Nordic Road Association
Technical Committee:
TC 34. Pavement Structure

NVF-34
Reykjavík, Iceland
June 25th, 2003

# Enhanced Mechanistic Understanding of Structural Behaviour of Pavements

## - Experiences from Iceland -

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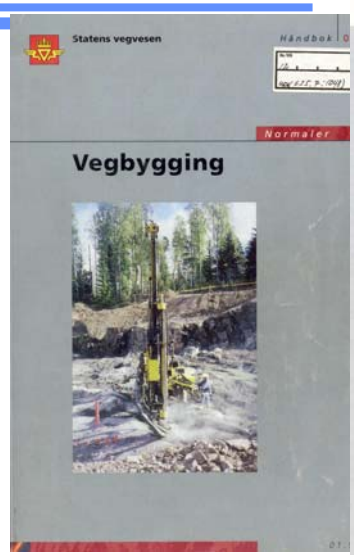
**Faculty of Engineering**
**University of Iceland**

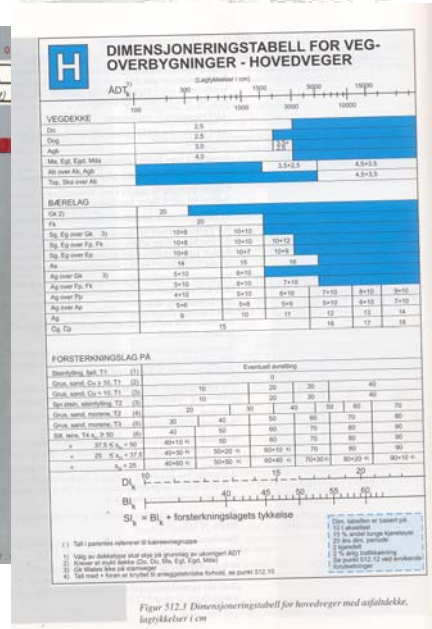
UNIVERSITY OF ICELAND

# Outline

- Current Design Methods used in Iceland
- Mechanistic-Empirical Design Methods
- Recent and Ongoing Research Projects:
  - » Axle Load Spectrum Analysis
  - » Material Characteristics
  - » Seasonal Variation of Pavement Response
  - » Accelerated Testing of Pavement Structures
  - » Response Calculations and Distress Prediction
- AASHTO 2002 Design Guide

# Current Design Methods
# Alverk 95 & Vegbygging Håndbok 018




***Empirical design –***

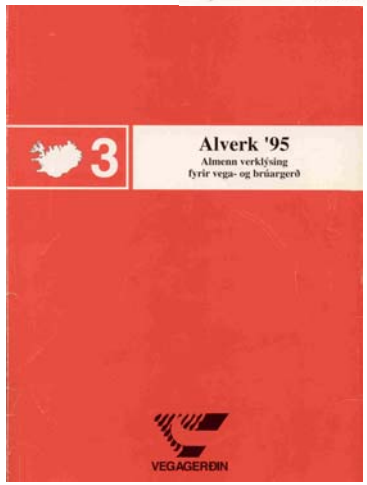
***AADT***

***Subgrade***

***Material Classification***

***Standard Specification***

***of Road Structures in Iceland (Alverk 95)***

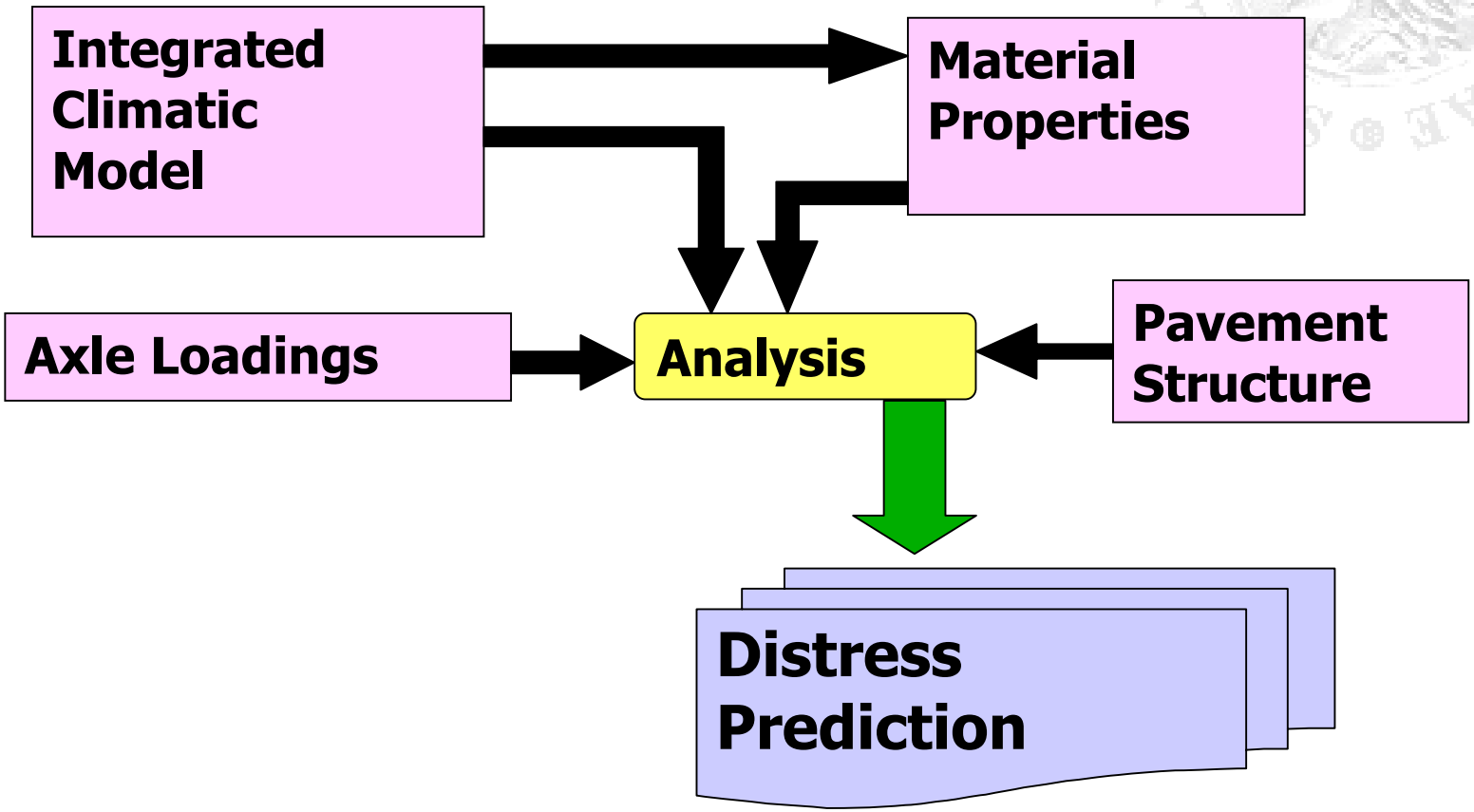


# Mechanistic – Empirical Design Method

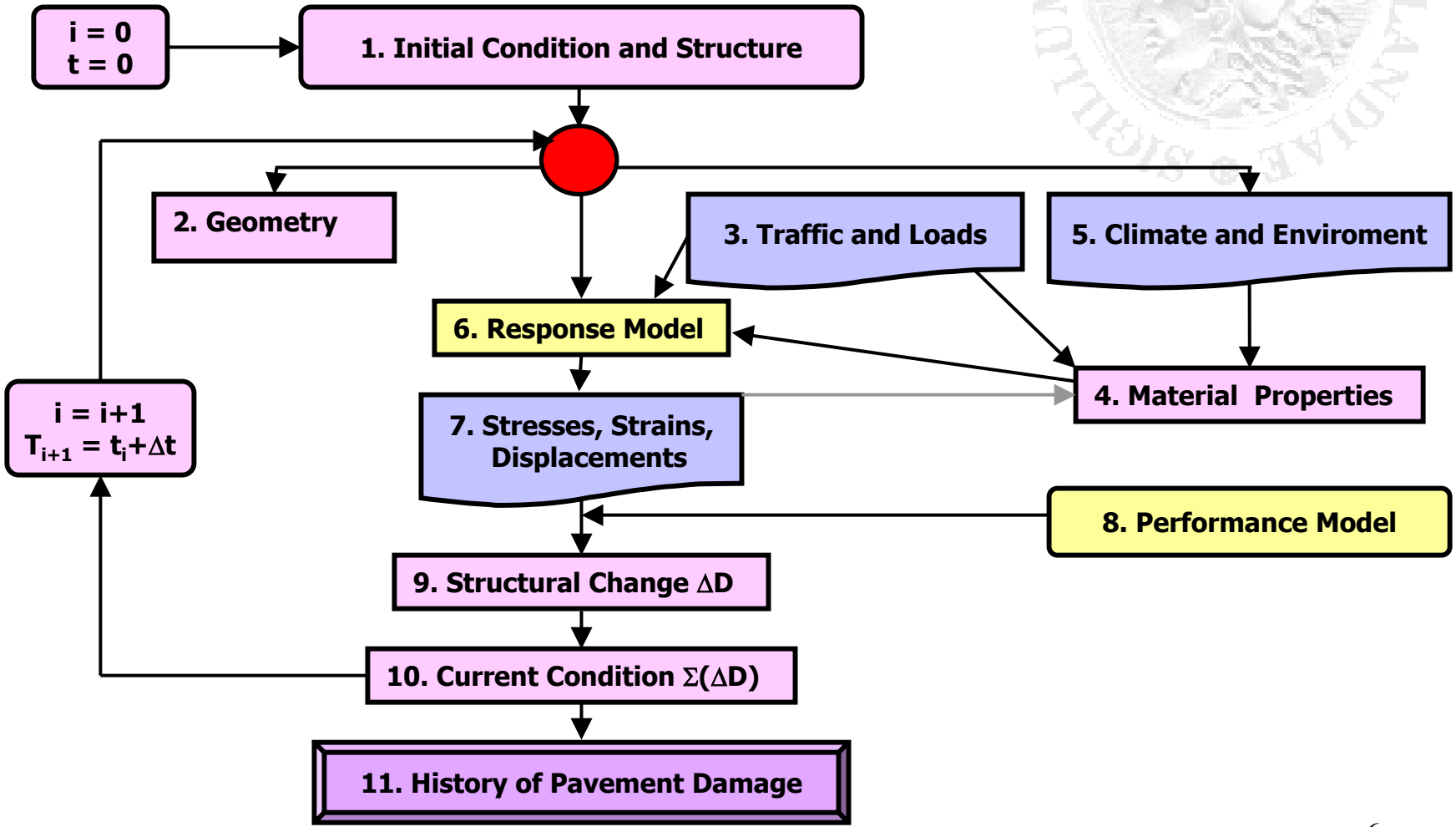
***What is a Mechanistic - Empirical Design Method ?***

***Using a mechanistic-empirical design method is applying the principles of engineering mechanics in evaluating the response of pavement structures to traffic loading and empirical design methods in carrying out distress prediction.***

# Mechanistic Pavement Design Model



# Incremental design procedure – Flow diagram



# Recent and Ongoing Research Projects

- ***Axle Load Spectrum based on WIM-data***
- ***Material Characteristics***
- ***Seasonal Variation of Material Properties***
- ***Full Scale Testing (APT)***
- ***Response Calculations and Distress Prediction***

# Axle Load Spectrum - *Weigh in Motion*

- **WIM-stations**

  **provide information on:**

  **Axle loads**

  **Number of load repititions**

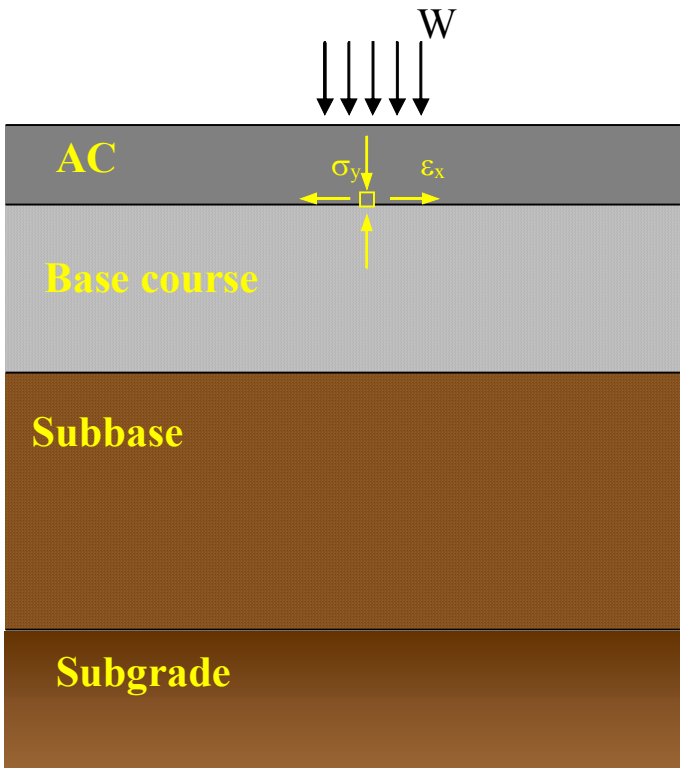
  **Frequency distribution**

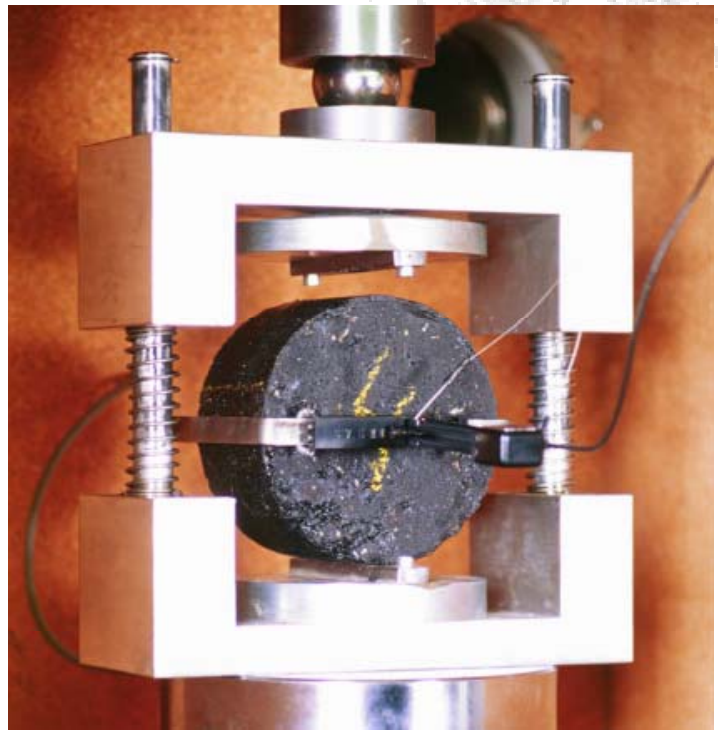
# Material Properties - Dynamic testing

**Dynamic testing simulates field conditions better than static testing, therefore a better correlation is expected with field performance.**

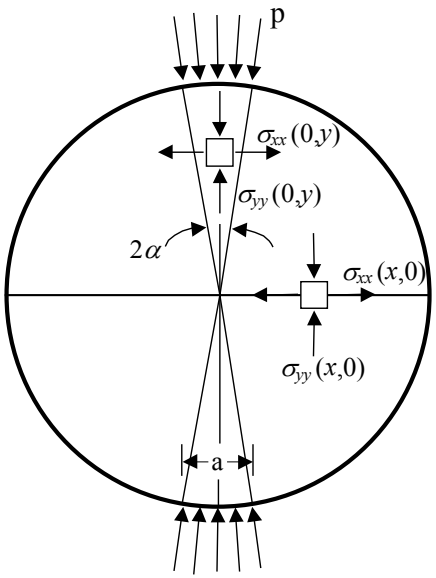
| Layer | Test method | Property |
|---|---|---|
| Asphalt Concrete | Indirect tension test<br>Uniaxial compression | Stiffness, Fatigue<br>Creep |
| Bitumin.stab. Base Course | Indirect tension test<br>Uniaxial compression | Stiffness, Fatigue<br>Creep |
| Unbound granular materials | Triaxial testing | Stiffness, Permanent Deformation Behaviour |

