PAVEMENT MATERIALS

Lecture 5

Course Heads

- Subgrade
  - Natural
  - Stabilized
- Subbase
- Base Course
  - Unbound
  - Bound
- Surface Courses

Sequence

- SUBGRADE

- Investigation
- Material Classification/Identification
- Material Evaluation
- Material Selection
- Construction of Subgrade
- QA/QC
- Post Construction Investigation

Subgrade Evaluation

- Strength → This Lecture
- Stiffness
- Stability → Lecture 06

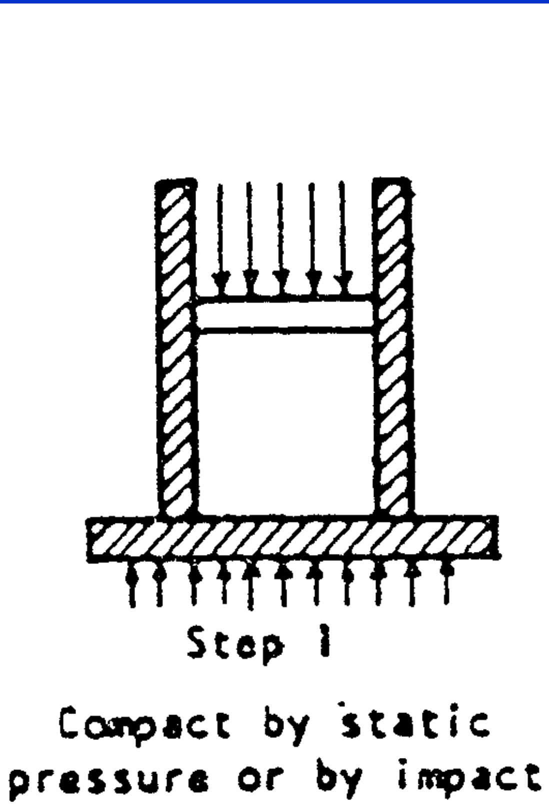
Strength

- **Field**
  - Penetration Tests (SPT, CPT, DCPT…)
  - In-situ CBR
- **Laboratory**
  - California Bearing Ratio (CBR) Test
  - Triaxial Compression Test (Static)
  - Direct Shear Test

California Bearing Ratio (CBR)

- **The CBR (California Bearing Ratio) test measures the resistance of the soil to penetration.**
- **A piston with an end area of 3 square inches is pressed into a six inch diameter, five inch tail soil specimen in a steel compaction mold at a standard rate of 0.05 inches per minute. The load required to force the piston into the soil is measured at given penetration intervals.**
- **The resulting penetrations are compared to the penetration recorded for a standard, well-graded crushed stone to get the bearing ratio as a percentage of the standard.**
- *Because this test is arbitrary in nature, it has many limitations.*
- **An advantage is the relatively simple equipment needed and the large amount of historical data available for correlating results with field performance.**
- **Another disadvantage is that the test method is very sensitive to the method of specimen preparation.**
- **There have been significant modifications to the original CBR method to improve its applicability.**

California Bearing Ratio (CBR)



California Bearing Ratio (CBR)

