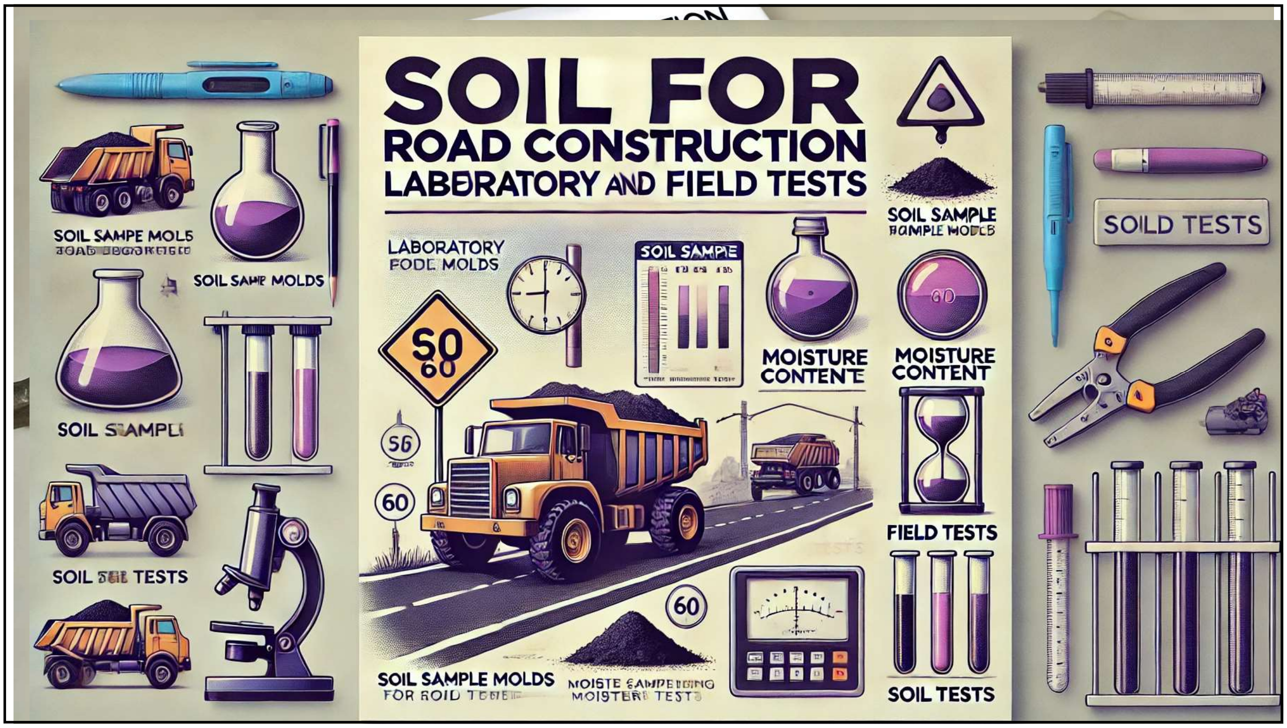

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Soil for Road Construction

Laboratory tests

Test Name	Purpose	Standards
Triaxial Shear Test	Measures soil strength under load	ASTM D4767, AASHTO T296/T297
Unconfined Compression Test	Measures compressive strength for cohesive soils	ASTM D2166, AASHTO T208
Consolidation Test	Measures soil settlement under long-term load	ASTM D2435, AASHTO T216
Permeability Test (Hydraulic Conductivity)	Determines soil drainage capacity	ASTM D2434
Particle Size Distribution	Determines particle size for classification	ASTM D422, AASHTO T88
Atterberg Limits (LL, PL, PI)	Measures soil plasticity and consistency	ASTM D4318, AASHTO T89/T90
Proctor Compaction Test	Determines maximum dry density and optimum moisture content	ASTM D698, ASTM D1557, AASHTO T99, T180
California Bearing Ratio (CBR)	Measures soil bearing capacity for subgrades	ASTM D1883, AASHTO T193

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Soil for Road Construction

Field tests

Test Name	Purpose	Standards
Nuclear Density Test	Measures in-situ density and moisture content	ASTM D6938
Field Density Test (Sand Cone Method)	Determines in-situ soil density and compaction	ASTM D1556, AASHTO T191
In-Situ CBR Test	Evaluates bearing capacity directly on the field	ASTM D4429
Plate Load Test	Evaluates load-bearing capacity of soil	ASTM D1194
In-Situ Moisture Content Test	Measures natural soil moisture content	ASTM D2216
Dynamic Cone Penetrometer (DCP)	Measures strength and compaction quality of subgrades	ASTM D6951
Standard Penetration Test (SPT)	Assesses soil strength and density for deep foundations	ASTM D1586, AASHTO T206
Field Permeability Test	Determines field permeability and drainage	Various