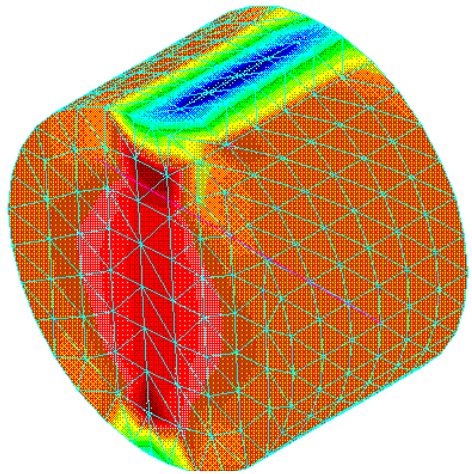
# Material Properties
# Asphalt Concrete

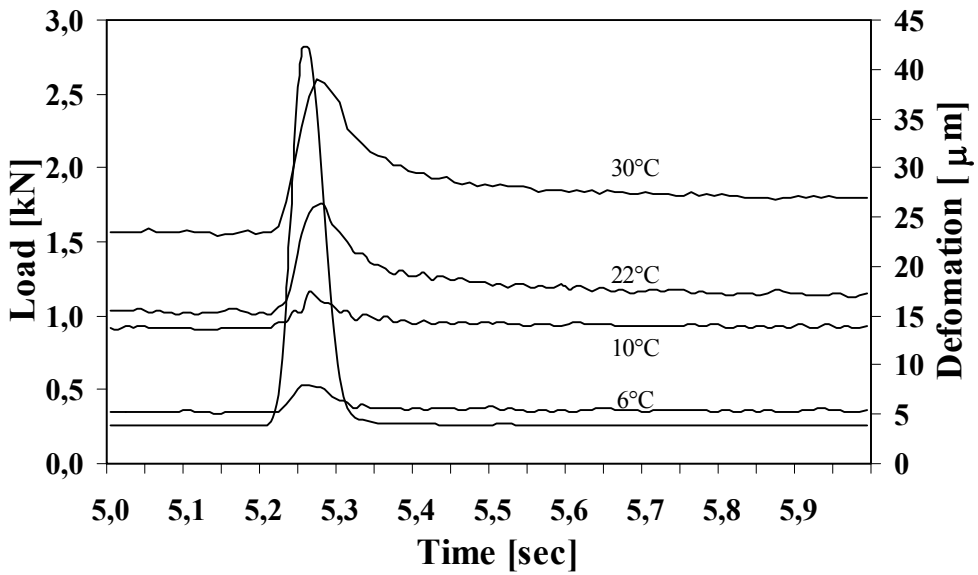


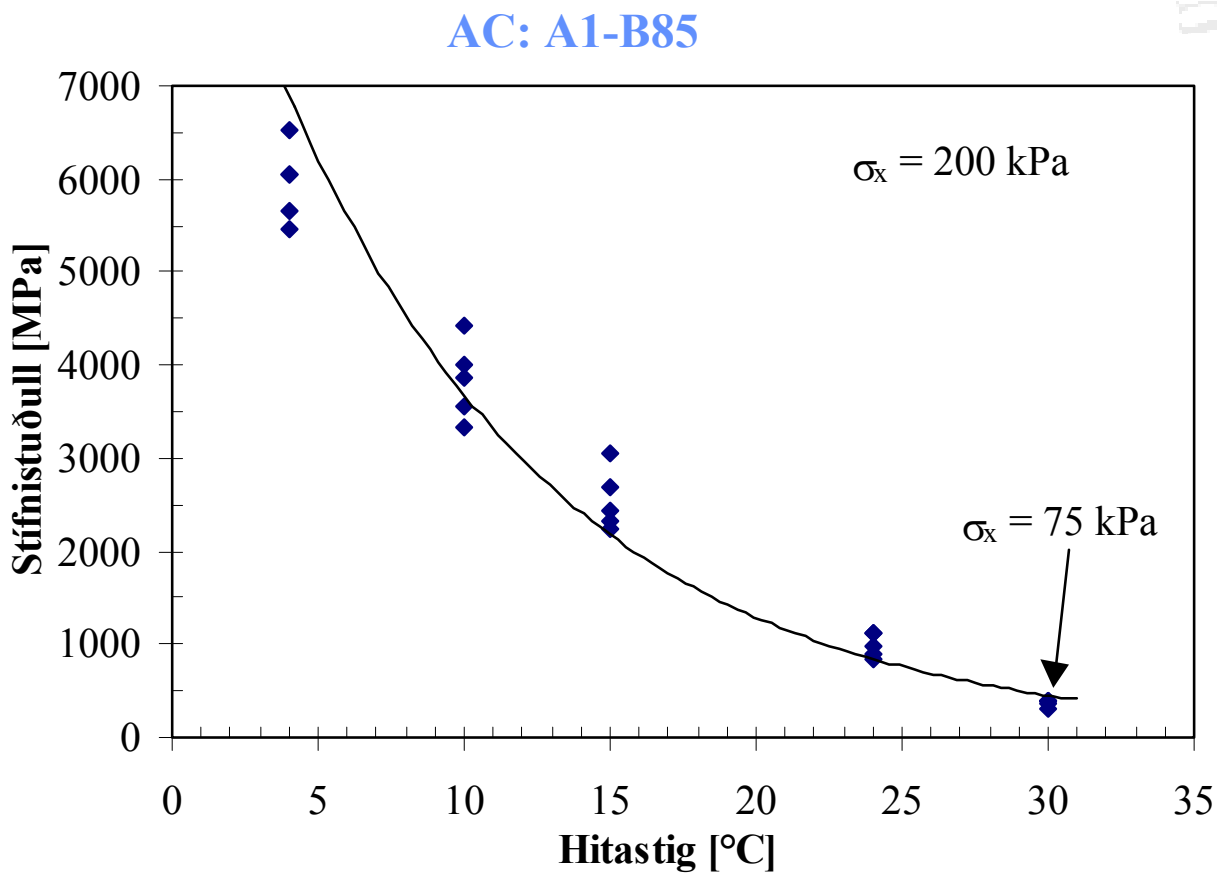
# ITT: Testing & FEM calc.: Comparisons



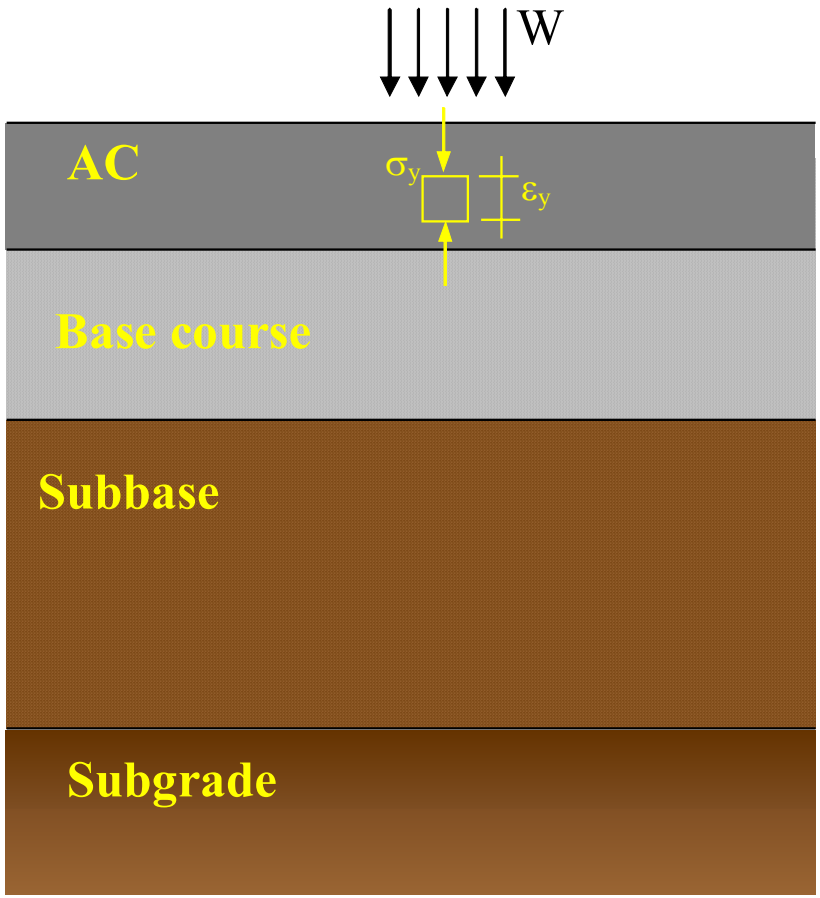



# Stiffness as a Function of Temperature




$$M_r = a \cdot e^{-b \cdot T}$$

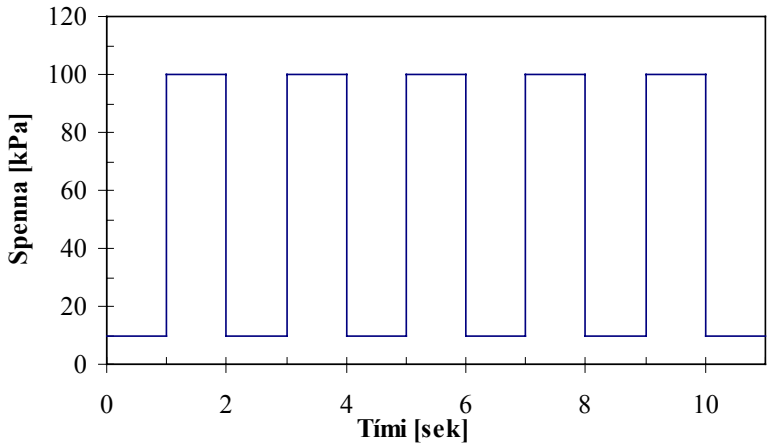
# Uniaxial Compression Test



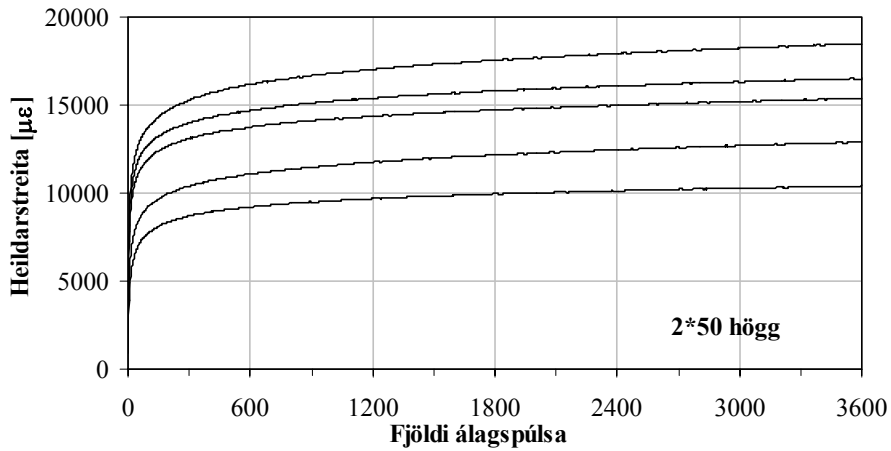

# Uniaxial Compression Test - Example

**AC: B4-B180**

## Applied load

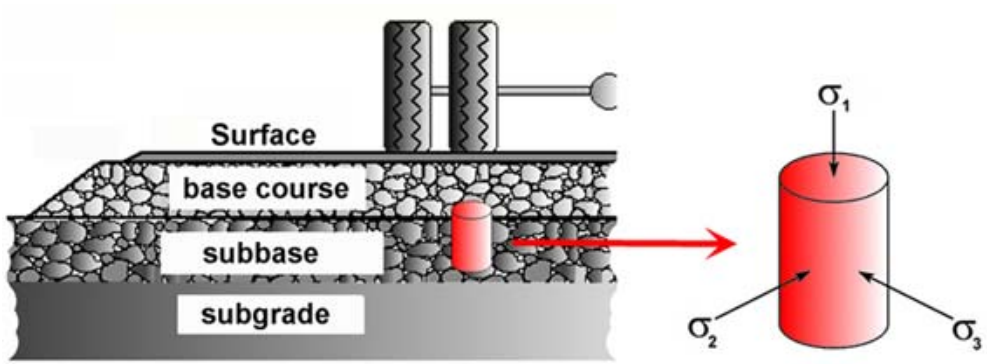


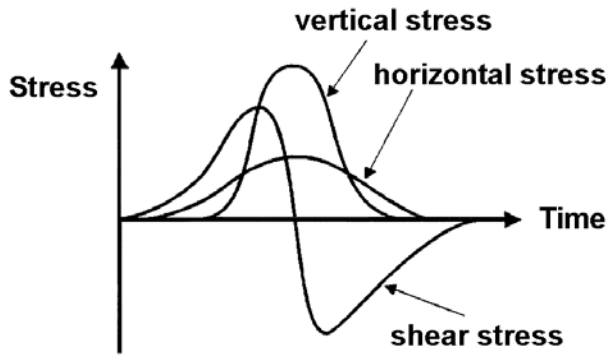

## Accumulated strain



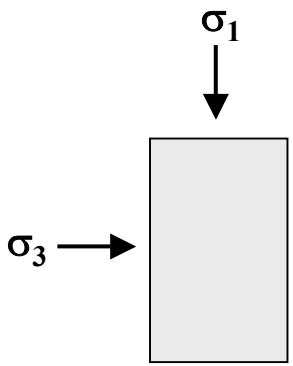
# Unbound Granular Materials

- Stiffness - $M_r$, $\nu$ (nonlinear behaviour).
- Permanent deformation behaviour