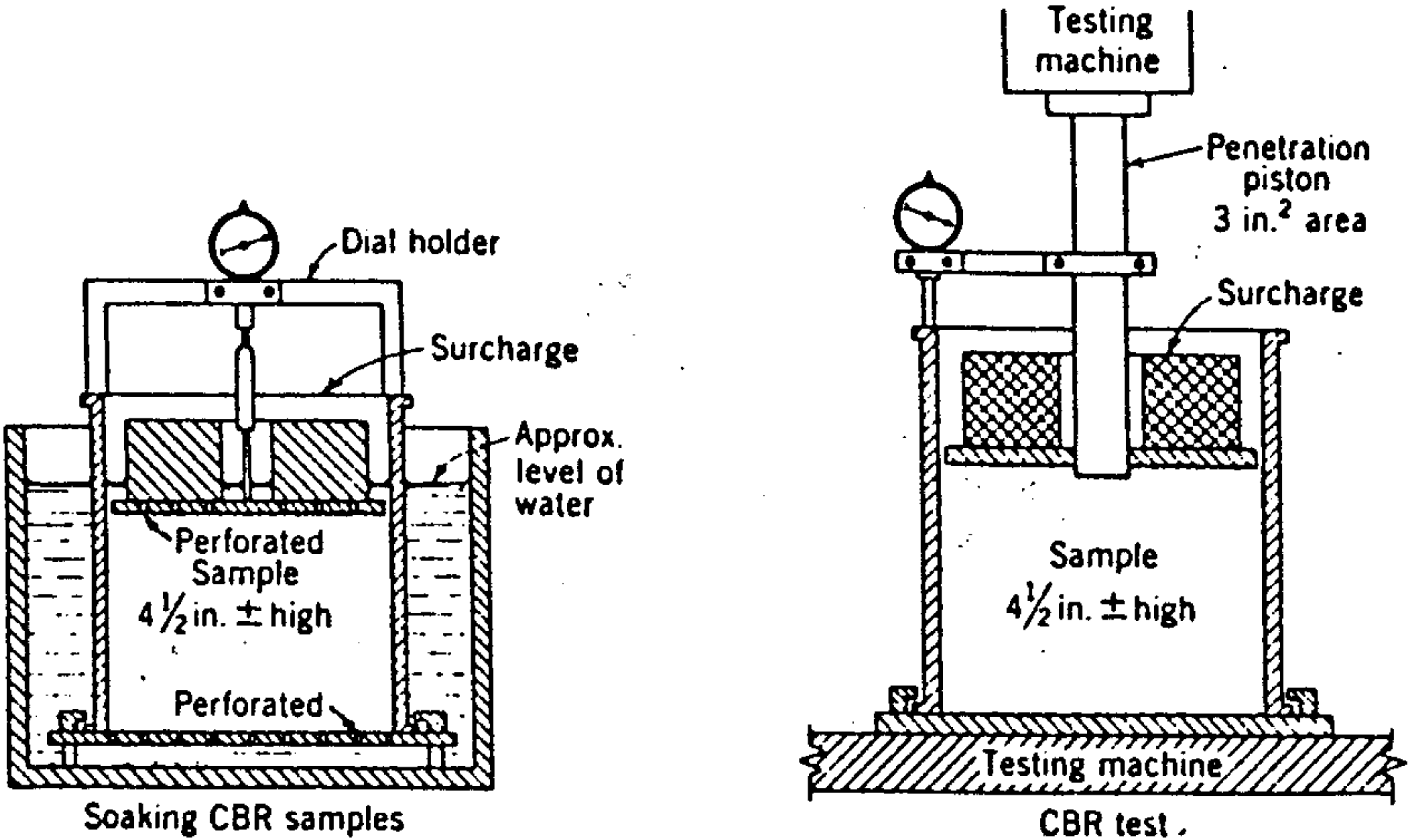


Fig. 7-11 The California bearing ratio test. (*After Walker, Yoder, Foster, and Johnson* [22].)

