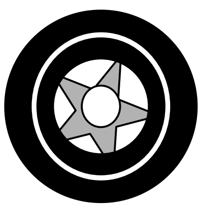


Material Characterization Model

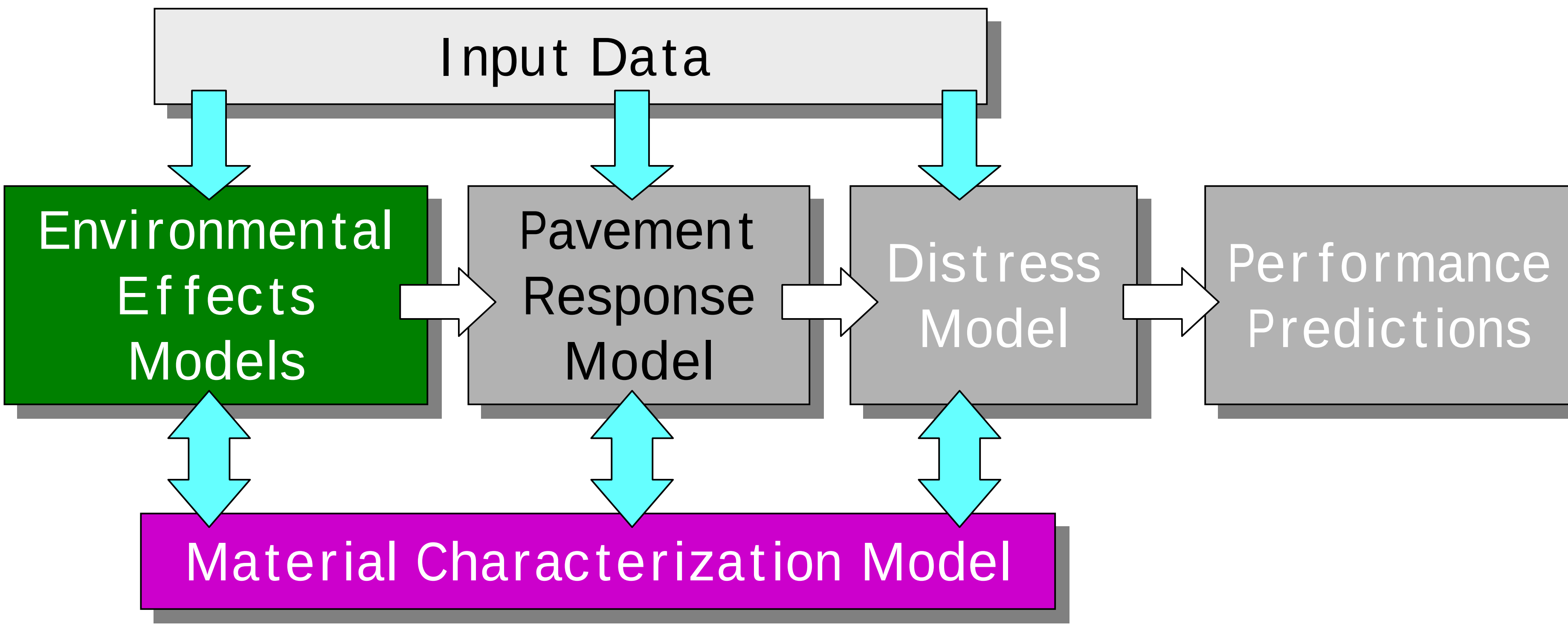
- Modulus, E = Stress / Strain
- Predictive Model
  - Strain = Stress / E



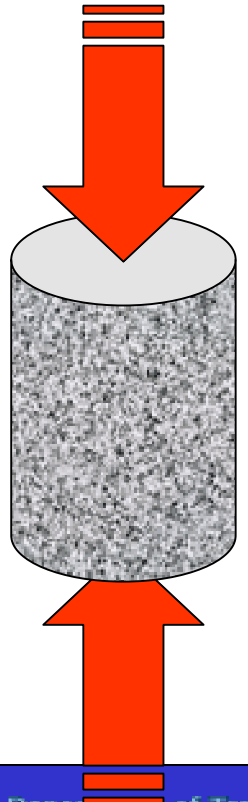
- Does our model work?