# Stresses in RLTT




**Before / after:**

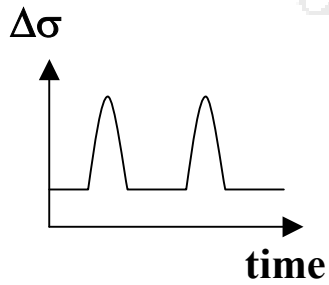
$\sigma_1 = \sigma_v$

$\sigma_3 = \sigma_h$

**During loading**

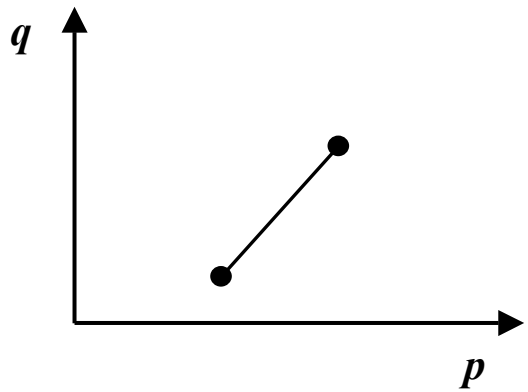
$\sigma_1 = \sigma_v + \Delta\sigma_v$

$\sigma_3 = \sigma_h + \Delta\sigma_h$




$$p = \frac{1}{3}(\sigma_1 + 2\sigma_3)$$

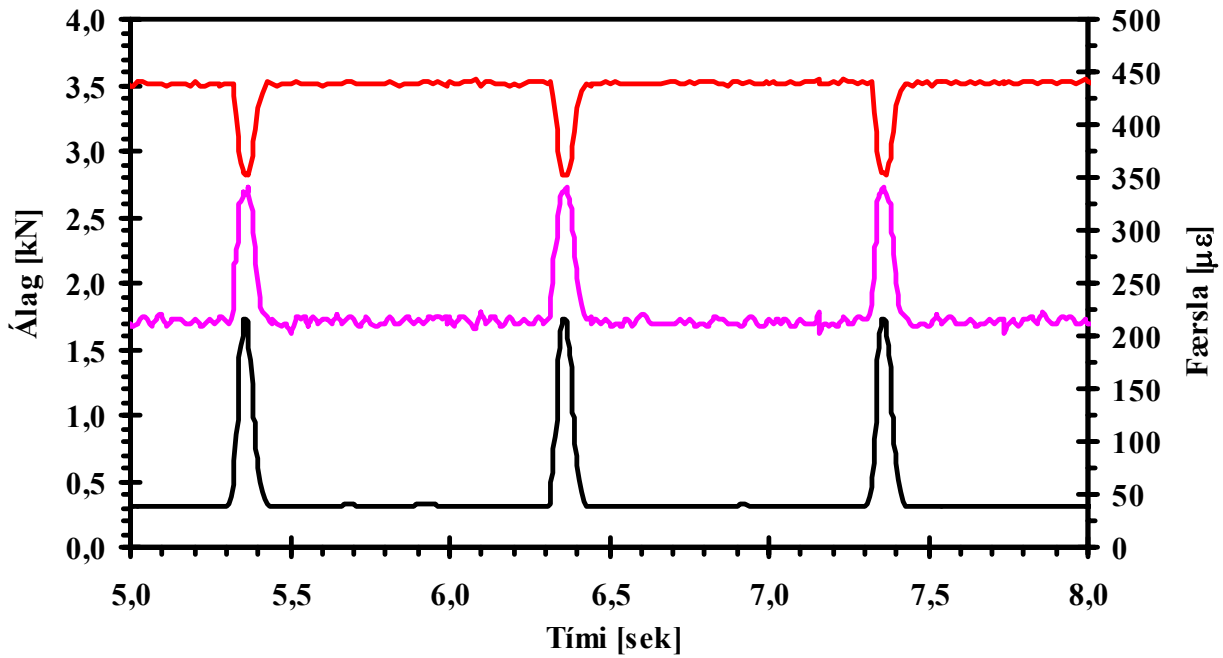
$$q = \sigma_1 - \sigma_3$$



# RLTT – Unbound granular materials

**Specimen size: 150 x 300 mm, $d_{max}$ = 30 mm**

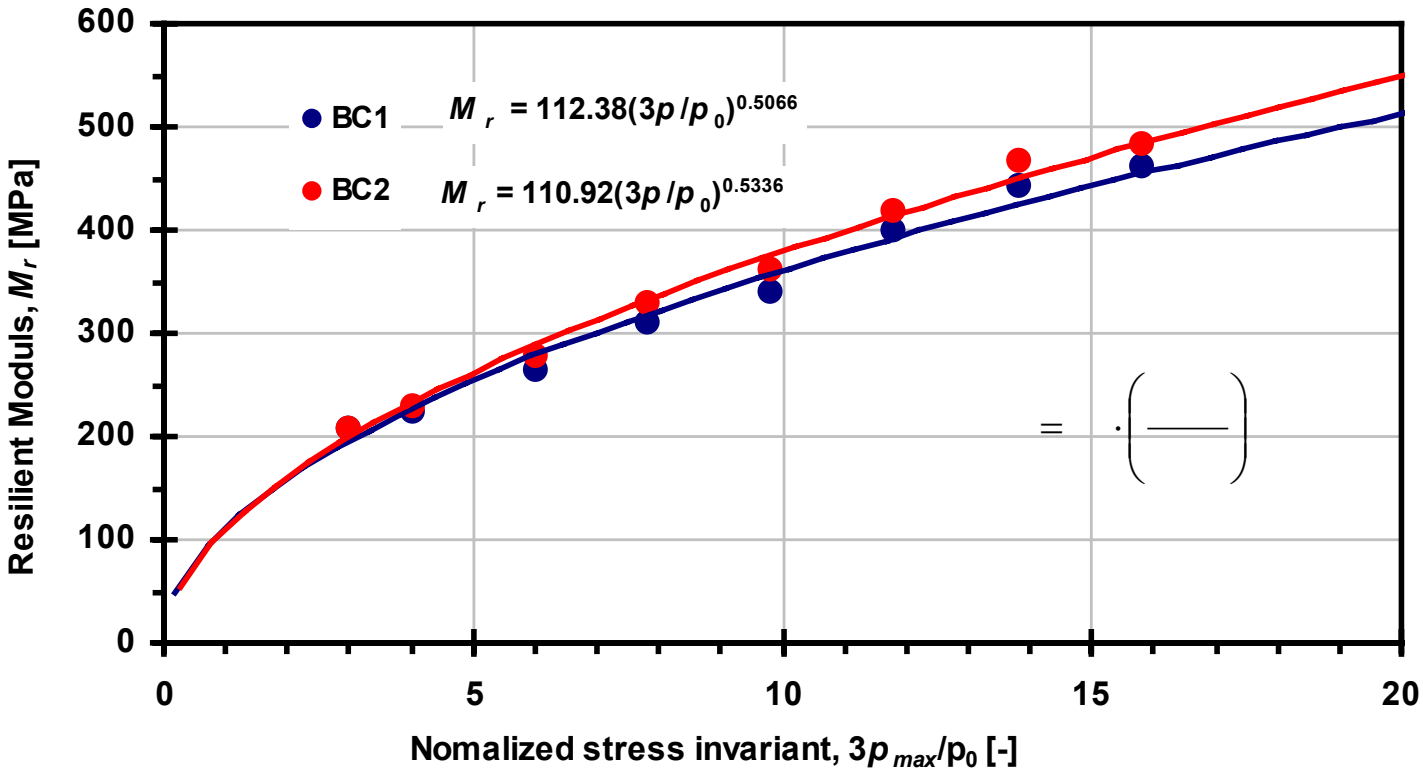
# RLTT - measurements



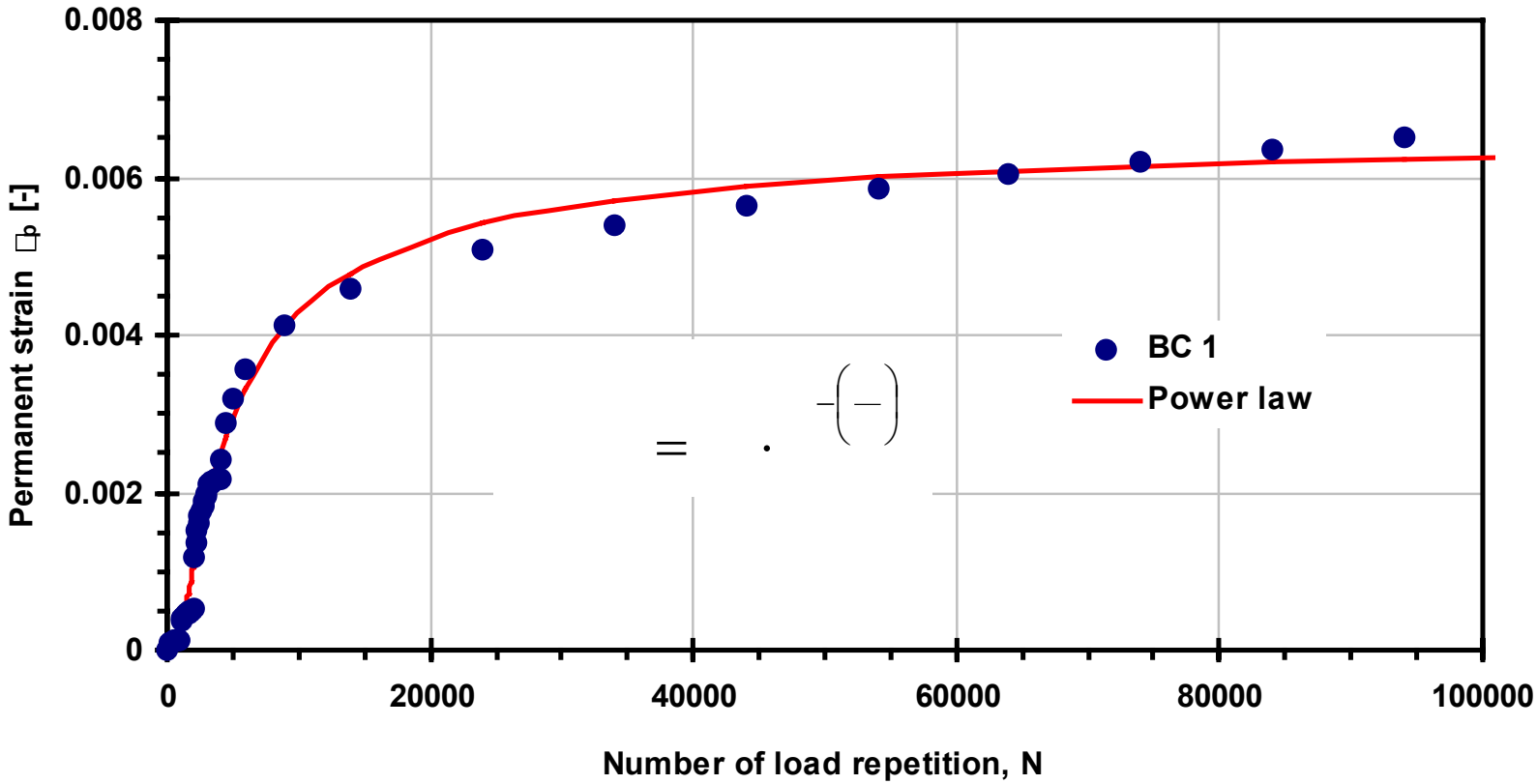

$$M_r = \frac{\sigma_d}{\varepsilon_1^r}$$

$$\nu = -\frac{\varepsilon_3^r}{\varepsilon_1^r}$$

# RLTT – Stiffness Testing - Typical Results



# RLTT – Perm. Def. Testing - Typical Results



# Seasonal Monitoring of Pavements Performance

- **Purpose**

  **To gather information on the seasonal variability of environmental factors (temp., MC, frost etc.) and bearing capacity and their relationsship for modelling purposes.**

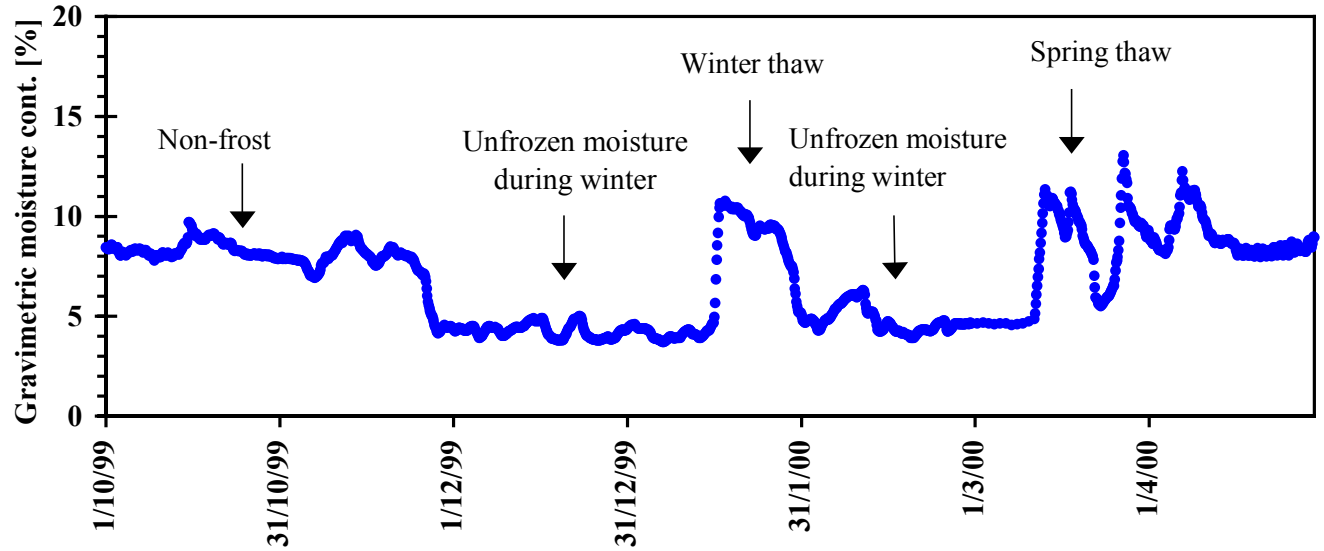
  **Spring Load Restrictions**

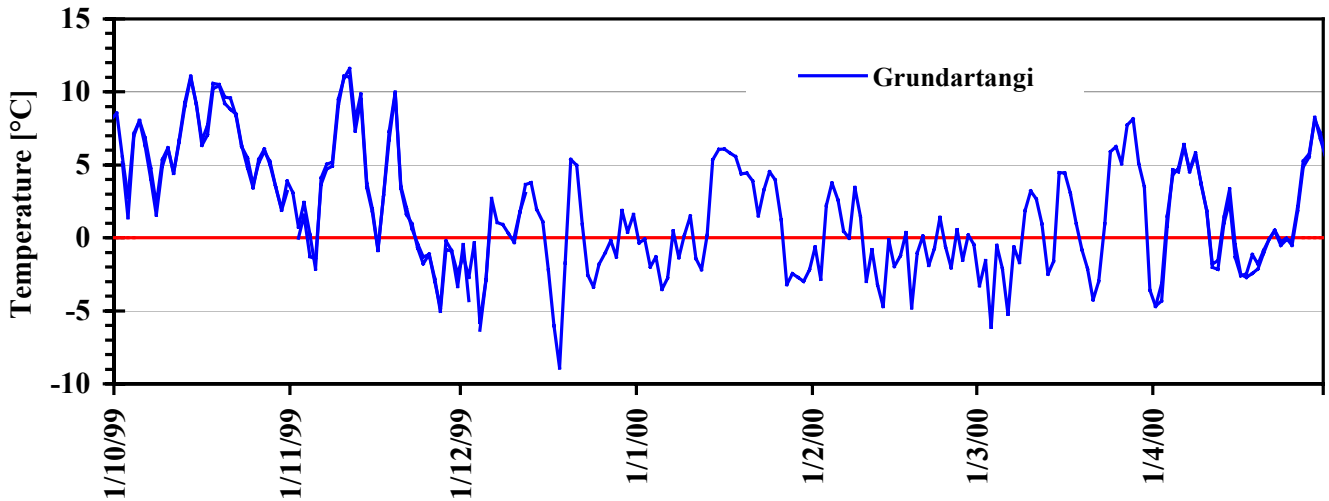
# Climatic Properties- Spring Load Restrictions