CBR

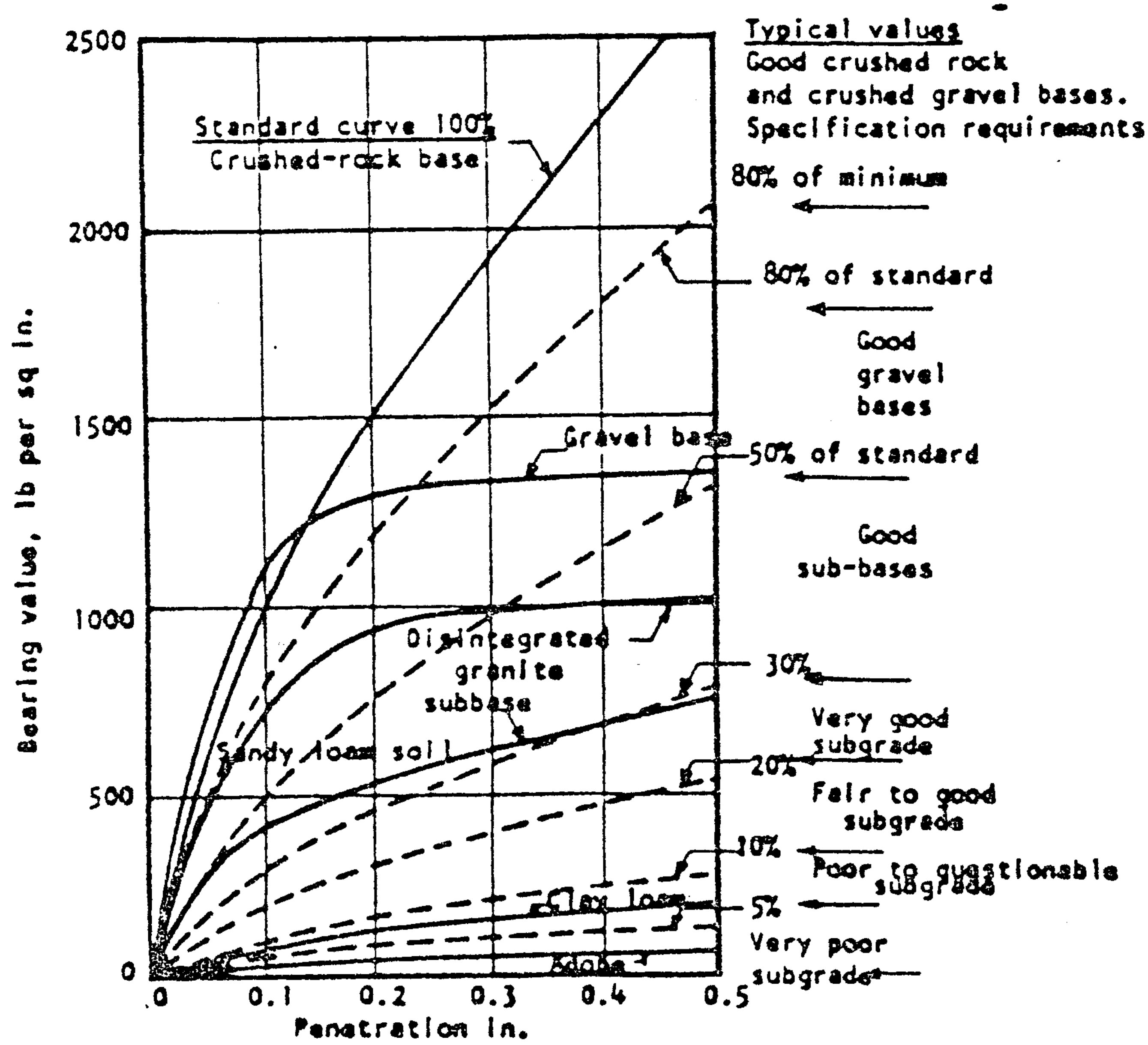
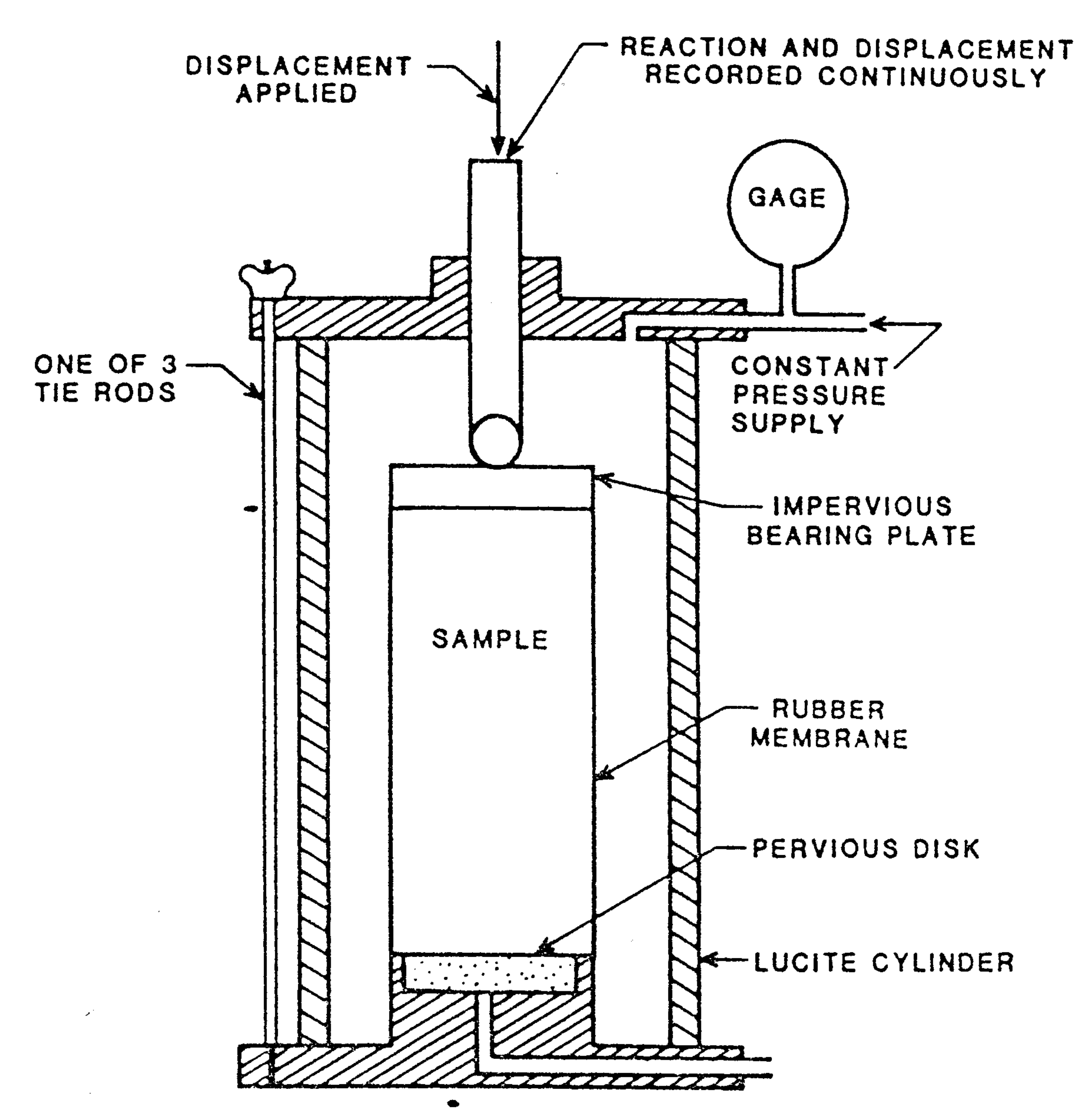


Figure 2-1.7. CBR Testing Procedure and Load-Penetration Curves for Typical Soils.

Triaxial Test



Triaxial / Direct Shear

- What is the outcome of Triaxial & Direct Shear Test?