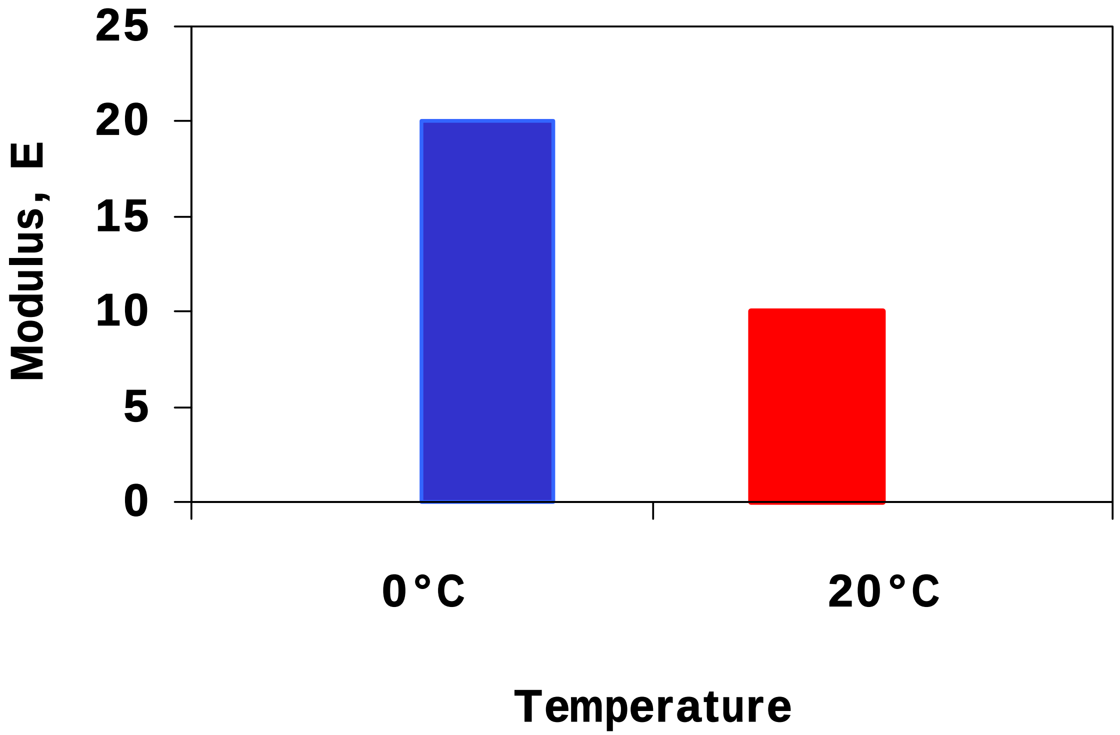


Environmental Effects



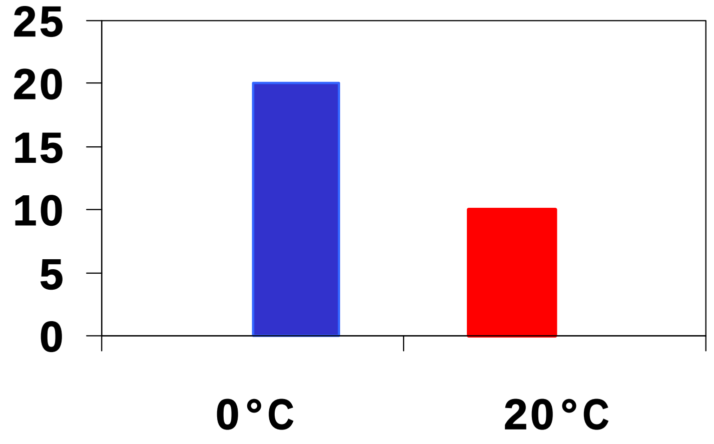
Glooptonyte





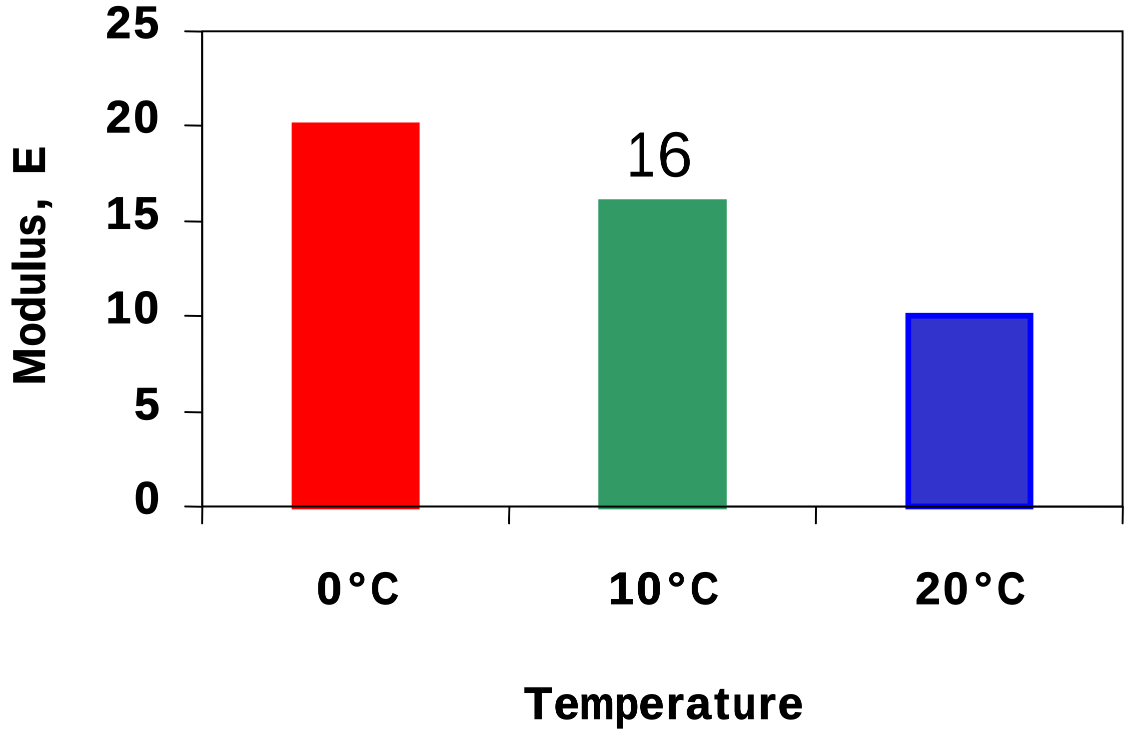
Environmental Effects Model

- Modulus, E = 20 – 0.5 (T)
  - T is the temperature in °C
- Does our model work?