# Measurements and Monitoring

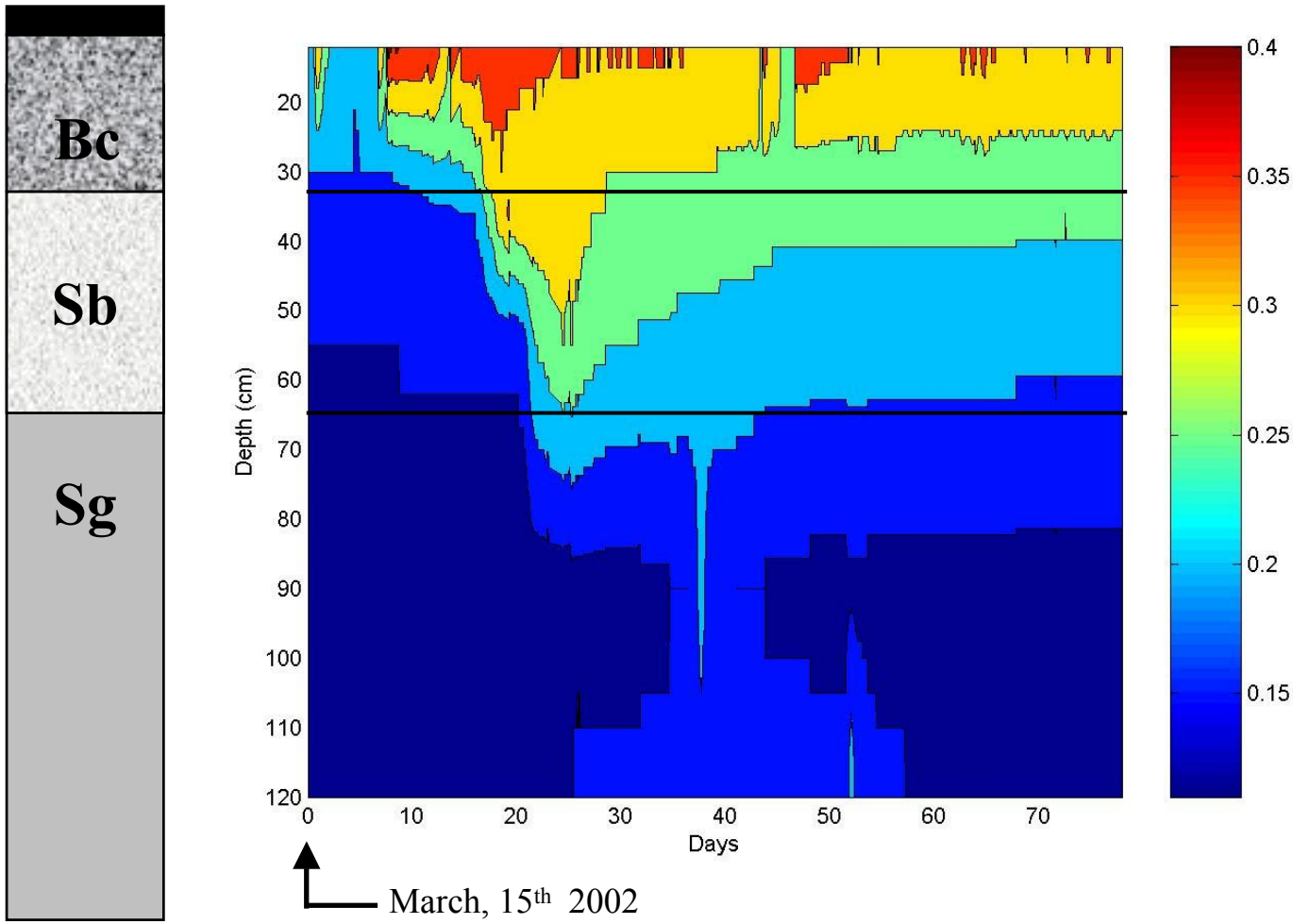
- **Collection of in-situ parameters :**
  - **Groundwater level**
  - **Frost penetration**
  - **Moisture (TDR) and temperature monitoring**
  - **Resistivity monitoring**
  - **Meteorological data (daily precipitation & air temperature)**
  - **FWD measurements**

# Moisture Content and Temperature Data

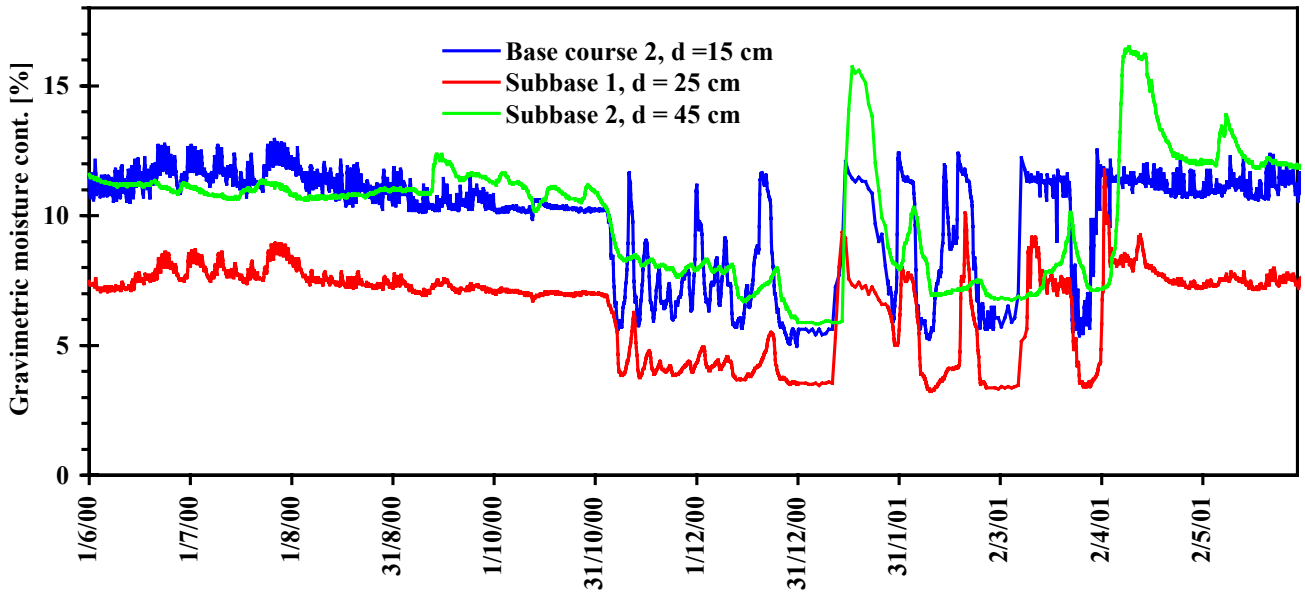


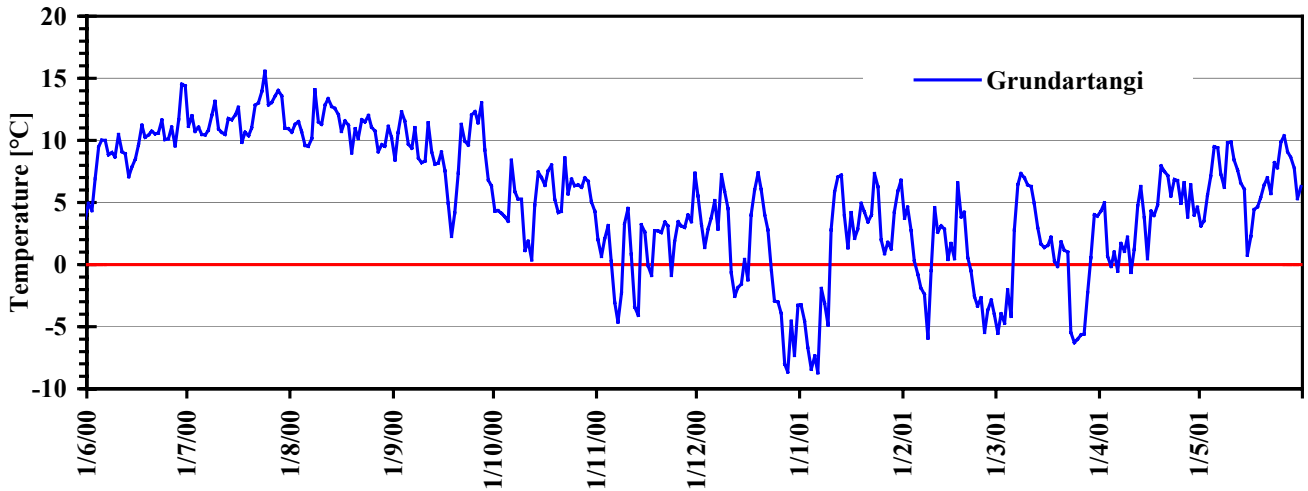



# Moisture Content vs. Time & Depth



# Moisture content, section 1.4.1

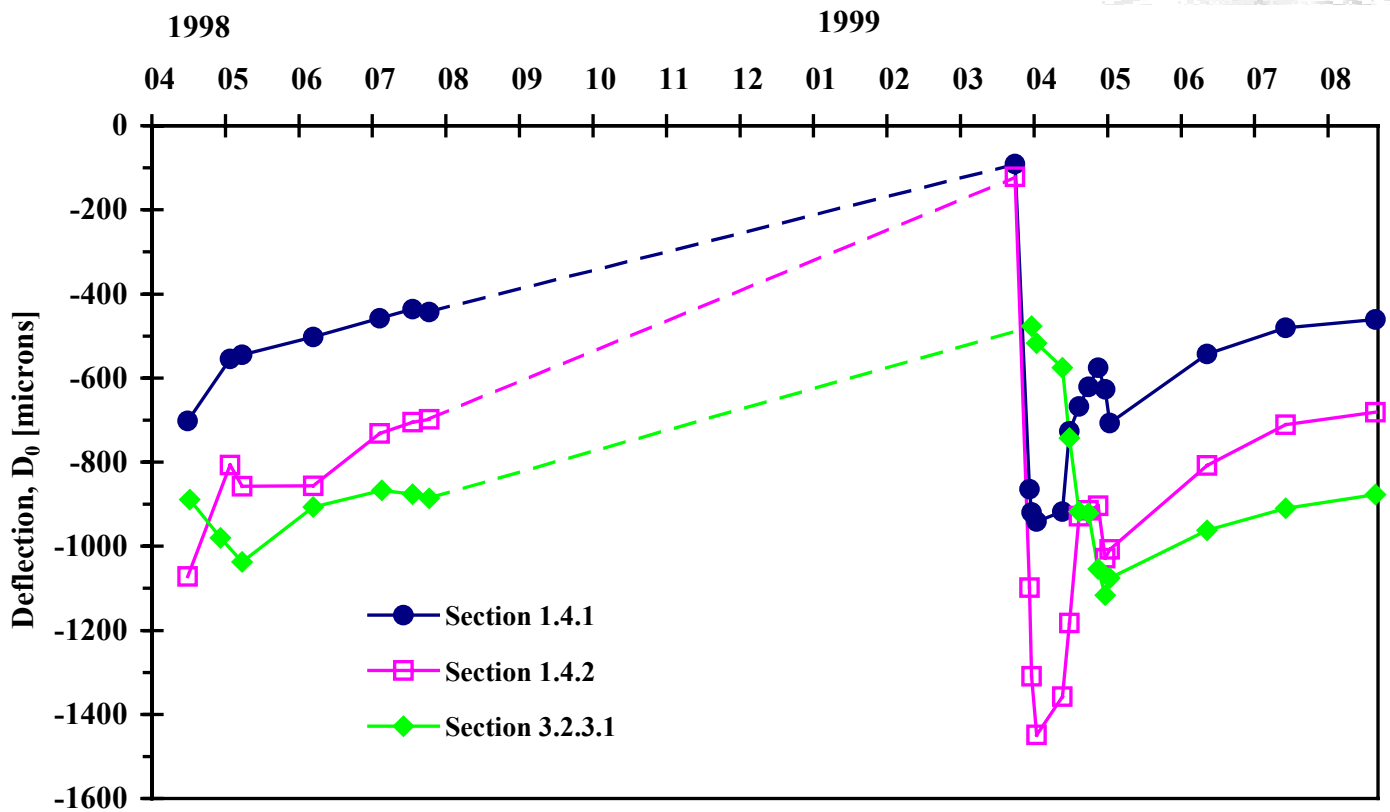


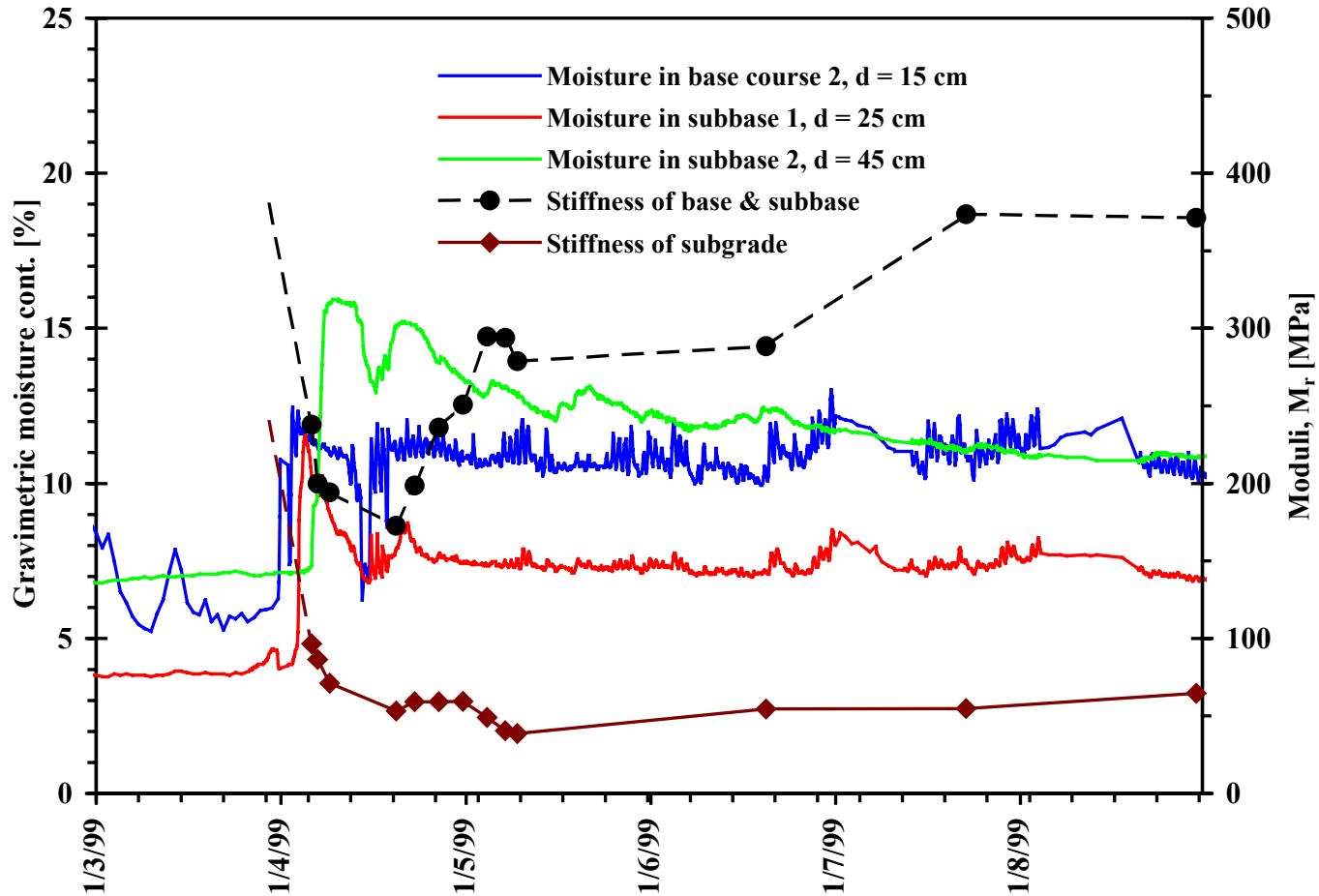
# Gravimetric Moisture: June 2000 – May 2001

| Section | Layer | Depth [cm] | USCS | D < 75 μm [%] | OMC Lab [%] | MC Field max. [%] |
|---|---|---|---|---|---|---|
| 1.4.1 | Base course 2 | 150 | GW-GM | 5,0 | 9,9 | 12,7 |
| | Subbase 1 | 250 | GW-GM | 5,8 | 10,5 | 12,0 |
| | Subbase 2 | 450 | SW-SM | 6,0 | 12,8 | 15,4 |
| 1.4.2 | Base course 2 | 130 | GW-GM | 5,0 | 9,8 | 12,6 |
| | Subbase 1 | 250 | SM | 14,7 | 10,8 | 13,1 |
| | Subbase 2 | 560 | SW-SM | 10,3 | 10,7 | 12,3 |
| 3.2.3.1 | Subbase 1 | 150 | SP | 3,5 | 12,0 | 15,4 |
| | Subbase 1 | 290 | SP | 3,5 | 12,0 | 17,1 |
| | Subbase 2 | 500 | SP-SM | 10,5 | 12,0 | 13,3 |