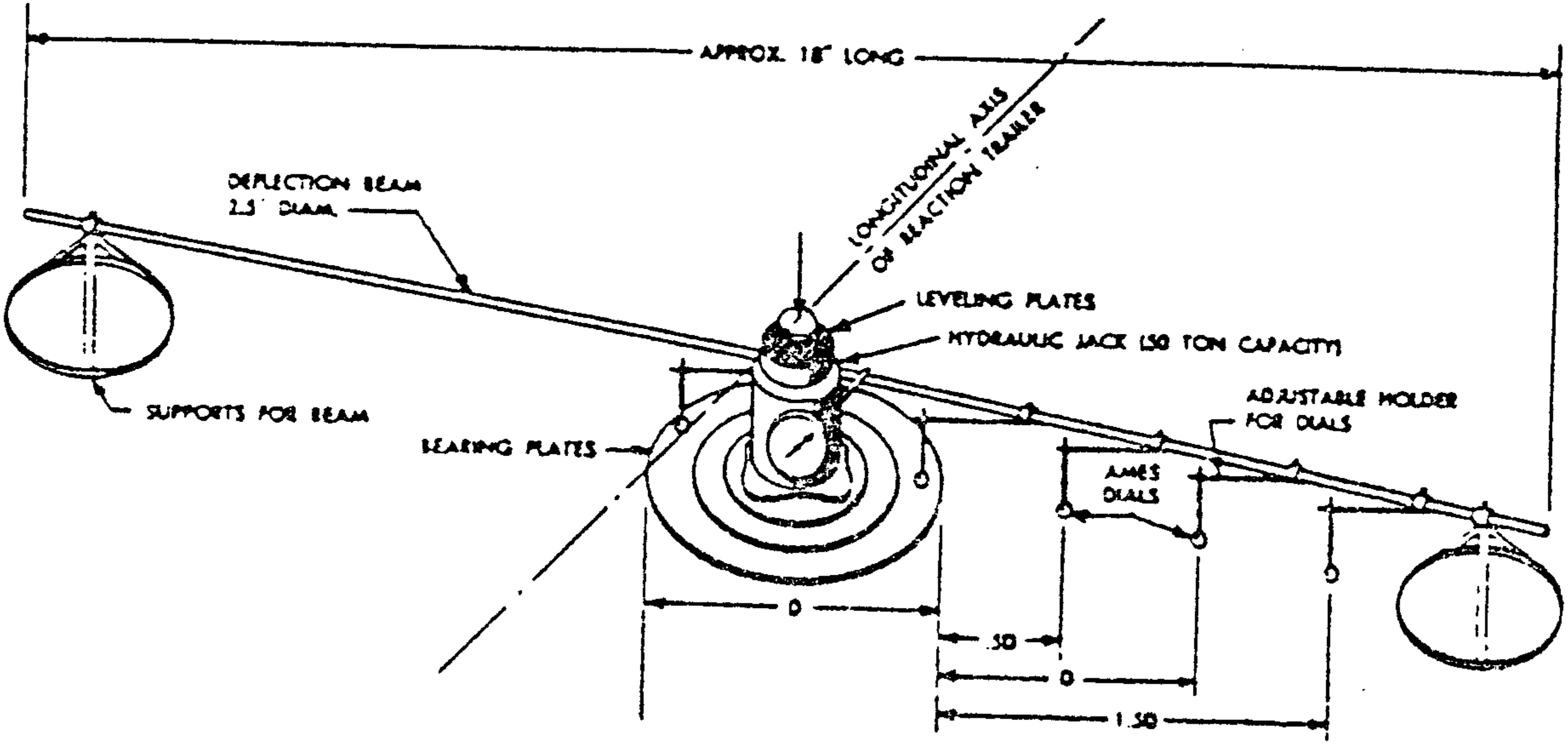
- Cohesion (c, c_u….)
- Angle of Internal Friction (ϕ, ϕ_u, ϕ')

- Use
  - Design (Embankments and other layers??)
  - Relative Improvement/Comparison etc…
  - Failure Criteria
  - Quality Control…...

Settlement / Consolidation

- **Field**
  - Penetration Tests
  - Plate Load Tests (k, E)
- **Laboratory**
  - Triaxial Compression Test (Static) E_i, E_s
  - Consolidation Test (C_c , c_v …..)

Plate Load Test



Stiffness

- What is Stiffness?