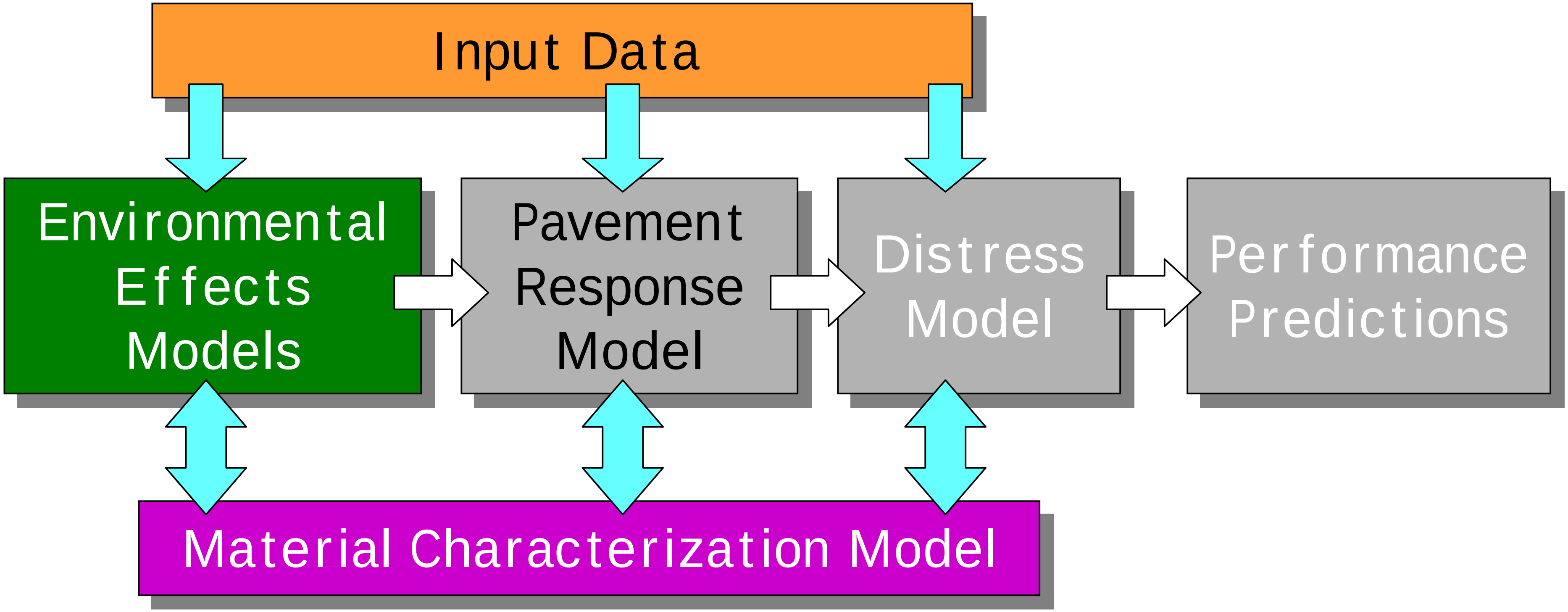


Testing the Model

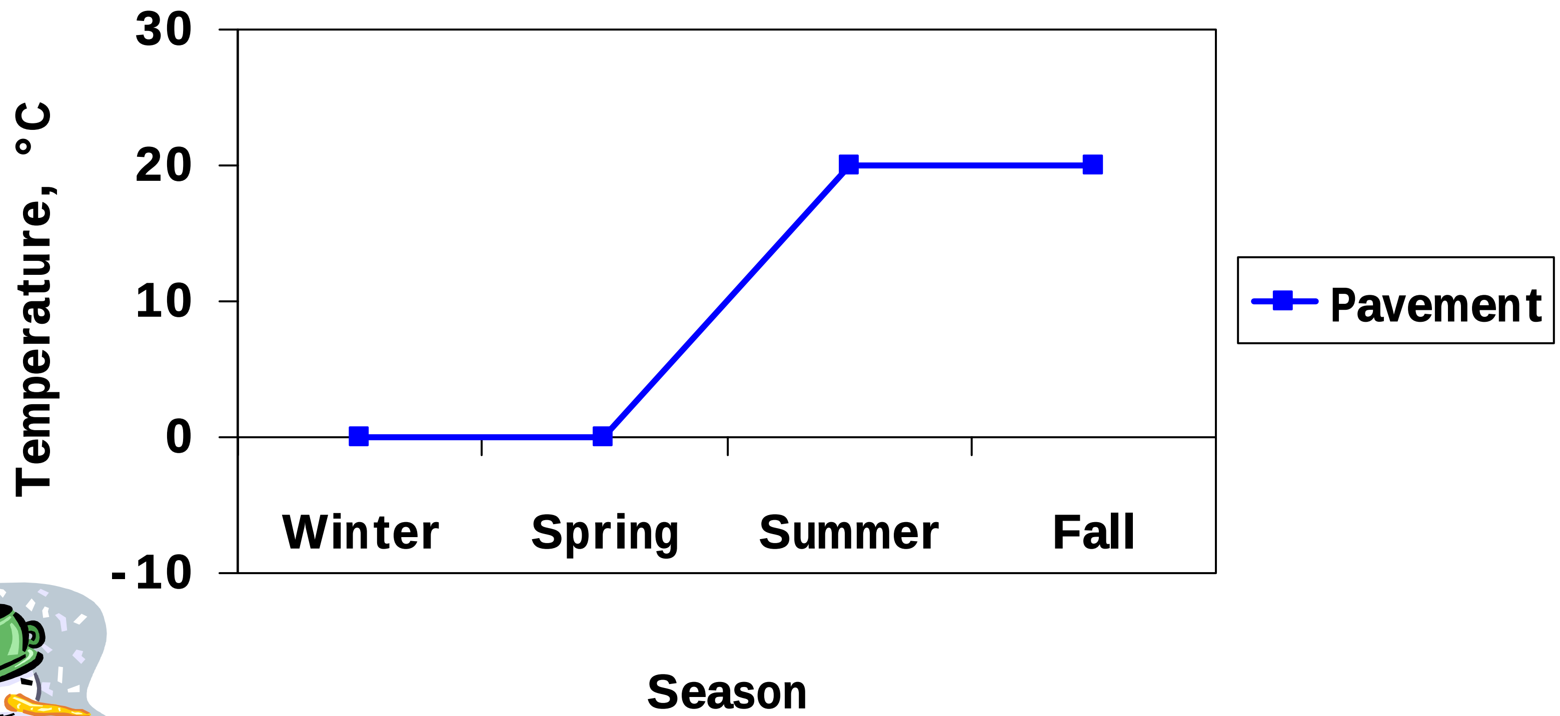
- $E = 20 - 0.5\ (T)$
- At T = 10°C
- E predicted = ?



Inputs

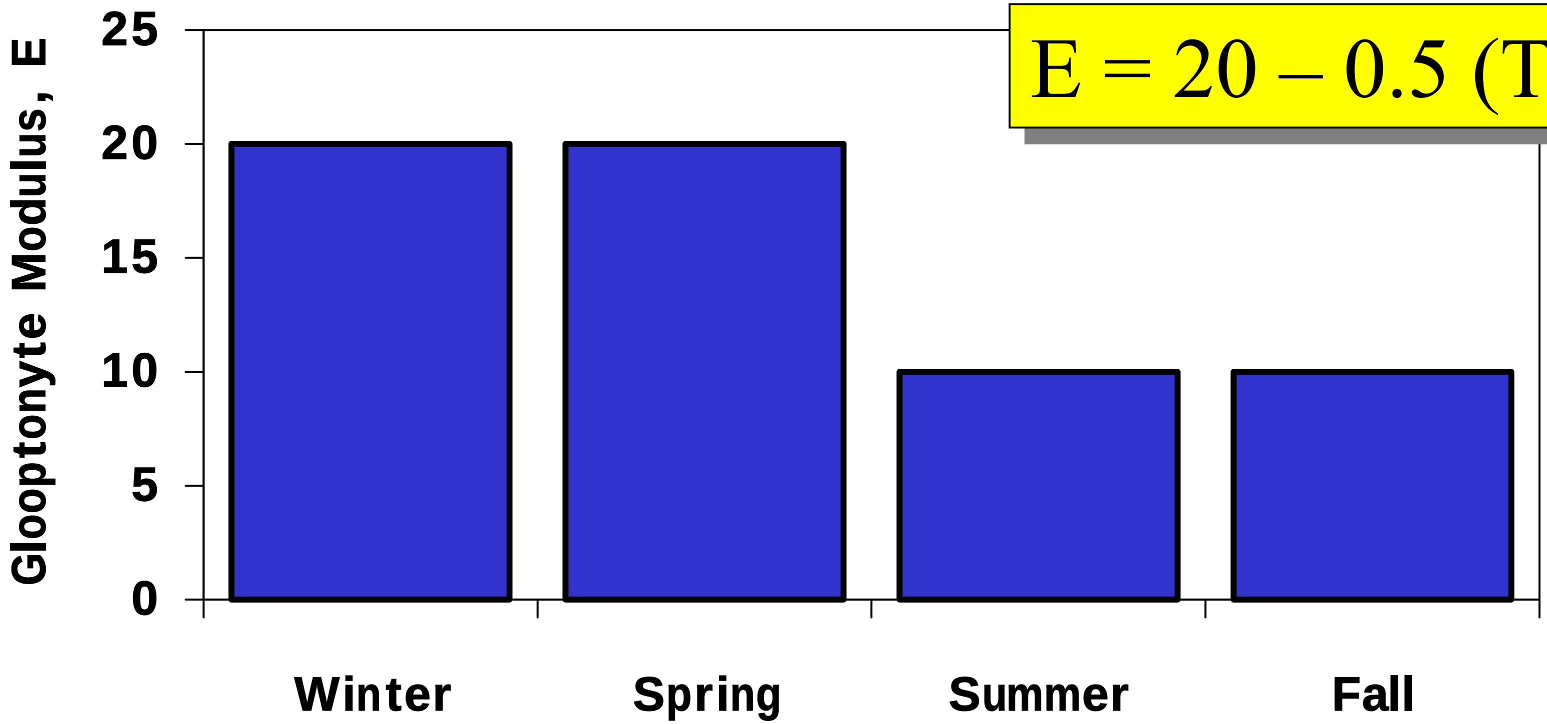

Input Data
Environmental Effects Models
Pavement Response Model
Distress Model
Performance Predictions
Material Characterization Model

Environmental Conditions



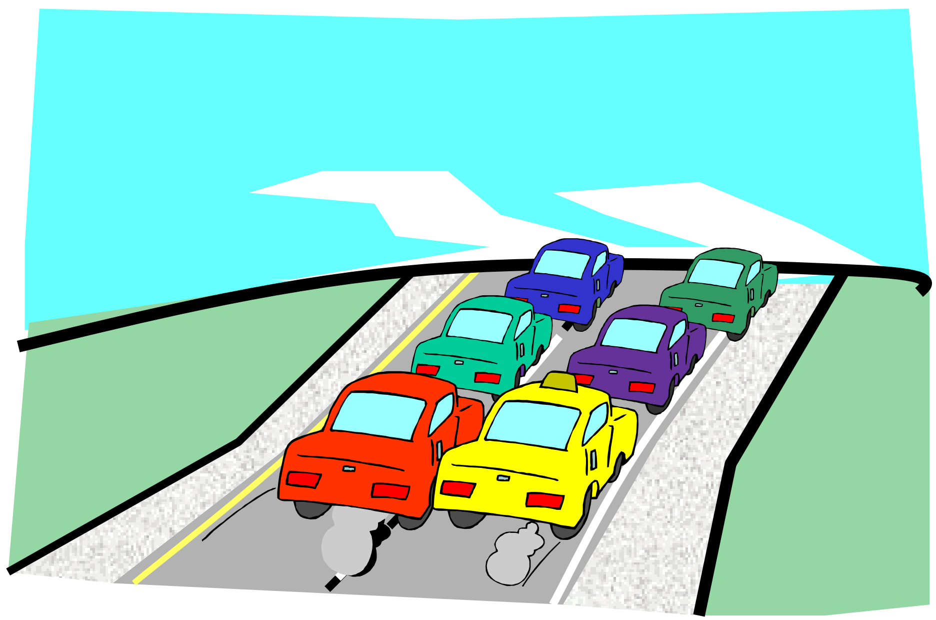
Environmental Effects Model

$$E = 20 - 0.5\,(T)$$



Traffic

- No more ESAL's
- Traffic input by
  - Vehicle type
  - Axle weight
- Load Spectra