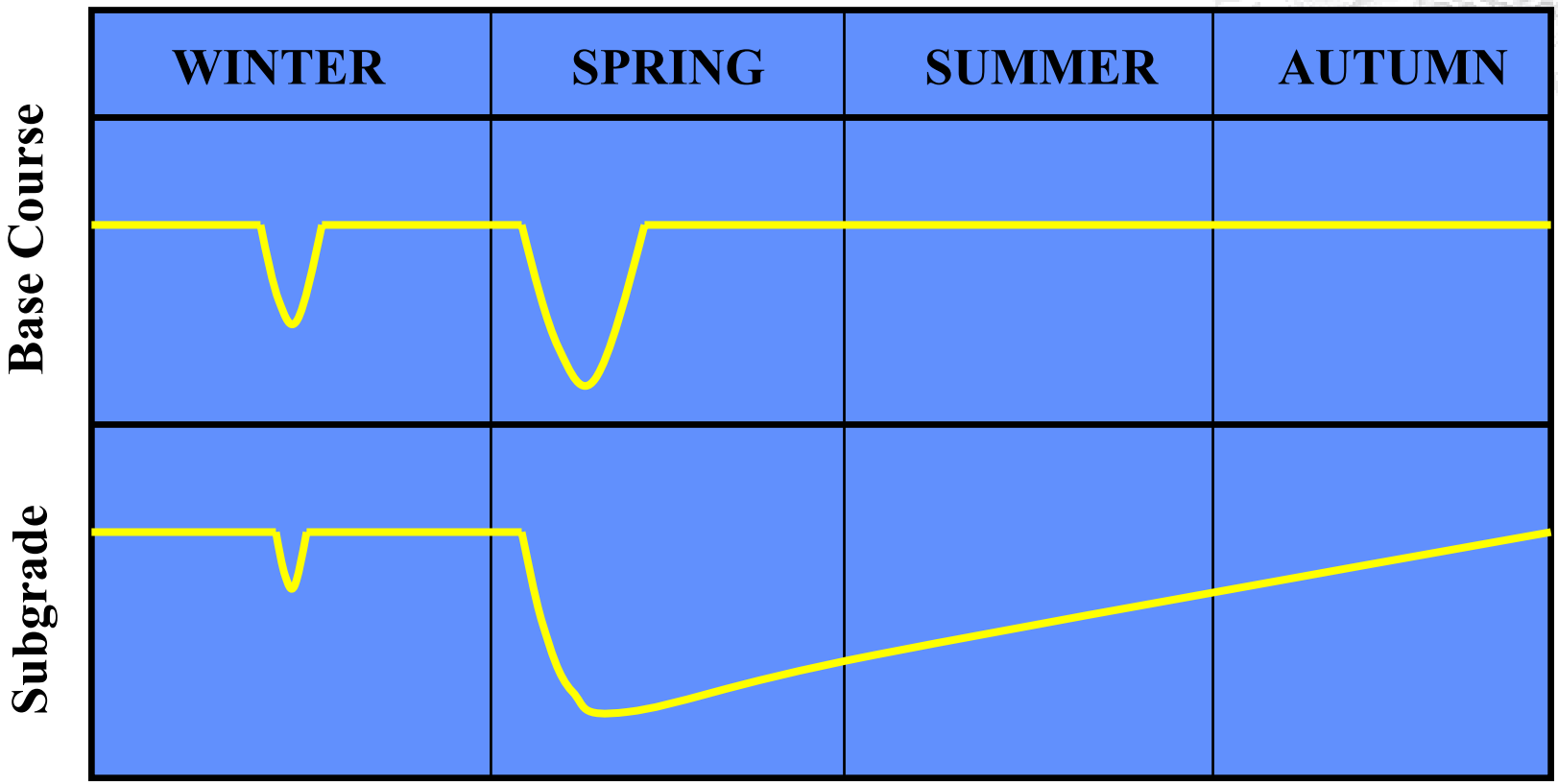
# Measured Deflection Values in 2nd Drop



# FWD results & grav. moisture in 1999
# Section 1.4.1

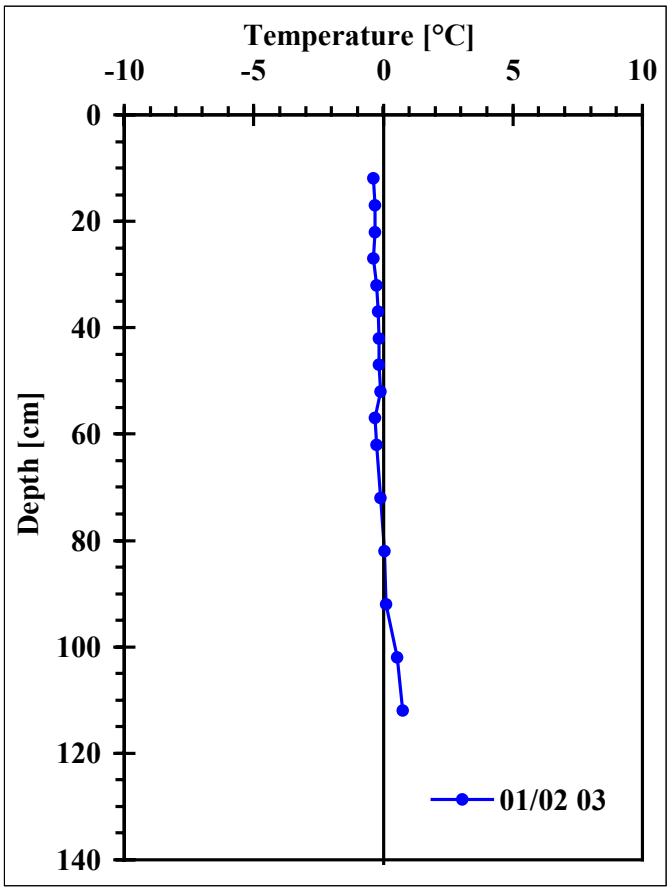


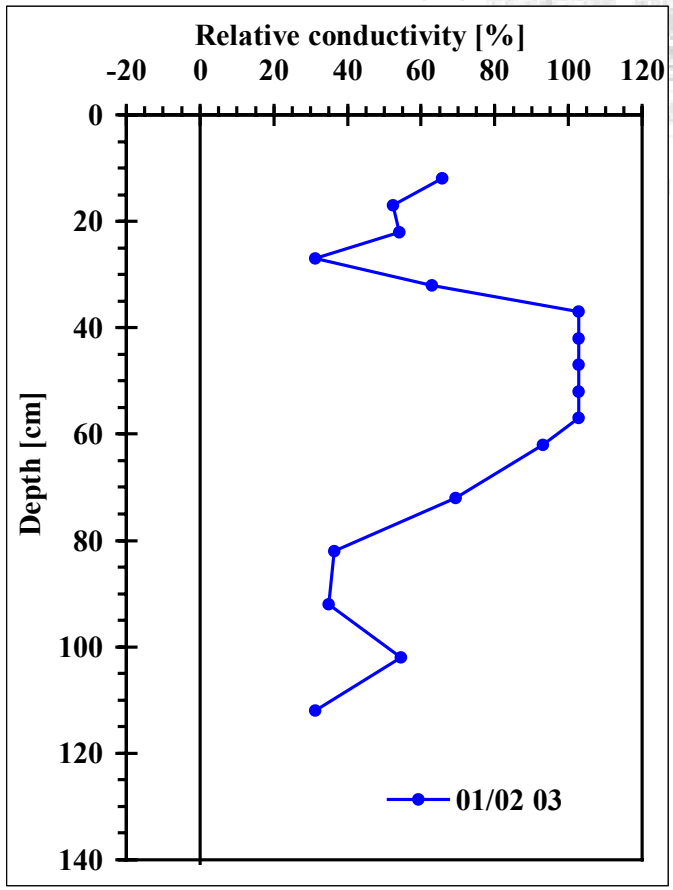
# Seasonal Variation of Stiffness in Unbound Layers