- *Types*
- Static
- Dynamic

Stiffness

- Design (Mechanistic)
- Comparative Study
- Quality Control

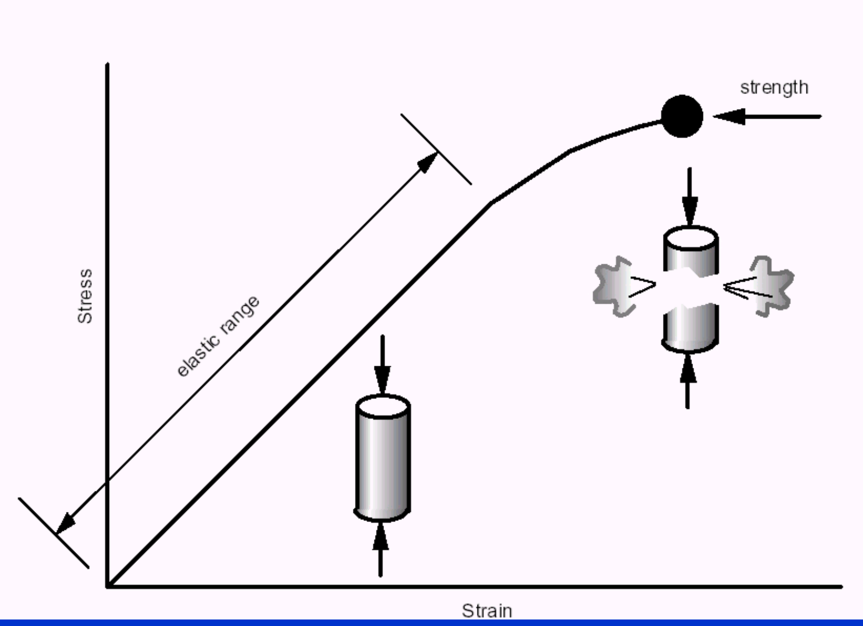
Dynamic Stiffness

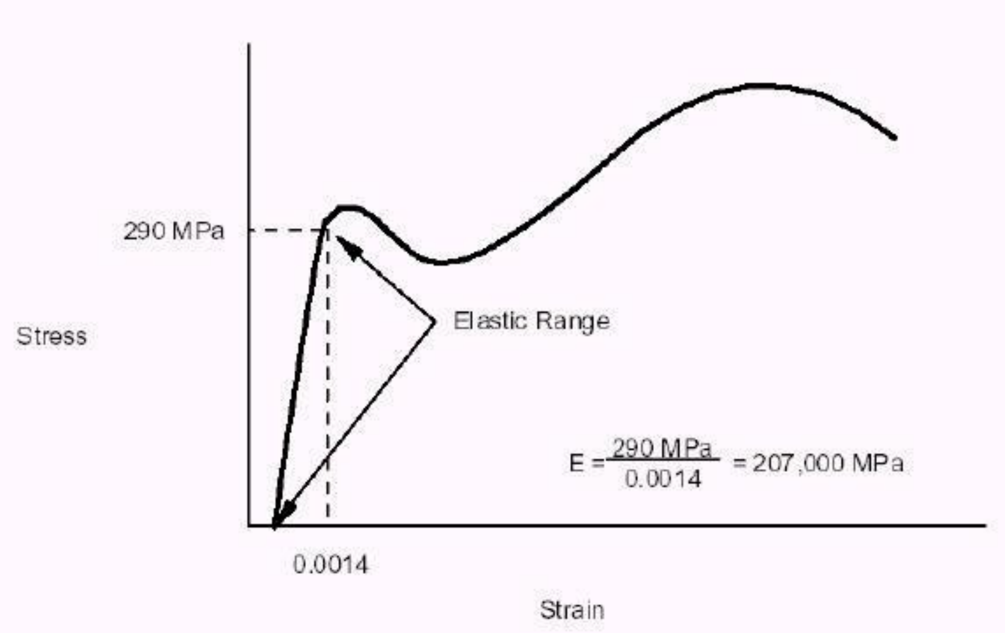
- Stiffness Response against
- *Repetitive Loads*

- *Difference with Static Load*
- Load Intensity
- Load Duration
- Load Repetition

Elastic and Resilient Behavior

- A prediction of Stresses, Strains, and Deflections induced in a layered pavement structure under traffic wheel loading requires an understanding of the stress-strain behavior of the materials comprising the structure.
- **Elasticity ??**
- **Resilience ??**