Traffic Conditions

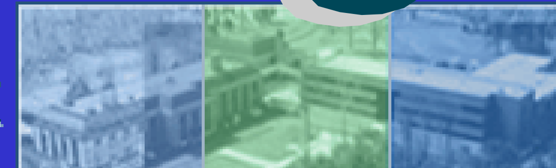
- State of Confusion
  - Unicycles only
  - Two loadings

Traffic Conditions

- <u>Category A Unicycle</u>
  - Load, P 750 lbs
  - Pressure, *p* 60 psi
  - Contact, a 2 in

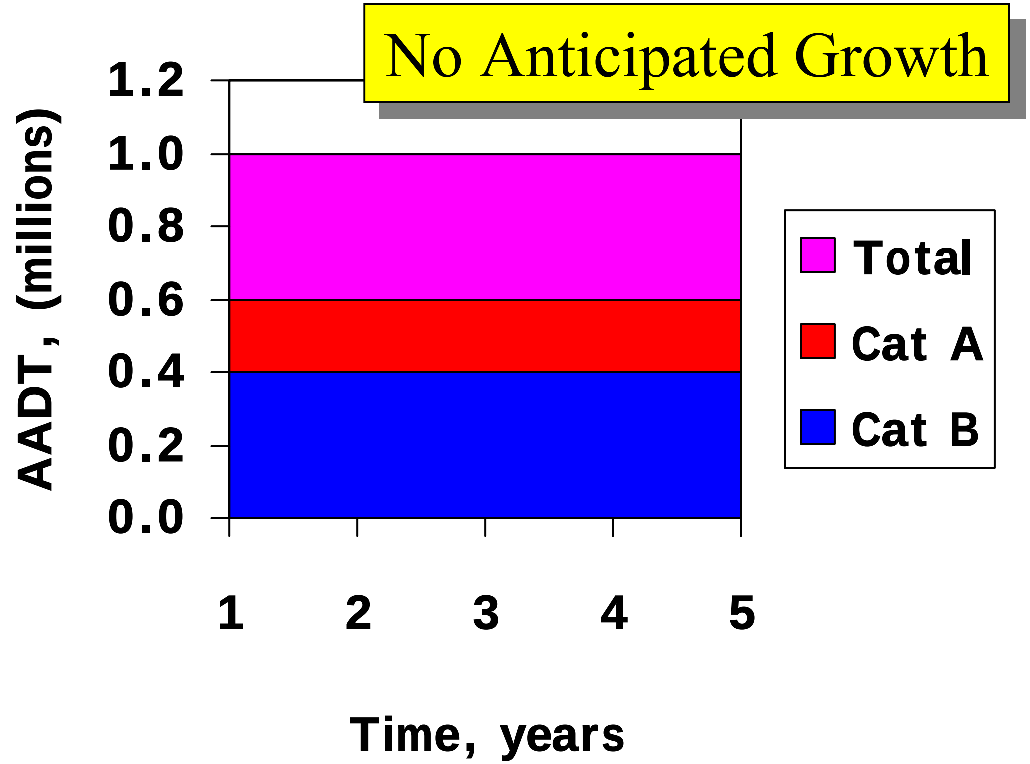
- <u>Category B Unicycle</u>
  - Load, P 1250 lbs
  - Pressure, *p* 100 psi
  - Contact, a 2 in

a, contact radius $p = P / (\pi r^2)$



Traffic Conditions

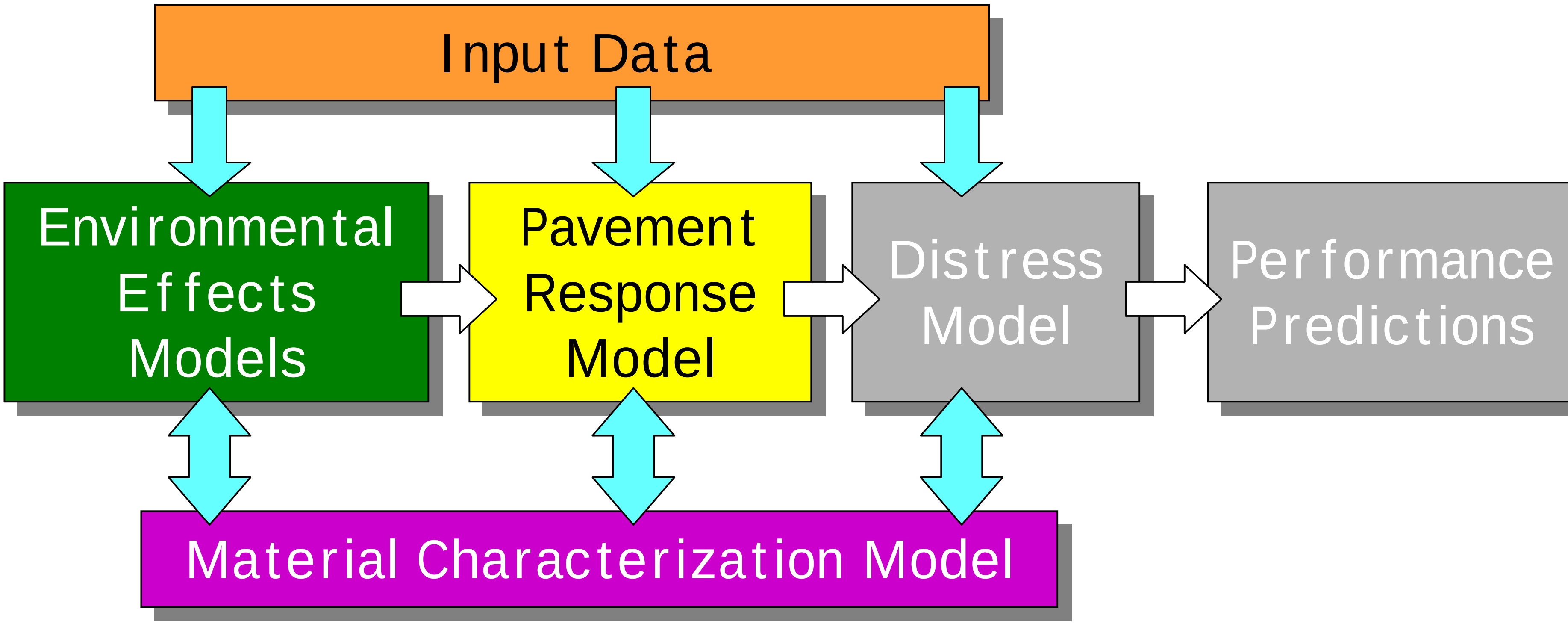
- Category A
  - AADT 600,000
- Category B
  - AADT 400,000