# Innovative Technique – Temperature & Resistivity Probe

# Temperature & Resistivity Probe



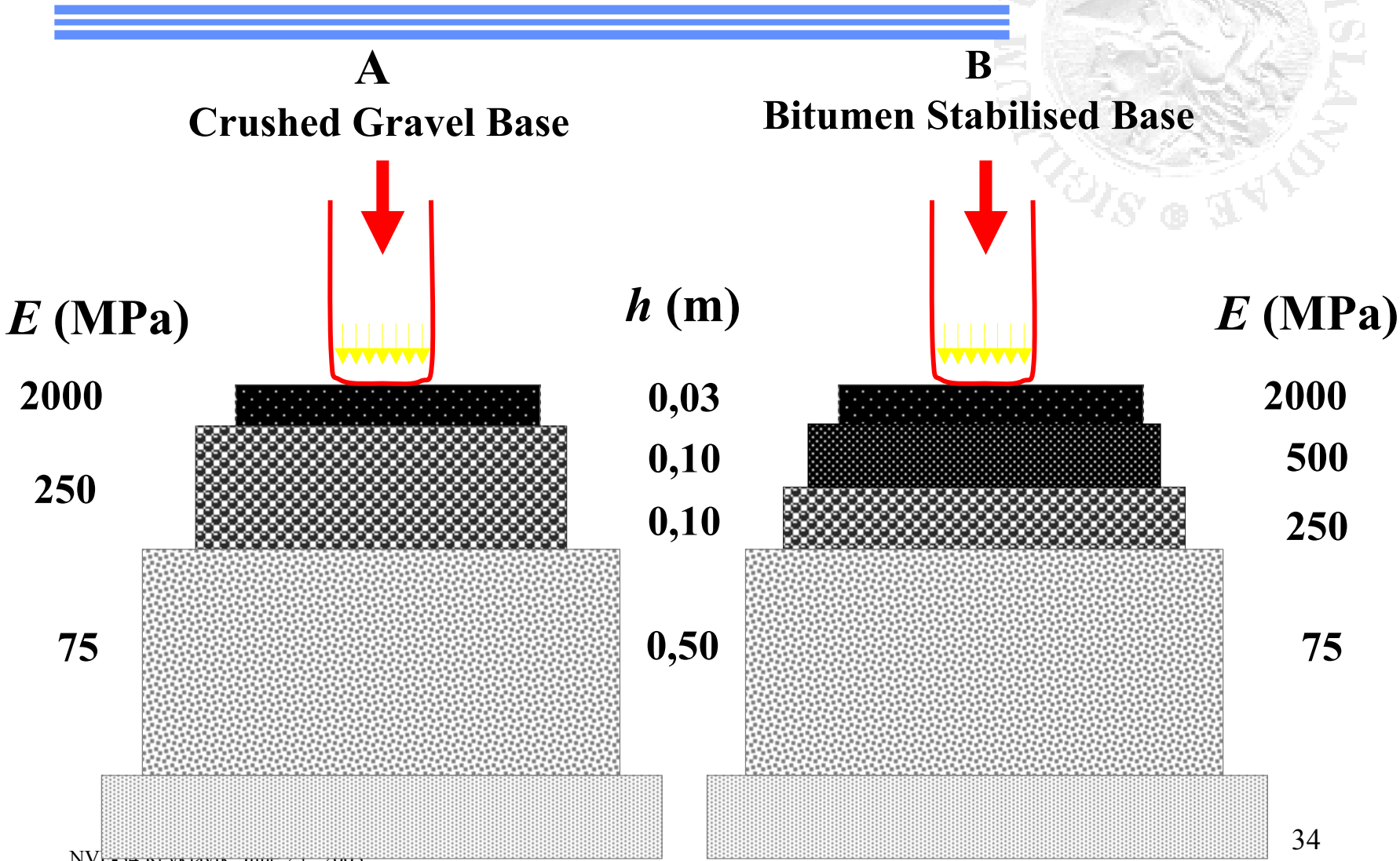



# Accelerated Pavement Testing

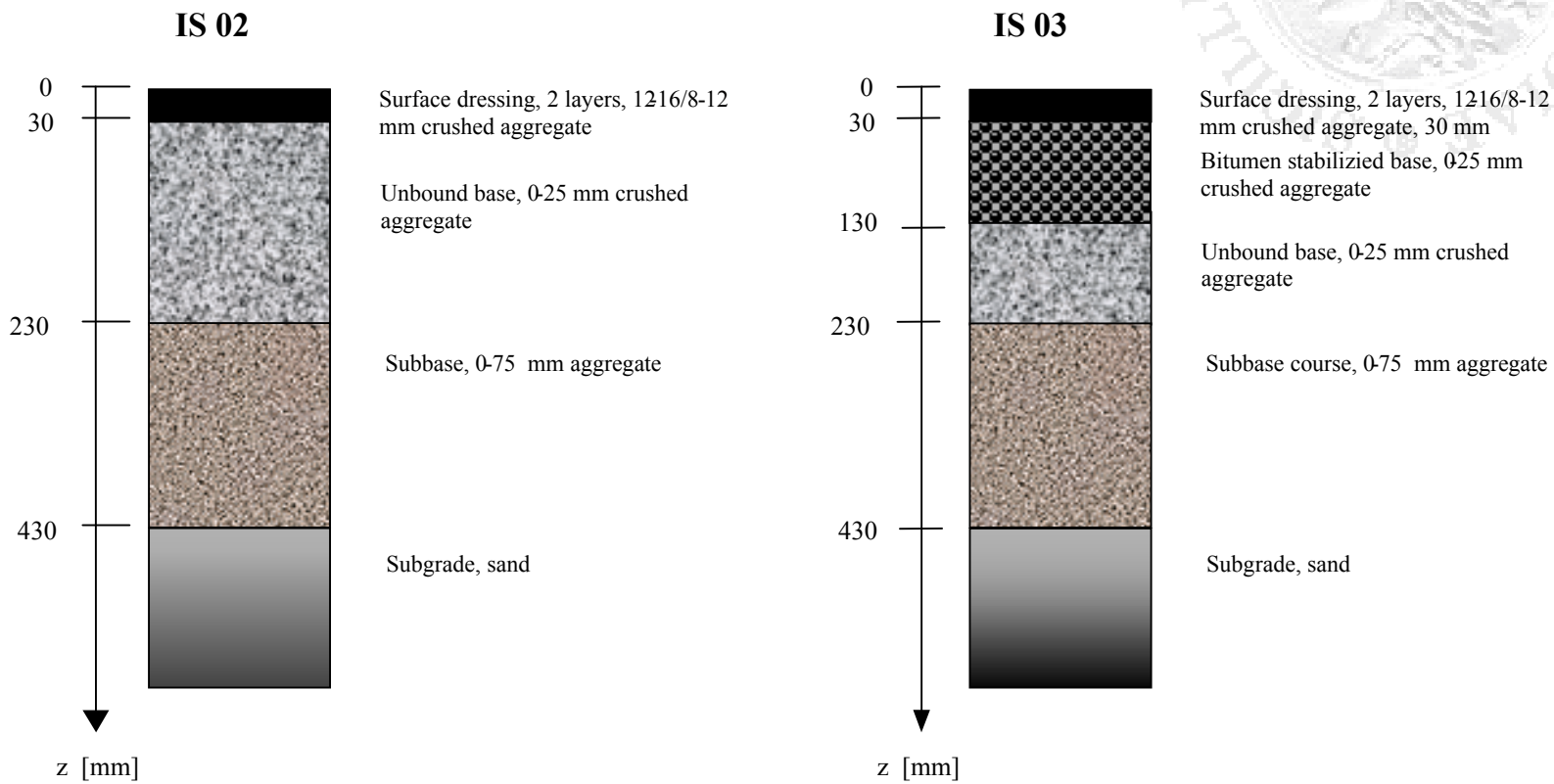
- **Purpose**

  **To increase the understanding of pavements performance under heavy loading conditions.**

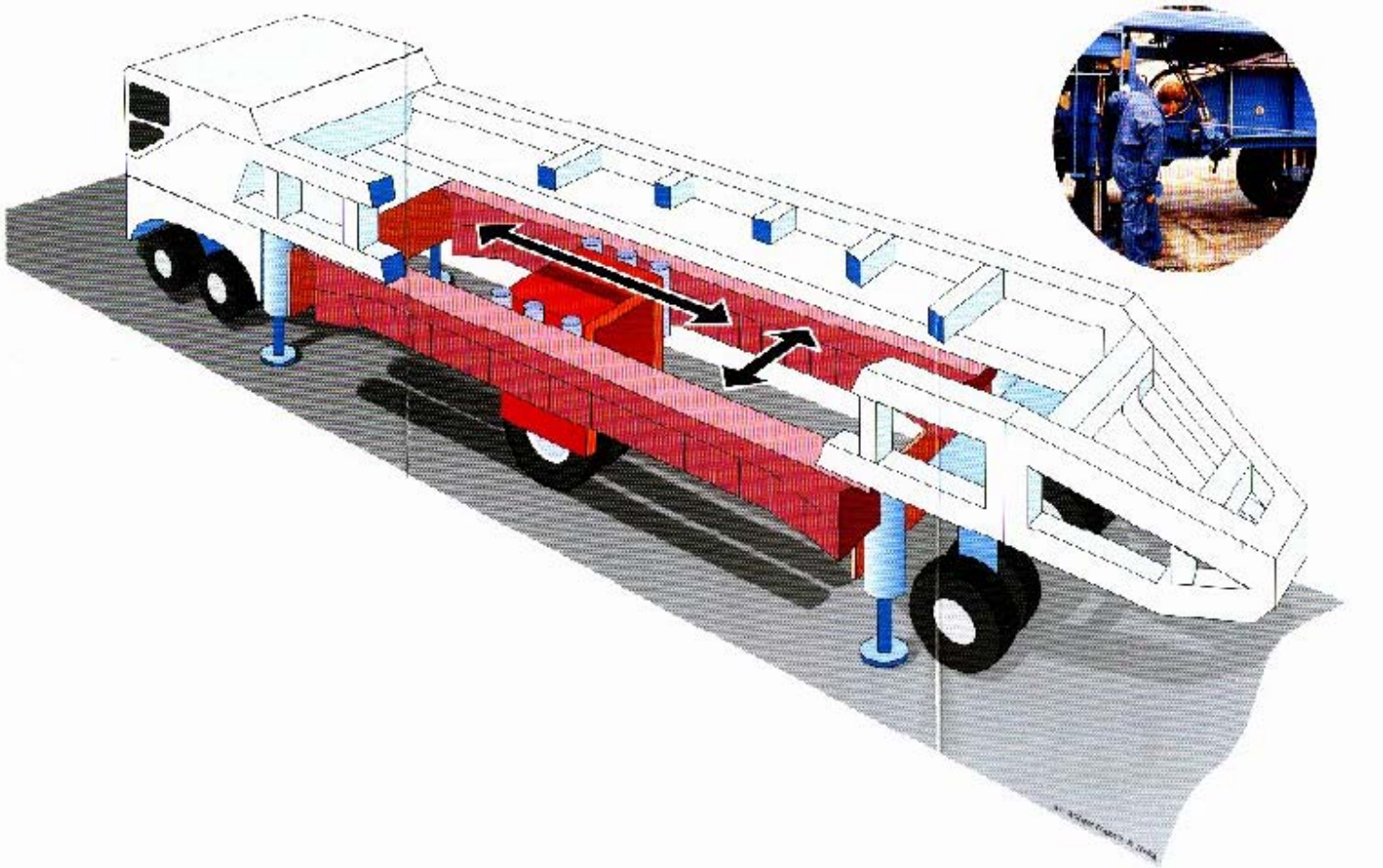
# Typical Pavement Structures



# The Pavement Structures (IS02 & IS03)



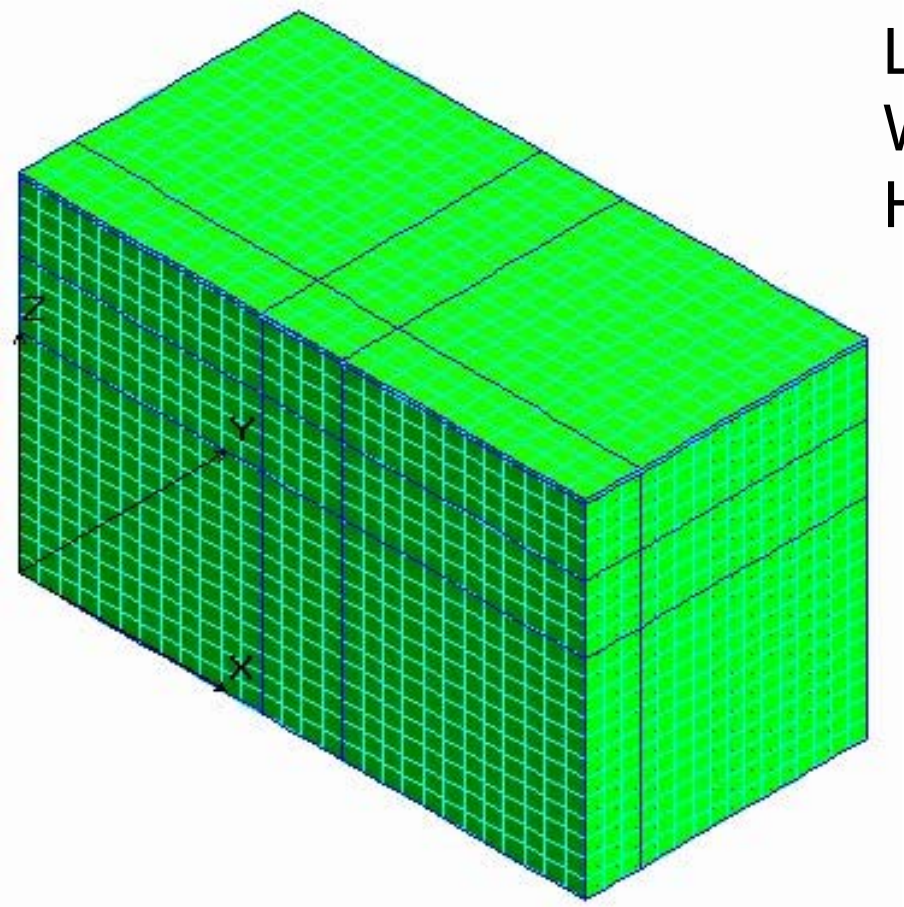
# The HVS-Equipment



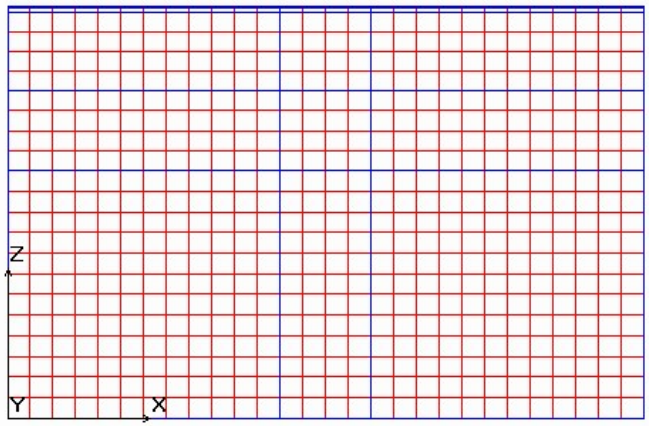
# Response Testing - Numerical Simulations

- 2-D Axi & 3-D analysis.
- MLET & FEM analyses
- Linear and non-linear base behaviour

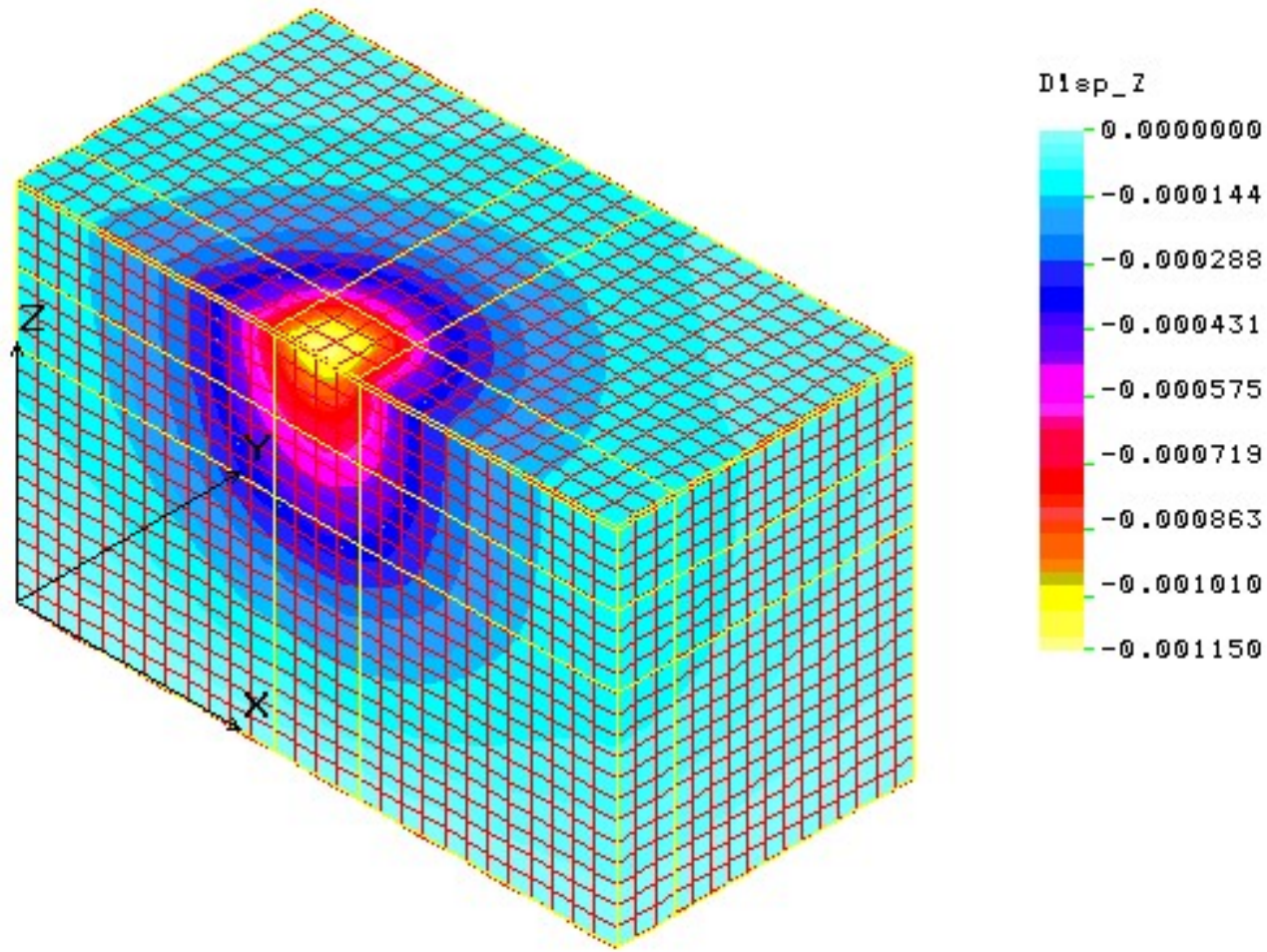
# IS02 – The mesh




Length: 1200 mm
Width: 600 mm
Height: 1000 mm

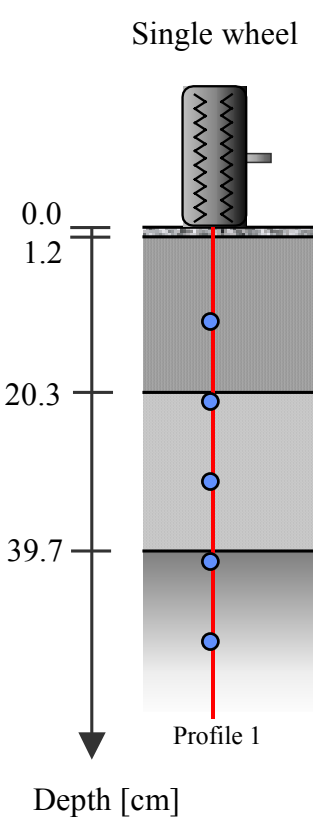


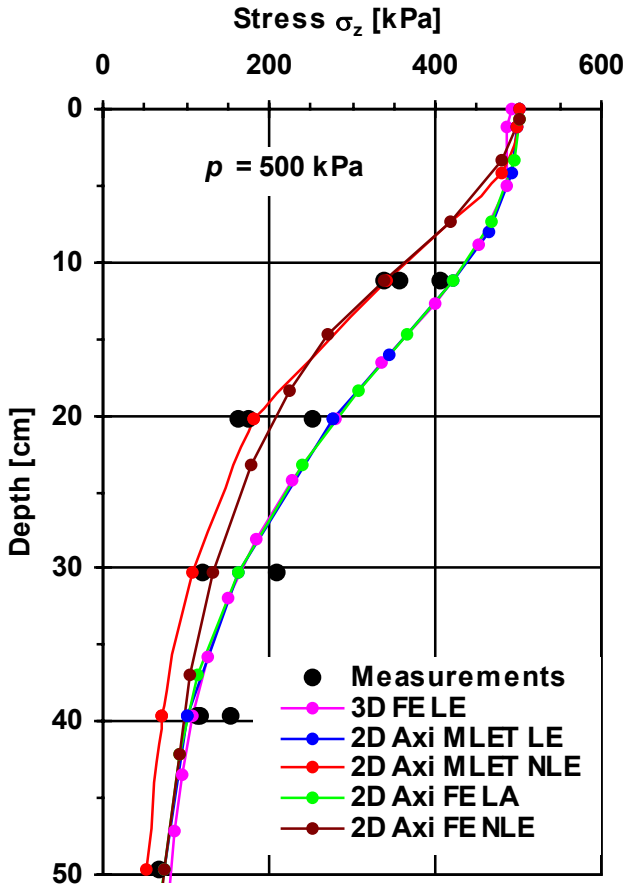
# IS02 – Single wheel, *p* = 800 kPa
# FEM: Vertical displacement