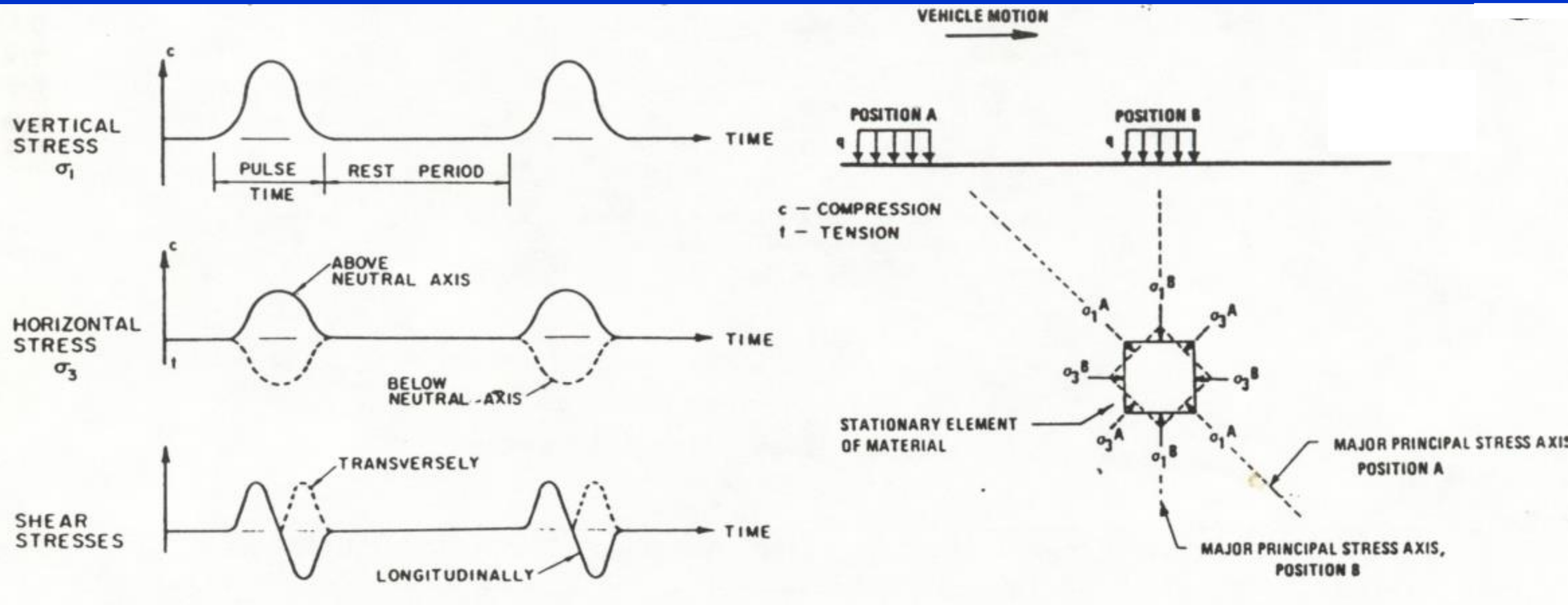
Resilient Behavior

- **Specifically, the elements in a pavement structure are subjected to a series of rapidly applied and rapidly released stresses on vertical and horizontal planes.**
- **While the magnitudes of the stress variation will differ between points in the same layer, the basic pattern is similar throughout the pavement structure.**

- **Another way of representing this situation is that the orientation of the principal stress axes of an element of material is gradually rotated as a wheel load moves along the surface.**
- **At an instant when the load is directly above the element, the principal stresses are oriented horizontally and vertically.**

- **Due to the fact that the principal stress rotates as the wheel load approaches and passes over an element,** a reversal of shear stresses occurs on vertical and horizontal planes of an element.