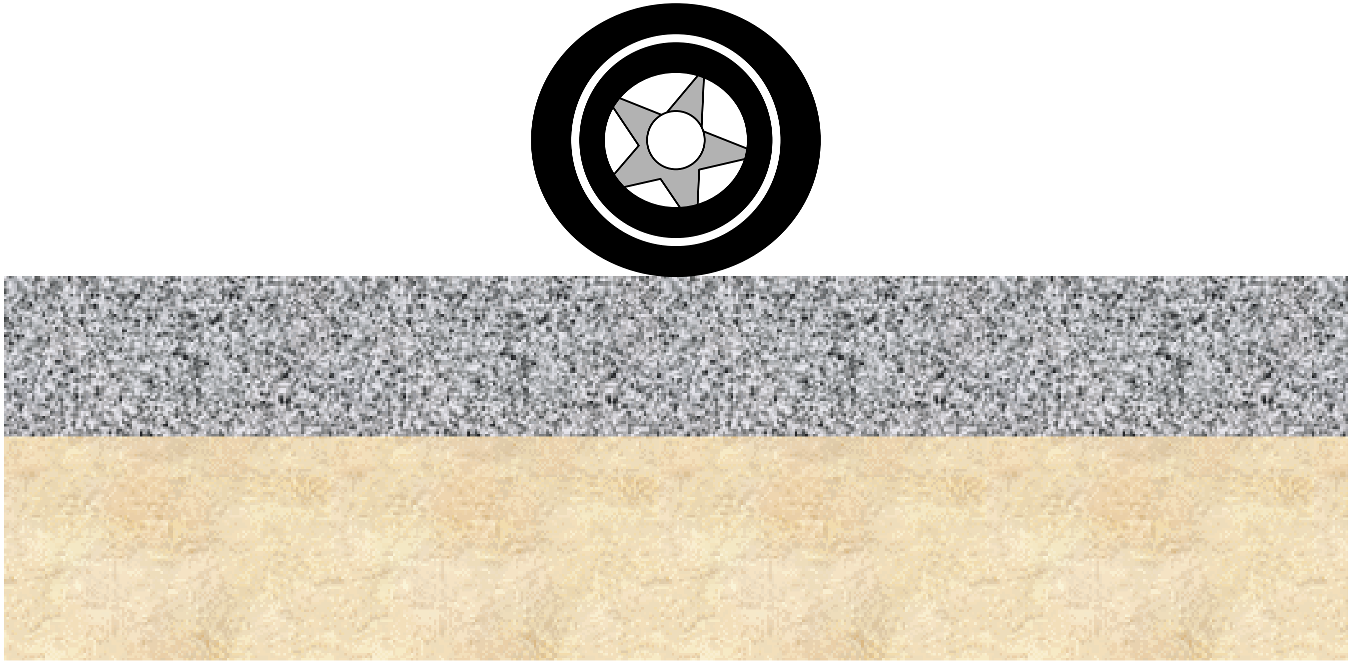
Design Life

- 20 years
- Total anticipated traffic:
  - Category A = 12 million
  - Category B = <u> 8 million</u>
  - TOTAL = 20 million

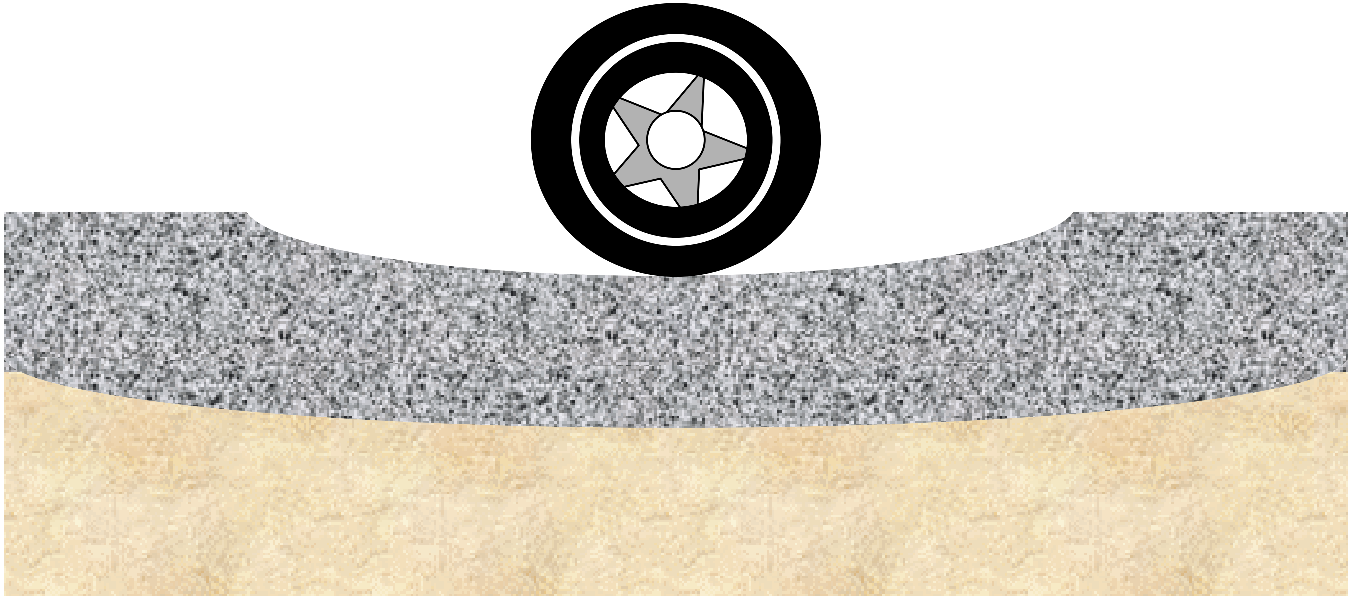
Pavement Response



Pavement Response



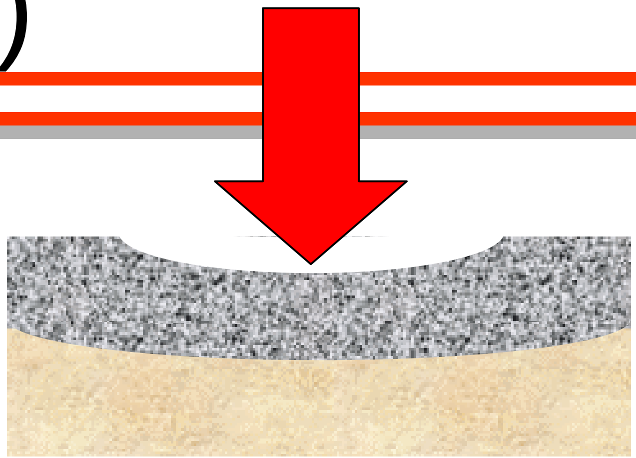
To Load



Pavement Response Tools

- Analytical solutions (e.g. Burmister)
- Multi-layer elastic theory
- Finite element analysis
  - 2D, 3D
- Hybrid methods

Analytical Solution (Burmister)



- Assumptions
  - $\mu = 0.5$ (Poisson's ratio)
  - $E_{BASE} = {}^{1}/_{10}\, E_{Glooptonyte}$

$$\text{Surface deflection} = \frac{1.5\, p\, a}{E_{BASE}} F_2$$

$F_2 = f\,(a, E_2 / E_1, t_1)$

Burmister

$$\frac{1.5\, p\, a}{E_{BASE}}\, F_2$$

- Glooptonyte, t = 8 inches
- Category A Unicycle, p = 60 psi, a = 2
- Summer time, T = 20°C
  - $E_1 = 20 - 0.5\,(T) = 10$ ksi
  - $E_2 = {}^{1}/_{10}\, E_1 = 1$ ksi = 1000 psi
  - $F_2 = f\,(a, E_2 / E_1, t_1) = 0.20$ (from a Table)