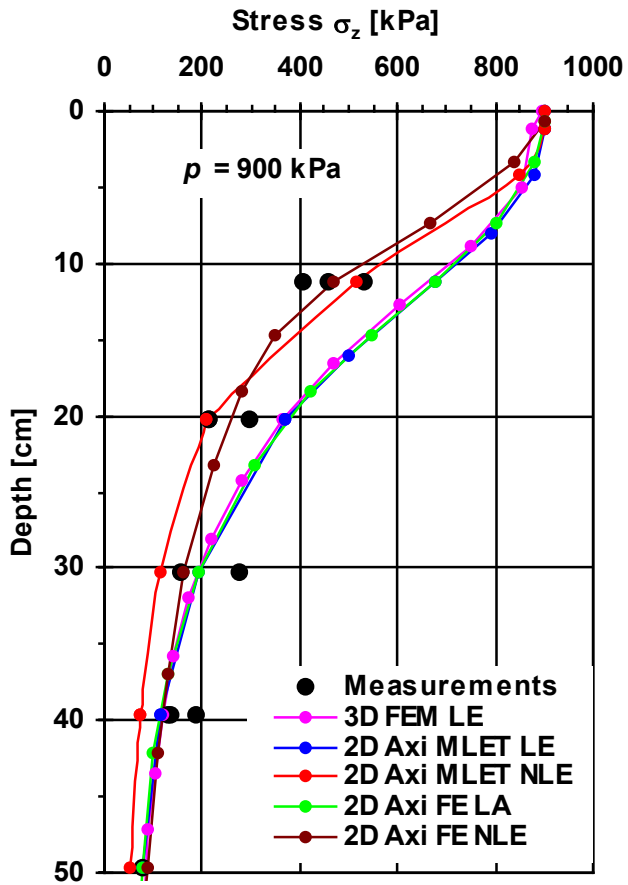


# IS02 Vertical Stresses vs. Depth

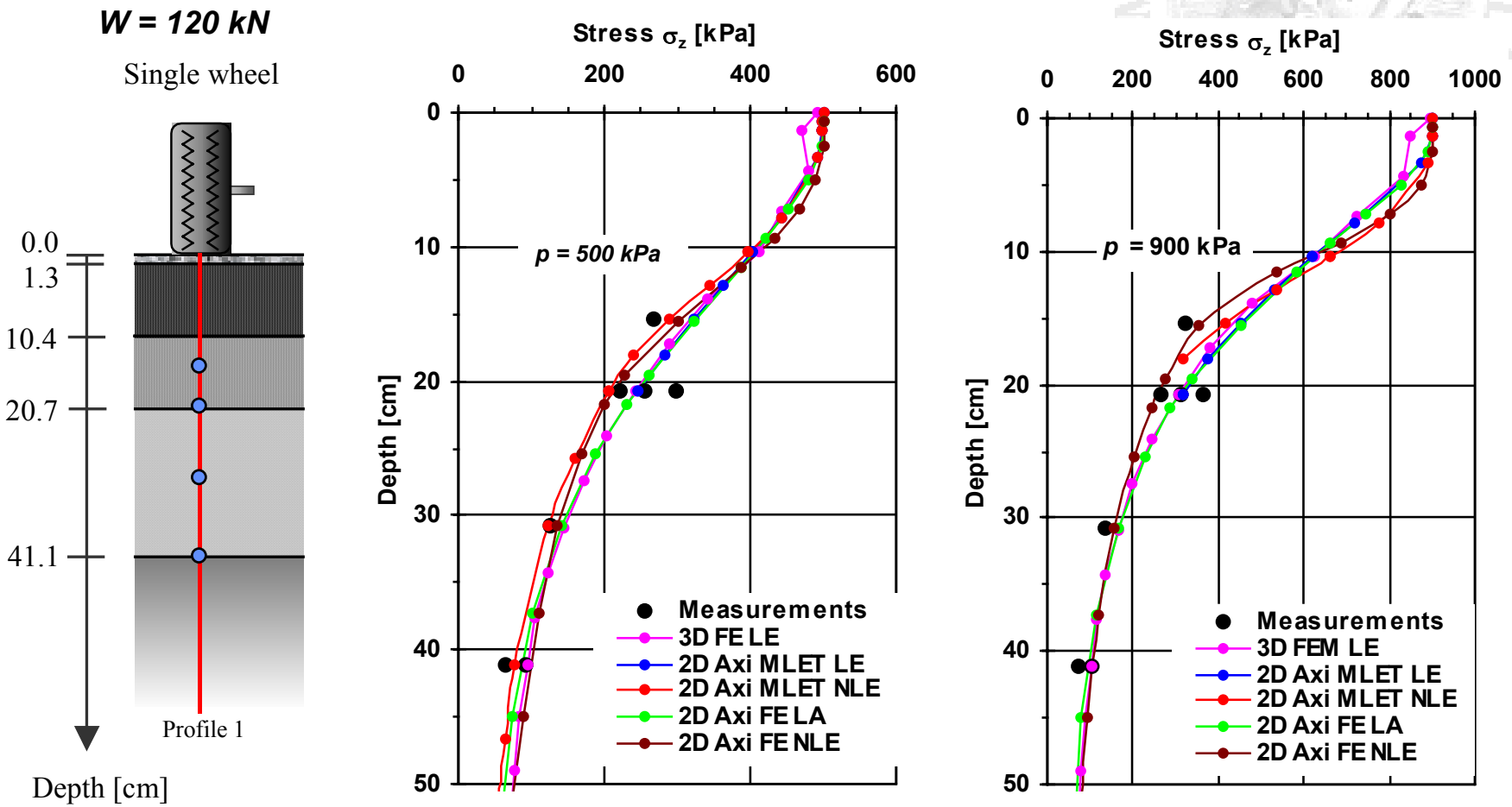
***W = 120 kN***



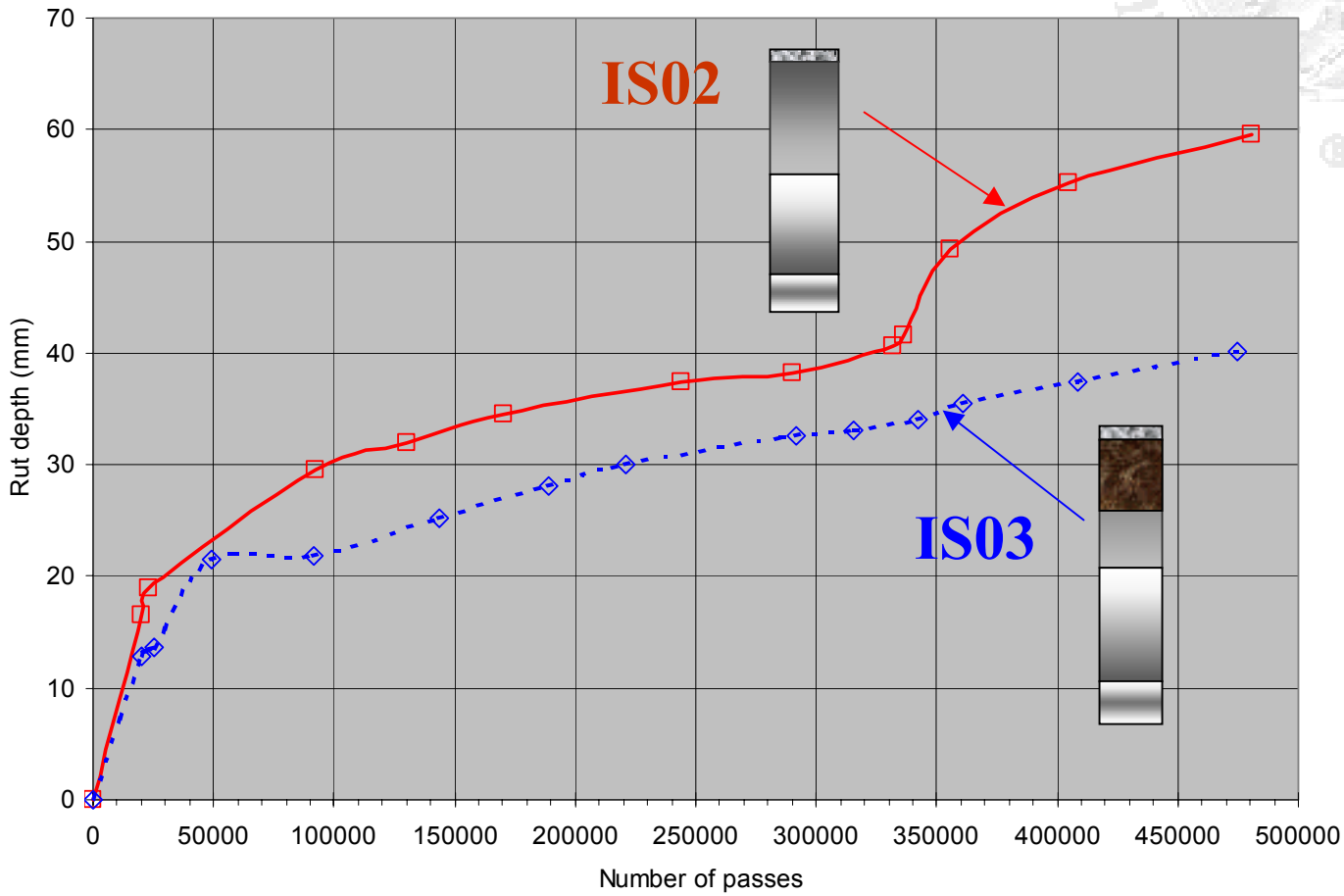



# IS03 Vertical stresses vs. depth

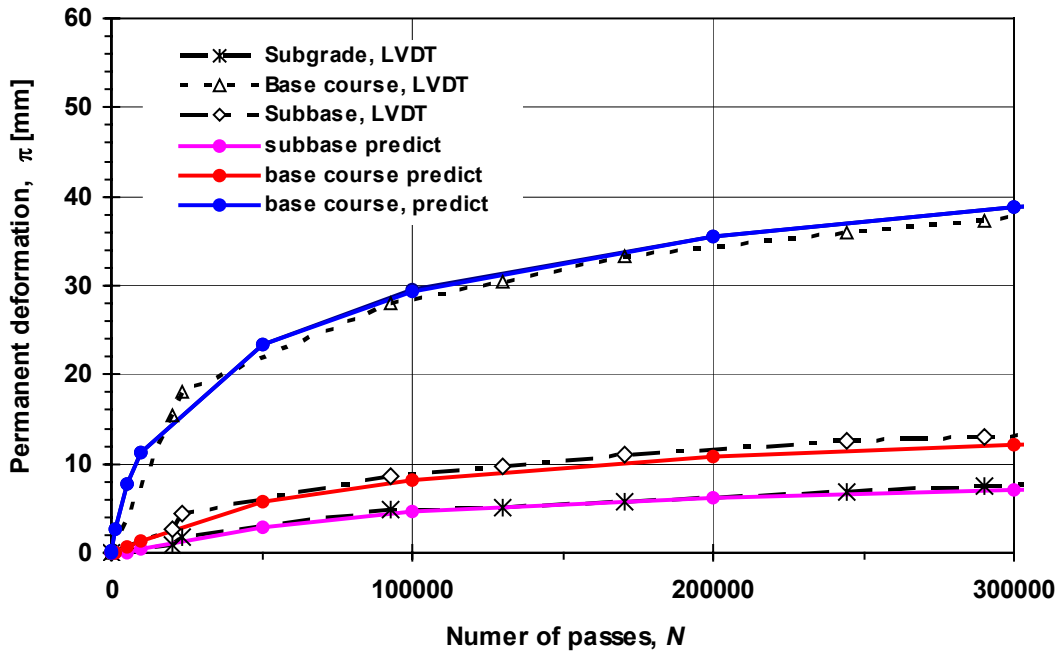


# Rutting

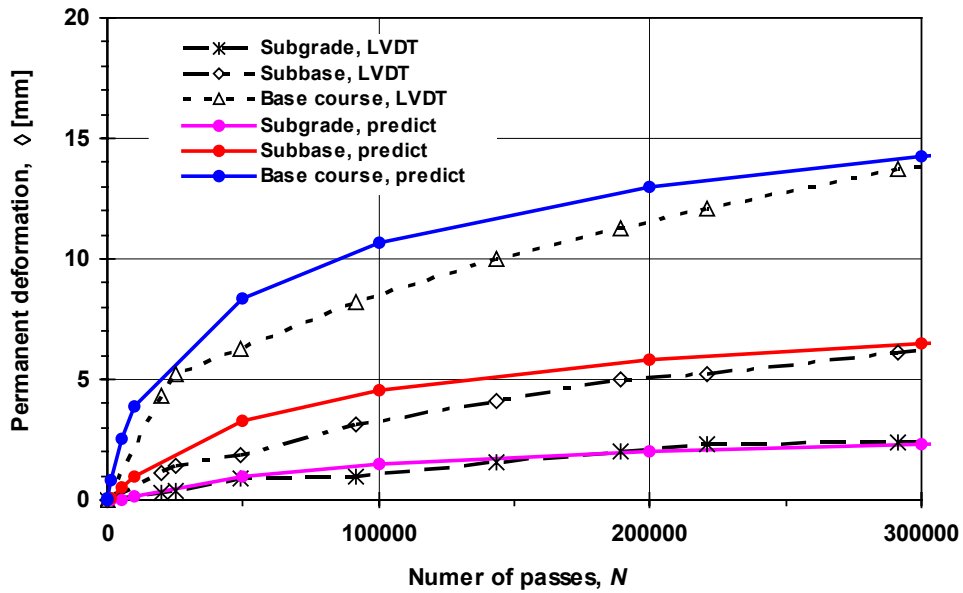

IS02
IS03
Rut depth (mm)
Number of passes
0
10
20
30
40
50
60
70
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000

# Distress prediction – rutting in IS02

$$= \sum_{=} \left[ \frac{}{} \cdot \; ^{-(-)} \cdot \int_{=-}^{=-} \cdot \left( \int_{-} \right) \right]$$



# Distress prediction – rutting in IS03

# Conclusions

- **Mechanistic-empirical based design methods will probably be in use in many countries in the near future. To be able to use such methods we need to obtain information for modelling purposes on factors affecting pavement performances, such as**
  - **Axle loading**
  - **Material properties**
  - **Weather and environmental conditions**

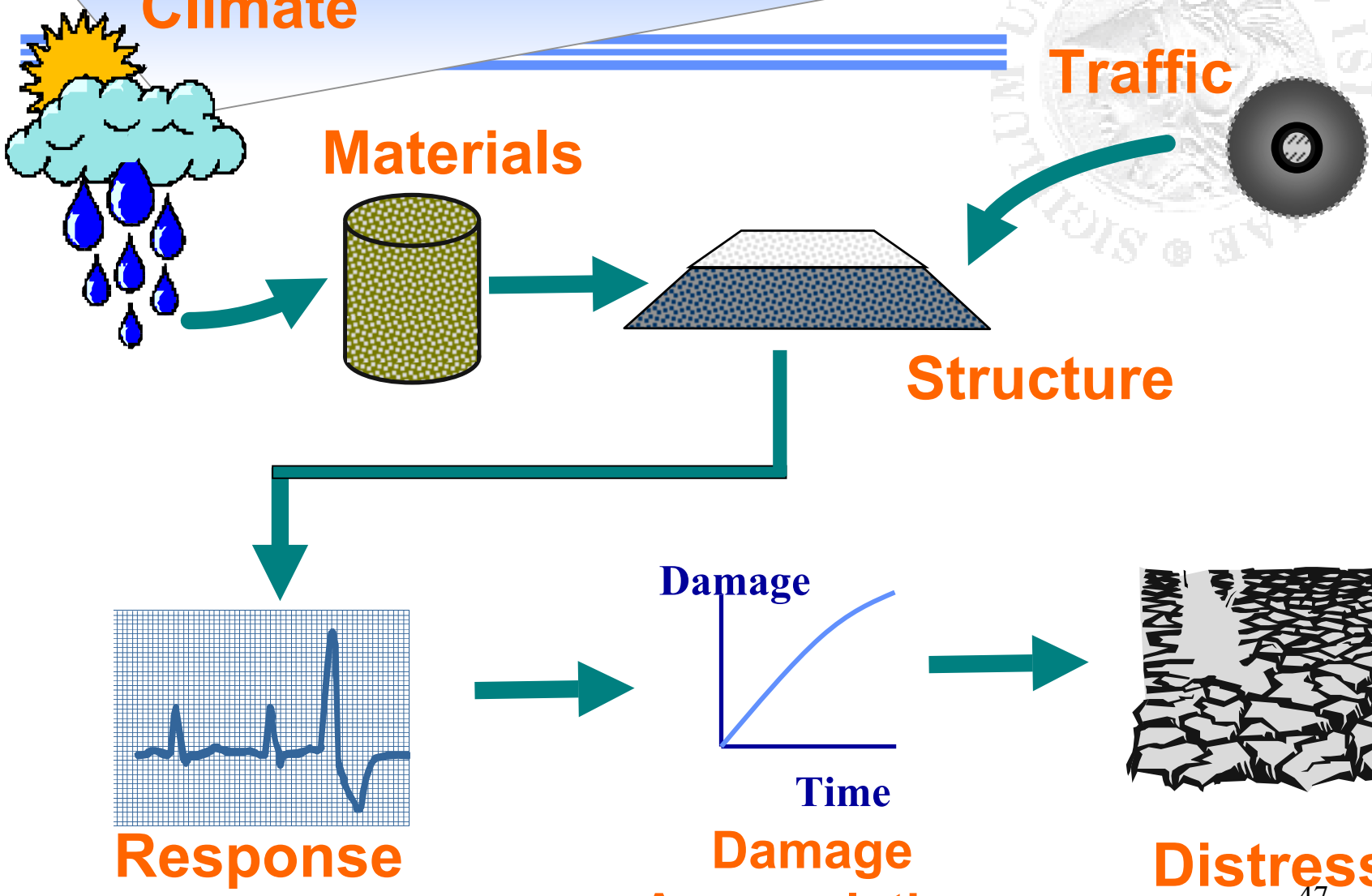
- **Further we need information to calibrate and validate such methods if acceptable agreement between real performance and our estimation is to be achieved.**