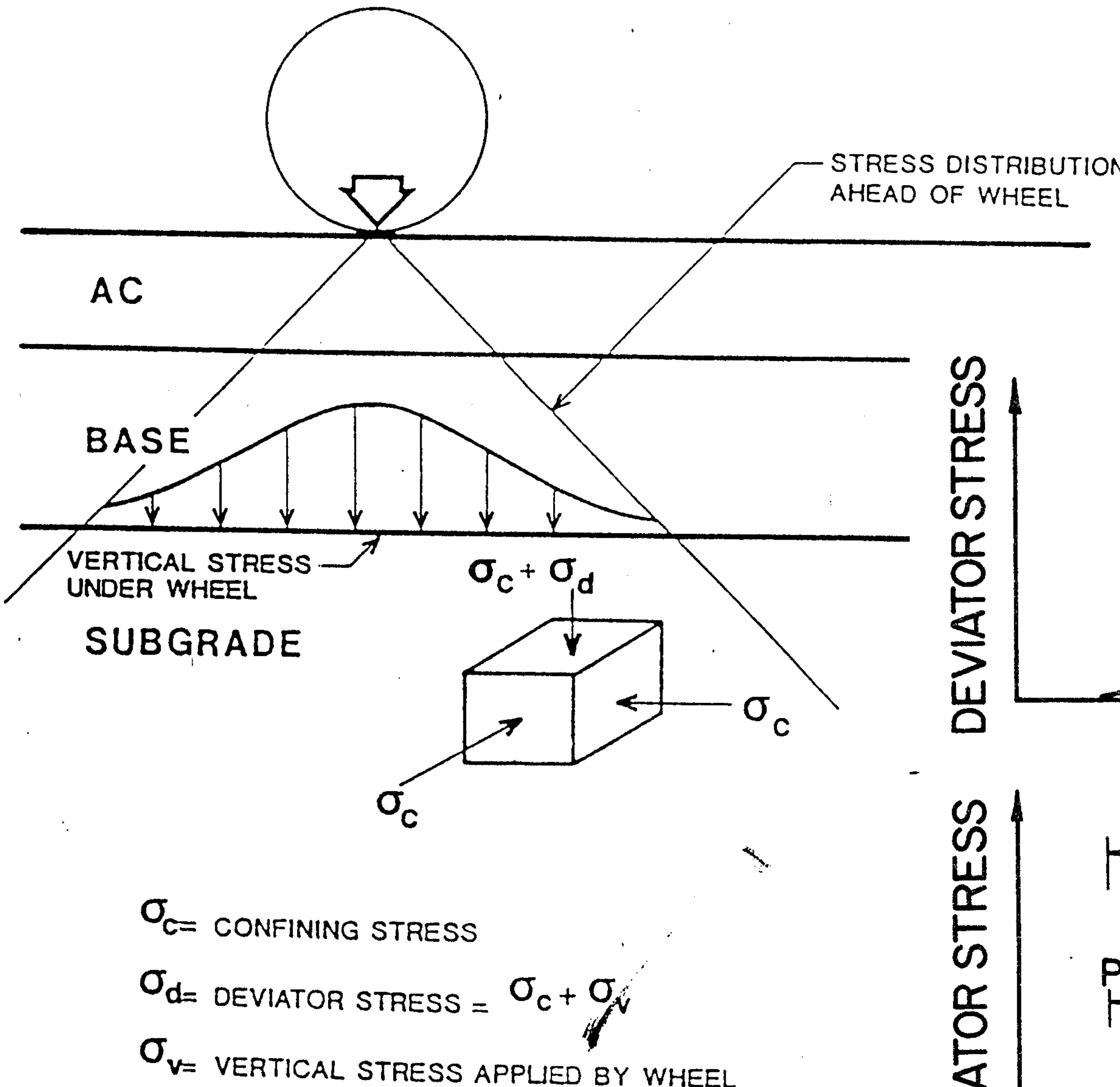
Resilient Behavior

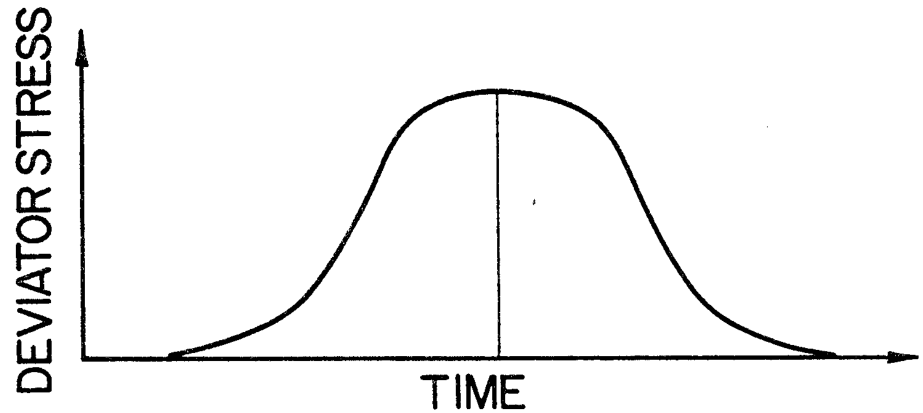


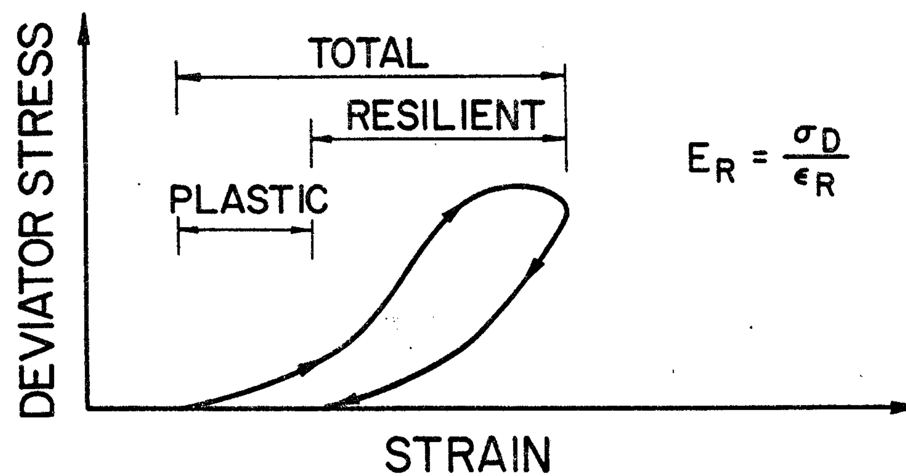
(a) Stress variations in typical asphalt concrete element due to moving loads (after Morris and Haas, 1974)

(b) Rotation of principal stress axis of an element as a vehicle moves over the surface (after Barksdale, 1971)

Resilient Modulus Test







Resilient Behavior

- Combined Stress-Strain behavior is typically expressed in terms of Modulus.

- The major component of deformation or strain that is induced by a single wheel load is not permanent or associated with rupture; it is recoverable (Resilient).

- Therefore, it is appropriate to identify the Resilient Modulus as the required input to determine the stresses, strains, and deflections in a pavement structure under wheel loadings.

Resilient Modulus Tests

- **Ideally, to estimate resilient Modulli of the materials comprising a pavement structure in the laboratory one would apply** Stress State Histories **to a specimen associated with a moving wheel load passing over a representative element at some depth in the structure.**

- **Laboratory**
- **Resilient Modulus Equipment (Repetitive Loading)**

- **Field**
- **Non-destructive Testing (FWD)**
- **Back-calculation of Modulli**

Resilient Modulus Test

- A number of test systems and procedures have been used to determine the resilient modulus of pavement materials, all based on the basic repeated-load tests:

- (1) Direct Tension
- (2) Beam Flexure
- (3) Indirect Diametral Tension
- (4) Uniaxial
- (5) Triaxial Compression

Bound Material (1)–(4)

Unbound Material (5)

Resilient Modulus Test

- **Diametral Indirect Tension Test**
- is used for bound materials, such as asphalt concrete or cement-treated base

- **Cyclic Triaxial Compression Test**
- is used for unbound materials, such as cohesionless base course soils or cohesive subgrade soils.

- **Uniaxial Compression Test**
- is used for bound materials such as asphalt concrete

Resilient Modulus

- Test Parameters
- Load Intensity
- Load Duration
- Load Repetition

- Relation with CBR ??