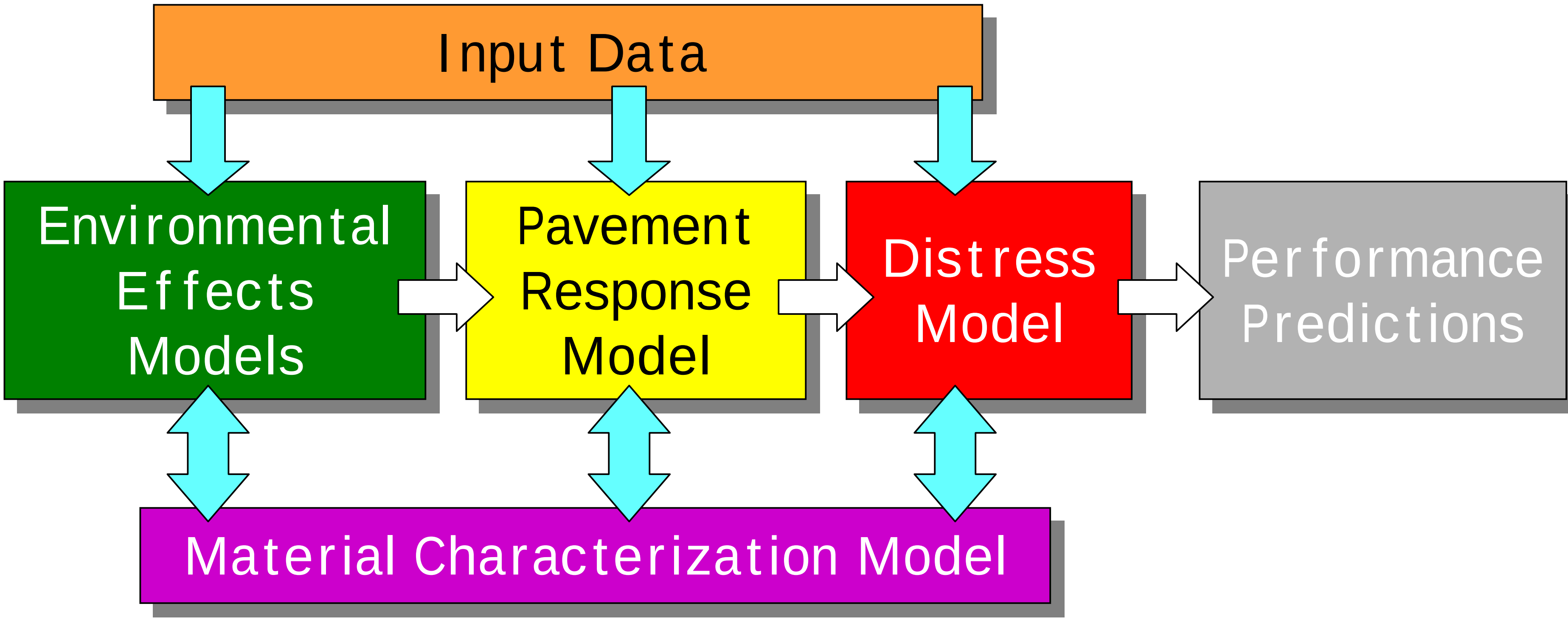
Surface Deflection = 0.04”

Pavement Sections

Pavement Response Model

Season	E_1 / E_2 psi	Category A p = 60 psi	Category B p = 100 psi
Winter / Spring (T_p = 0°C)	20 / 2	$\delta_{4"} = 0.03$ $\delta_{6"} = 0.025$ $\delta_{8"} = 0.02$	$\delta_{4"} = 0.045$ $\delta_{6"} = 0.038$ $\delta_{8"} = 0.03$
Summer / Fall (T_p = 20°C)	10 / 1	$\delta_{4"} = 0.06$ $\delta_{6"} = 0.05$ $\delta_{8"} = 0.04$	$\delta_{4"} = 0.09$ $\delta_{6"} = 0.075$ $\delta_{8"} = 0.06$

Distress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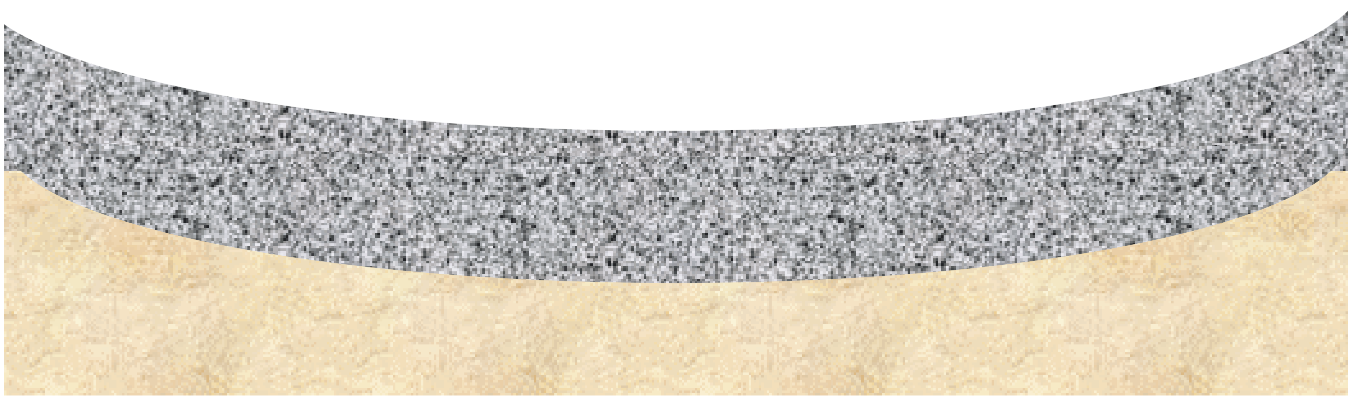
Glooptonyte

- Only fails in <u>rutting</u>

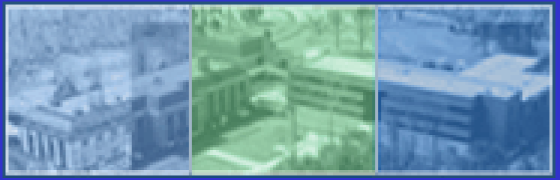


Pavement Distress Model

- Empirical
- Mechanistic
- Mechanistic-Empirical

Empirical Model

Pavement Response + Traffic Loading → Pavement Performance



Empirical Model

- $Log(\delta_P / \delta_B) = C_1 + C_2 \, Log(N)$

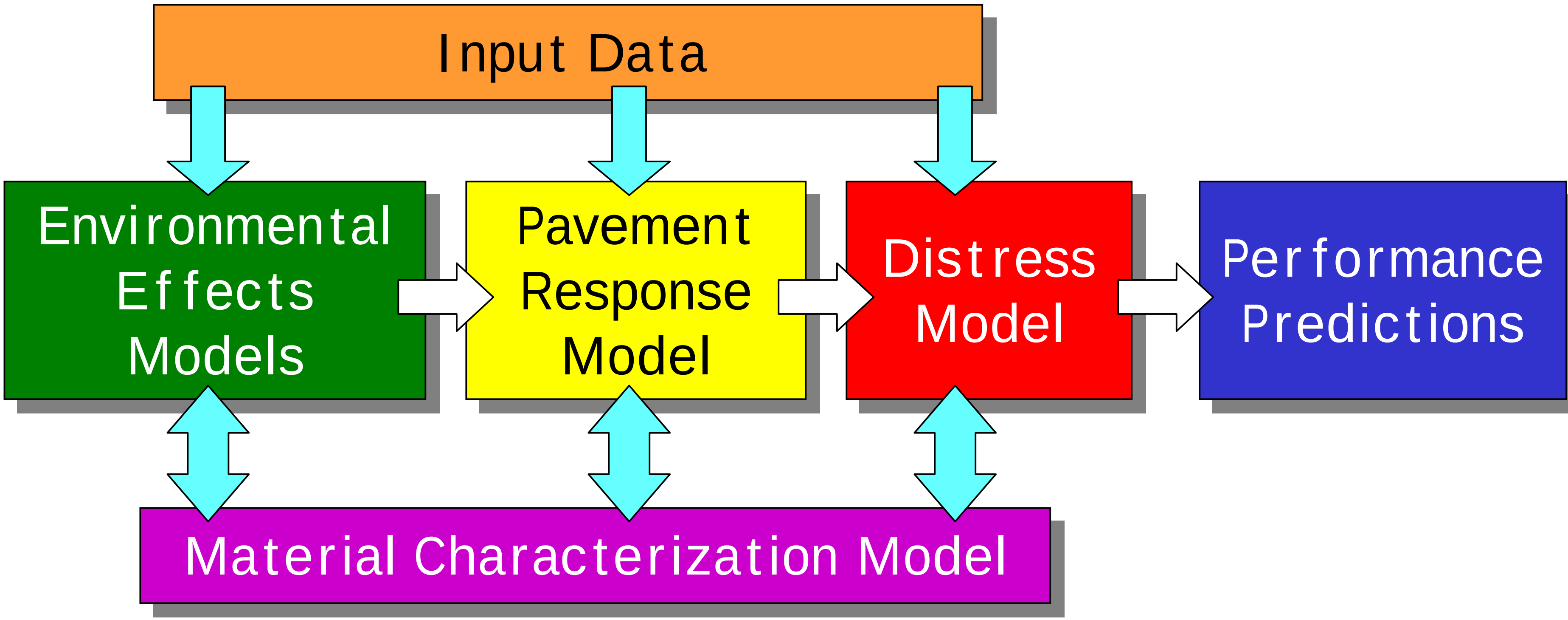
- Where:
  - δ_P, Permanent deformation
  - δ_B, Burmister deflection
  - C_1 and C_2, Constants (-3.1, 0.5)
  - N, load applications

Performance Criteria

- What is acceptable performance?