# AASHTO 2002 Design Guide

***Mechanical – empirical design procedure of pavement structure***

***www.2002designguide.com***

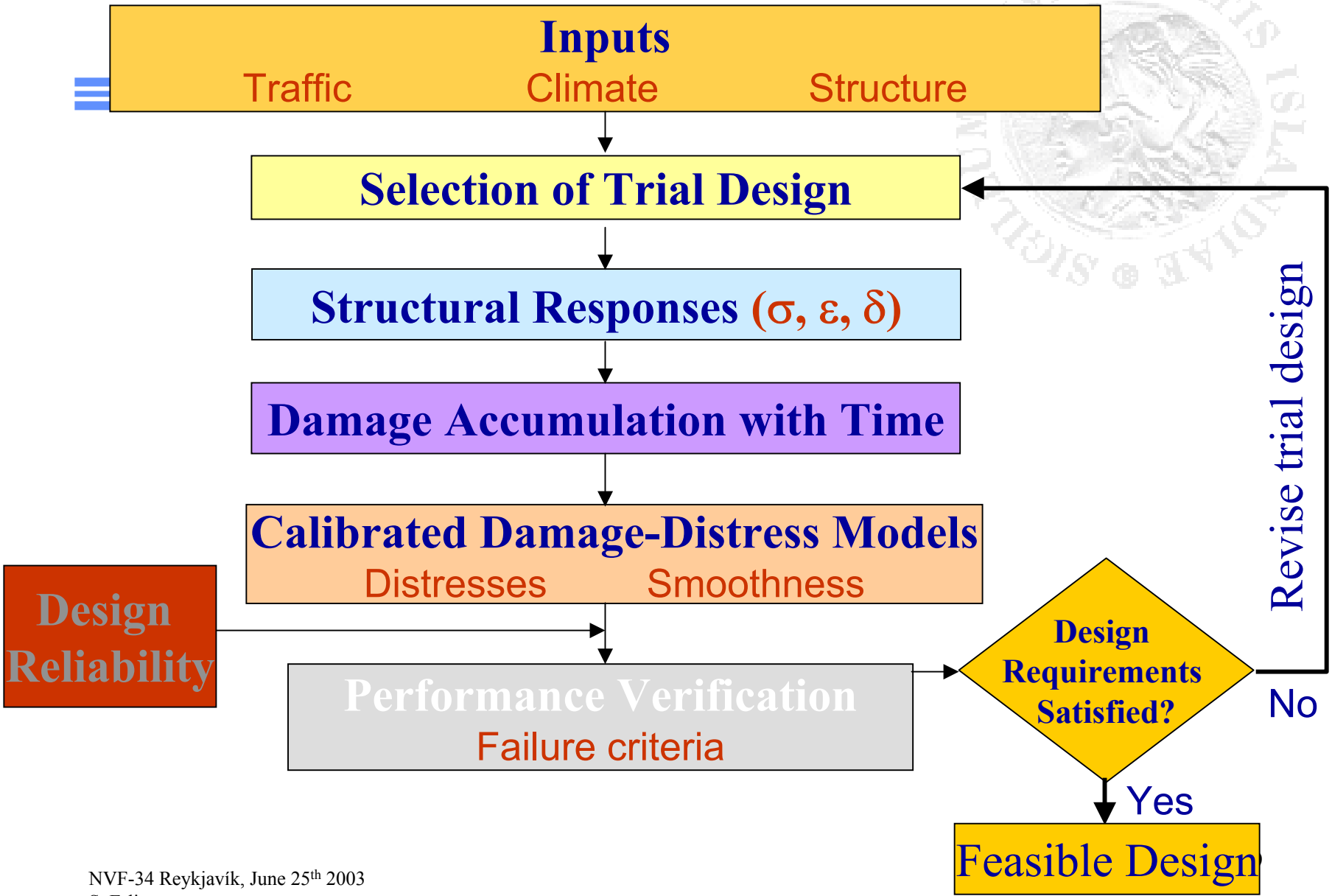
# Mechanistic-Empirical Design



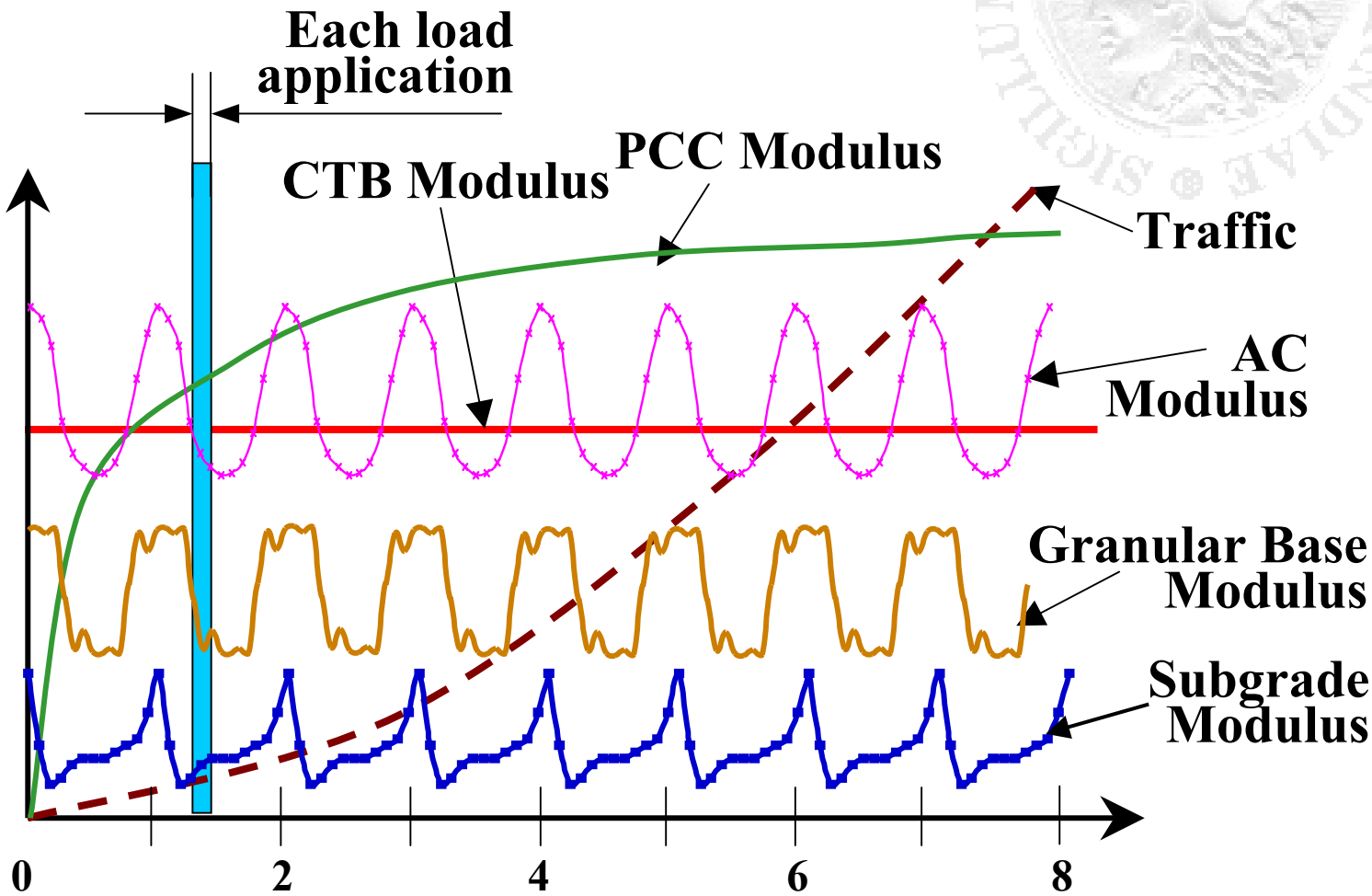
# Mechanistic-Empirical Design

- *Mechanistically* calculate pavement response (i.e., stresses, strains, and deflections) due to:
  - » Traffic loading
  - » Environmental conditions
- Accumulate *damage* over time
- *Empirically* relate damage over time to pavement distresses, e.g.:
  - » Cracking
  - » Rutting
  - » Faulting
- *Calibrate* predictions to observed field performance

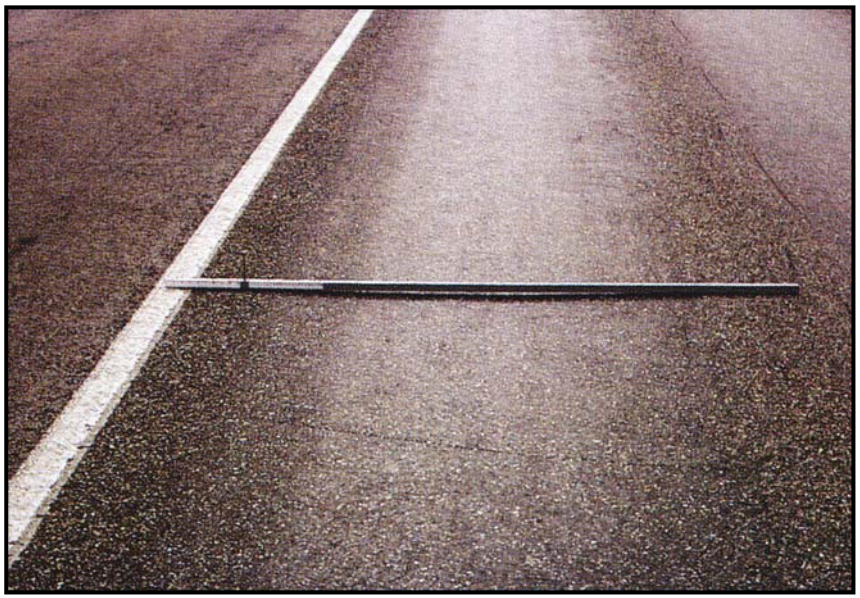
# 2002 Guide Design Process



# Design Parameters Over Pavement Life



# Rutting in Flexible Pavements



*(SHRP, 1993)*

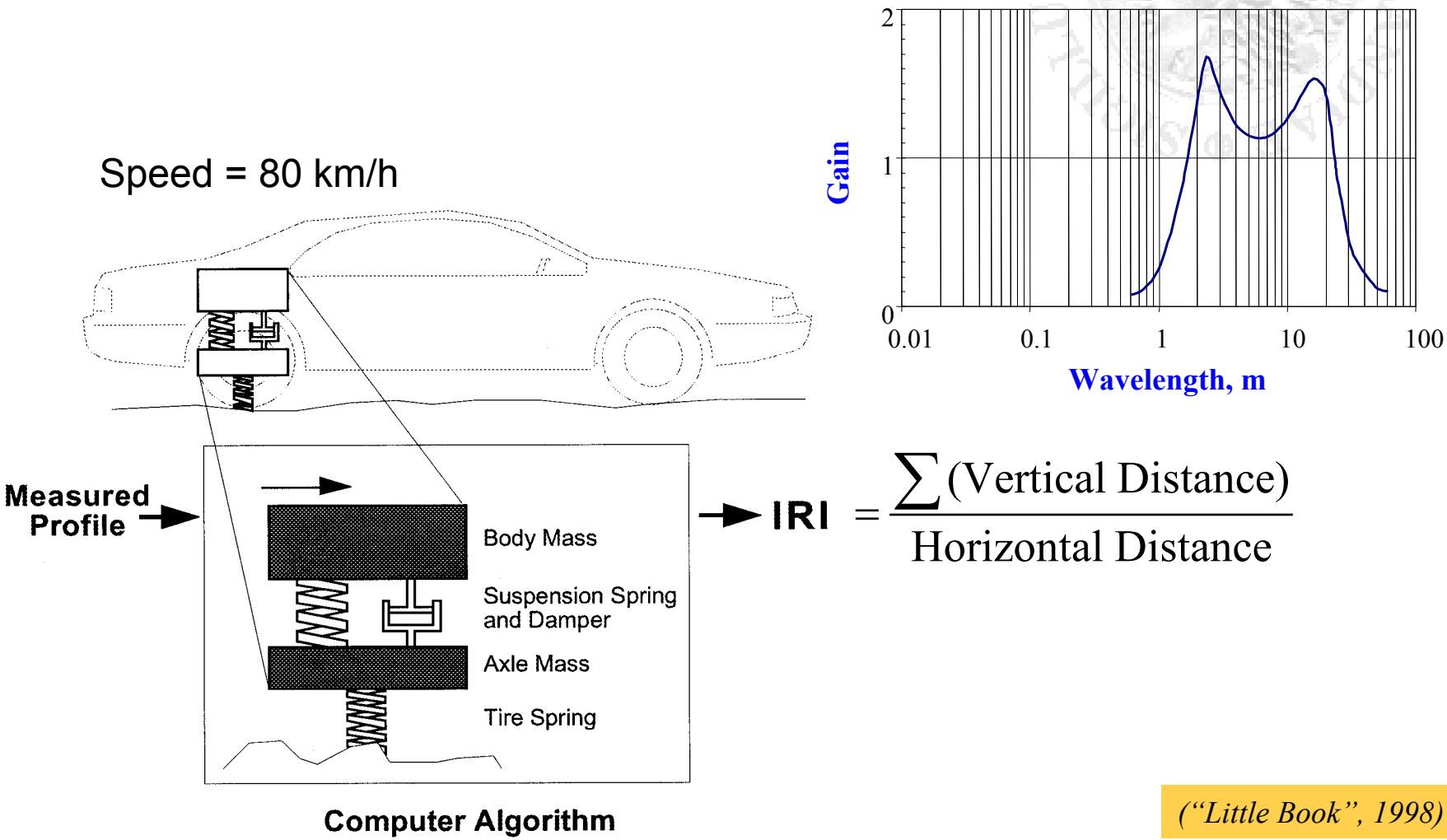
# Fatigue Cracking ("Alligator Cracking") in Flexible Pavements

*(SHRP, 1993)*

# Thermal Cracking in Flexible Pavements

*(SHRP, 1993)*

# Ride Quality – International Roughness Index (IRI)




*("Little Book", 1998)*

# AASHTO 2002 Design Guide – Design Inputs