- $Mr = 1500 \times CBR$ AASHTO 1993
- $Mr = 2555 \times CBR^{0.64}$ AASHTO 2002

M_r for Different Soils

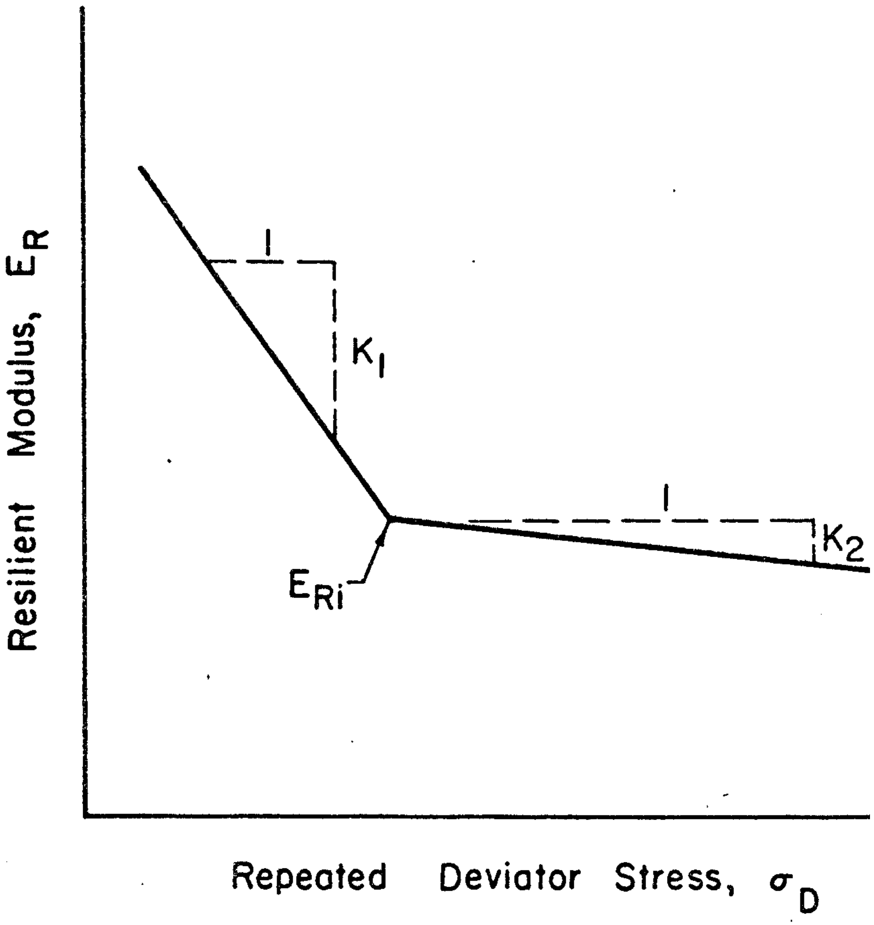
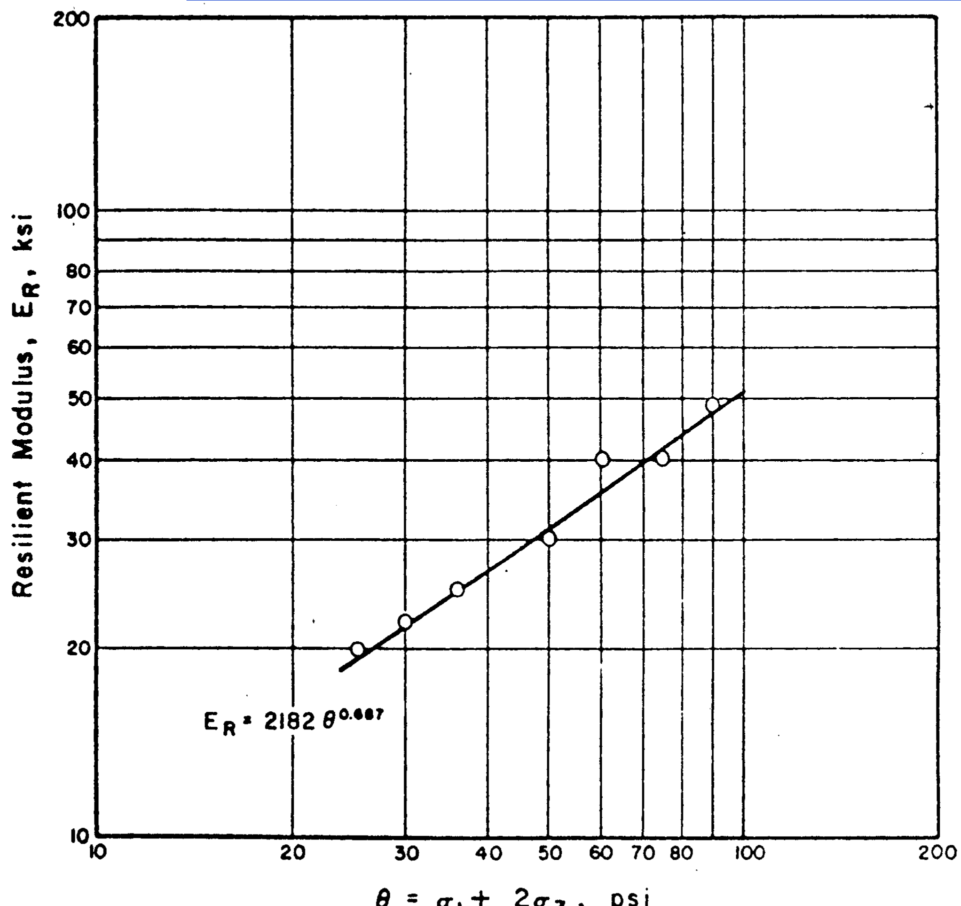


Figure 2. Arithmetic Model for Stress Dependent Behavior of Fine-Grained Soils.



THANK YOU