- Rutting ≤ 0.3 inches

Performance Prediction



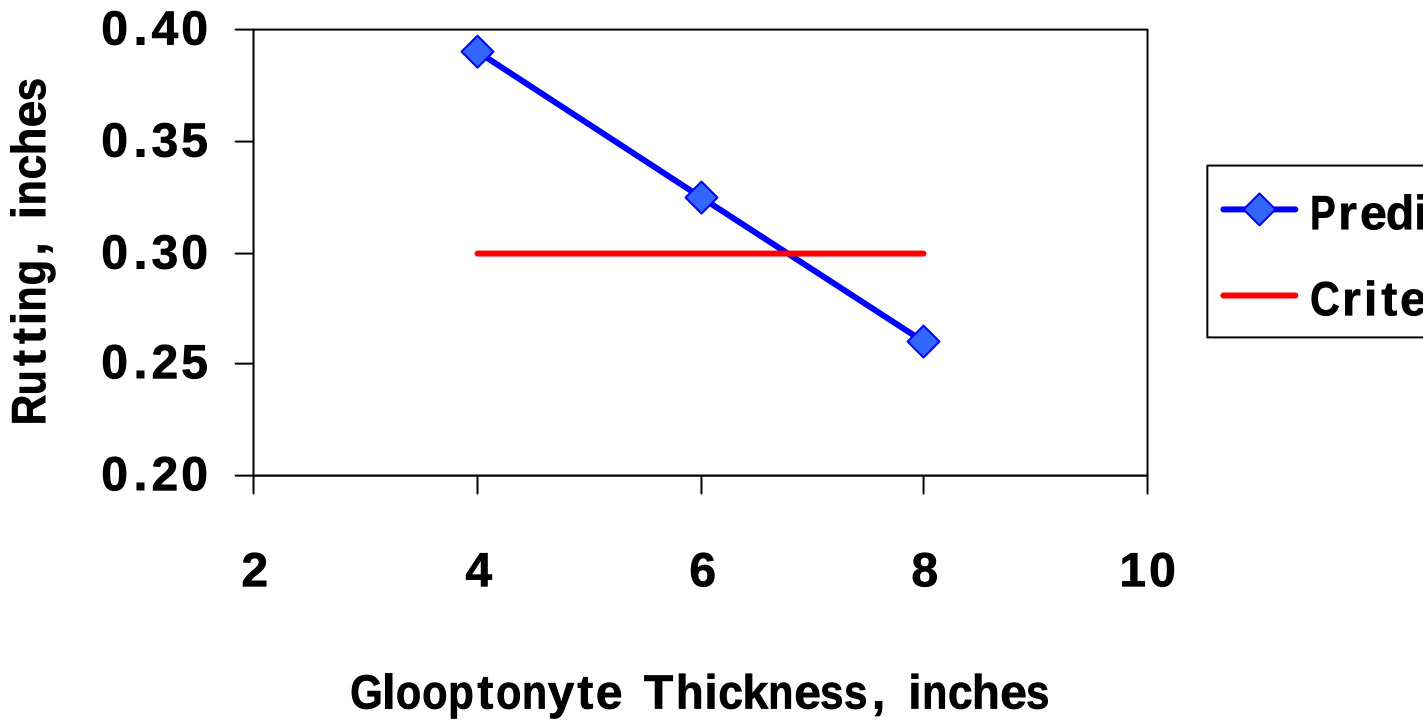
Empirical Model

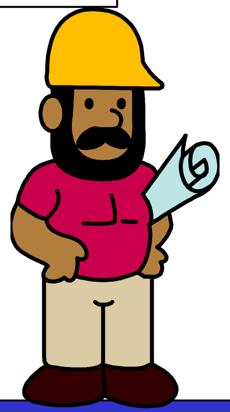
Rutting

Session	Cat	t	δ B	N design	δ P
W / S	A	4	0.030	6,000,000	0.06
S / F	A	4	0.060	6,000,000	0.12
W / S	B	4	0.045	4,000,000	0.07
S / F	B	4	0.090	4,000,000	0.14
					0.39

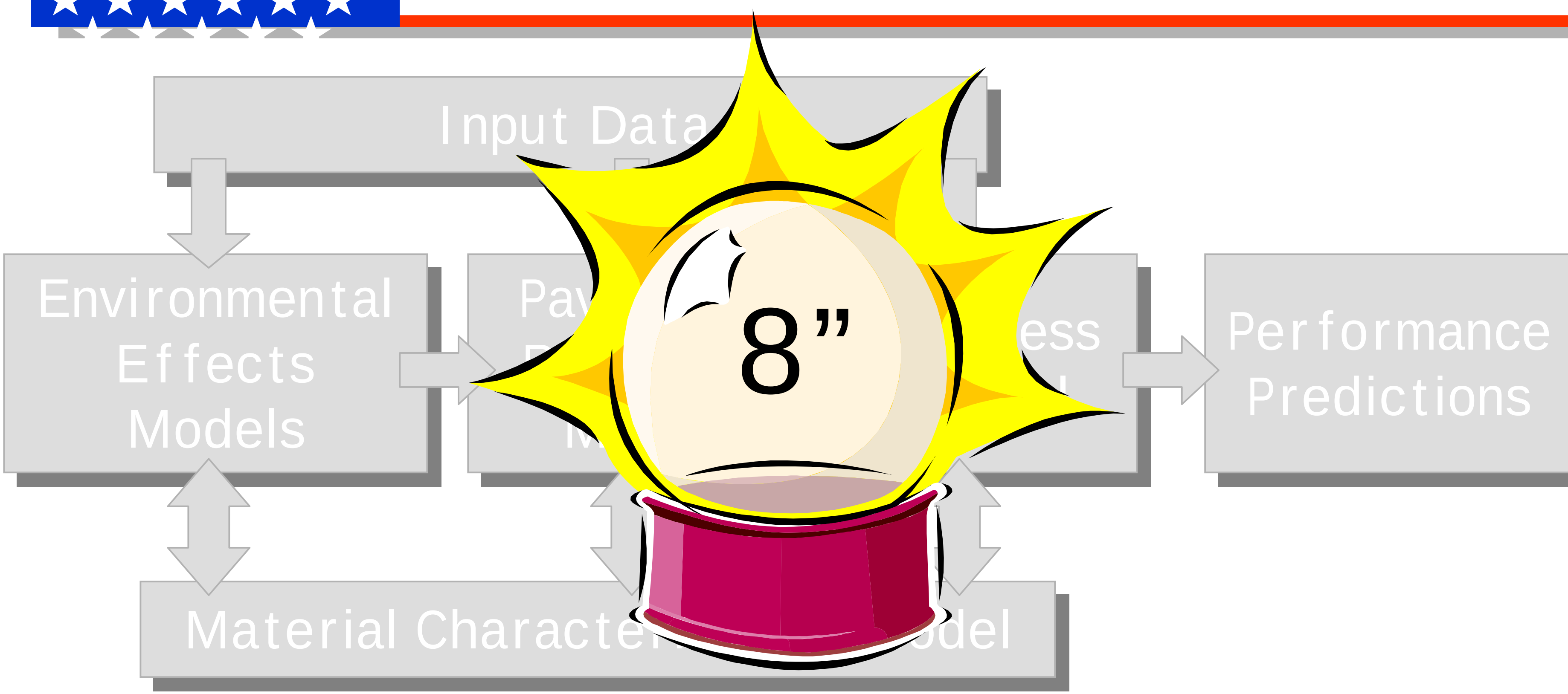
$$\text{Log}\,(\delta_P / \delta_B) = C_1 + C_2\,\text{Log}\,(N)$$

Performance Prediction





Performance Prediction

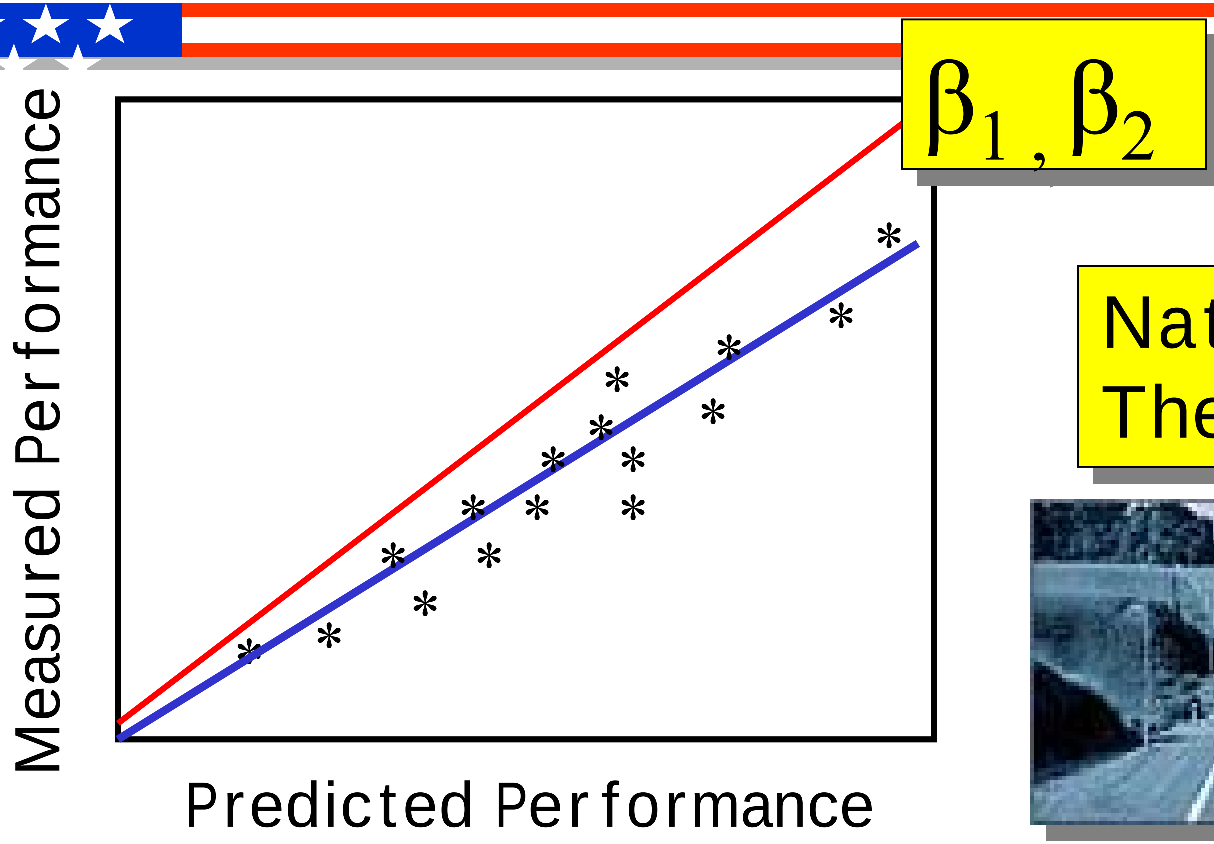


Models Calibration

- $\text{Log} (\delta_P / \delta_B) = \beta_1 C_1 + \beta_2 C_2 \text{Log} (N)$

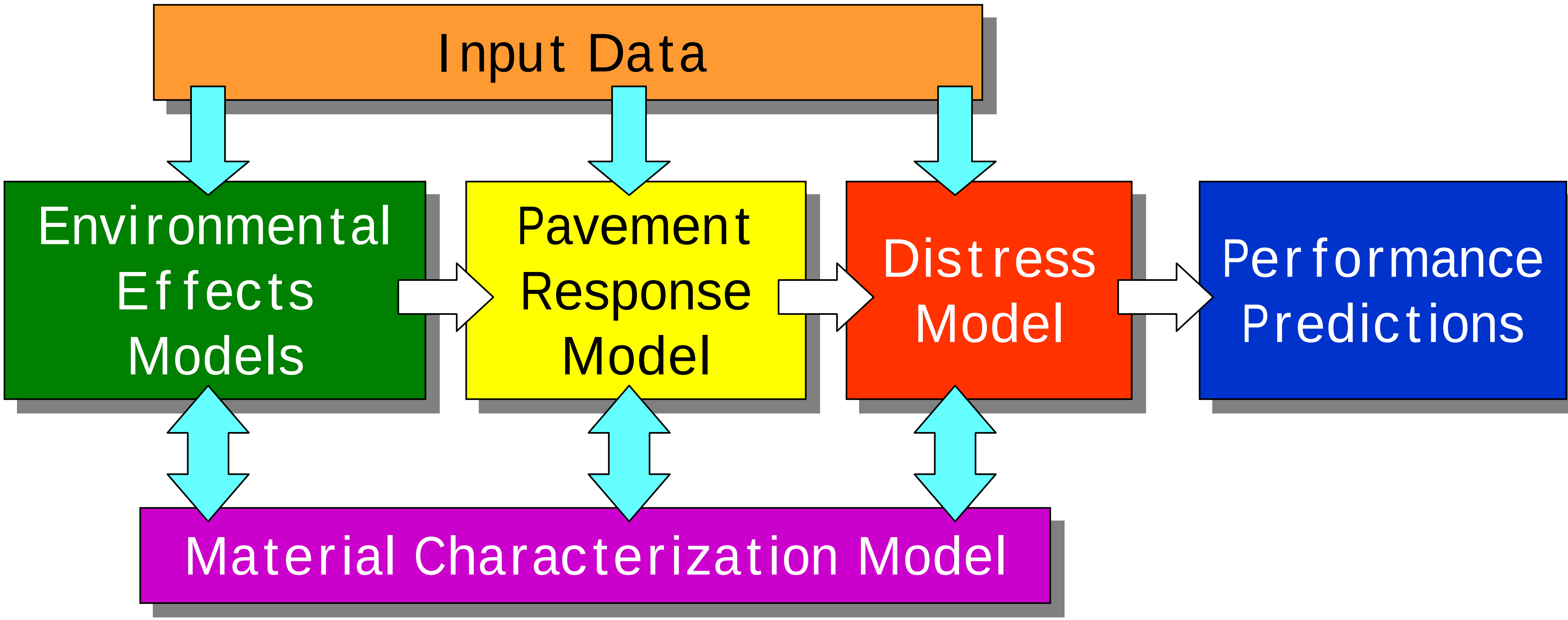
- Where:
  - β_1 , β_2 calibration factors

Models Calibration



National
Then Local

Performance Modeling



Thank You