CBR Test

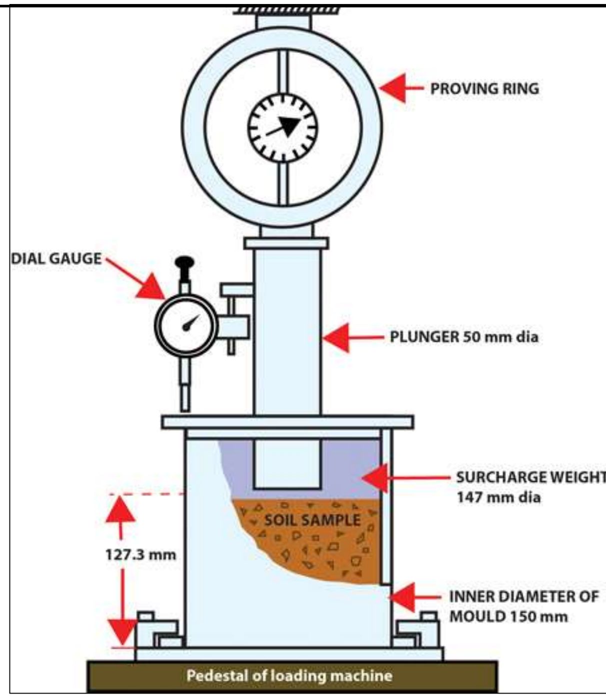
Overview

CBR (California Bearing Ratio)

1. What is the CBR Test?

❑ **1. What is the CBR Test?**

- **Definition**: The **California Bearing Ratio (CBR)** test is a **penetration test** used to evaluate the **load-bearing capacity** of soil or granular materials.
- **Purpose**: It is commonly used to assess **subgrade strength** for **road construction** and **pavement design**.



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CBR Test

2. CBR Test Procedure

- **Step 1**: **Soil Preparation**
  - *The soil sample is* compacted *into a mold to a specific* maximum dry density (MDD) *determined through a Proctor test.*
- **Step 2**: **Loading**
  - *A* penetration plunger *applies force to the sample at a controlled rate (1.25 mm/min), and the force required for penetration is recorded at* 2.5 mm *and* 5.0 mm *depths.*
- **Step 3**: **Calculation**
  - *The CBR value is calculated as the* ratio *of the measured force to the force required to penetrate a standard material (crushed stone).*

$$\text{CBR} = \left(\frac{\text{Measured Load}}{\text{Standard Load}}\right) \times 100$$

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CBR (California Bearing Ratio)

Test procedures

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CBR (California Bearing Ratio)

Determination

- **CBR** compares the bearing capacity of a tested material with that of obtained from an excellent coarse base material (a well-graded crushed stone)
- $CBR(\%) = \frac{Unit\ load\ of\ test\ materils}{Unit\ load\ of\ standard\ crushed\ stone}$ at <u>specific penetration</u>
- Two penetration points are used to determine CBR
  - *2.5 mm penetration*
  - *5.0 mm penetration*
- The unit load for the standard crushed stones are
  - *6.9 MPa (or 1000 psi) at 2.5 mm penetration*
  - *10.3 MPa (or 1500 psi) at 5.0 mm penetration*

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CBR (California Bearing Ratio)

Determination

$CBR\,(\%) = \dfrac{\text{unit load at 2.5 mm penetration (MPa)}}{6.9\,\text{MPa}} \times 100$
$CBR\,(\%) = \dfrac{\text{unit load at 5.0 mm penetration (MPa)}}{10.3\,\text{MPa}} \times 100$

OR

$CBR\,(\%) = \dfrac{\text{Stress at 0.1 in penetration (psi)}}{1000\text{ psi}} \times 100$
$CBR\,(\%) = \dfrac{\text{Stress at 0.2 in penetration (psi)}}{1500\text{ psi}} \times 100$

OR

$CBR\,(\%) = \dfrac{\text{Load at 2.5mm penetration (kg)}}{1364\,\text{kg}} \times 100$
$CBR\,(\%) = \dfrac{\text{Load at 5.0mm penetration (kg)}}{2045\,\text{kg}} \times 100$

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CBR (California Bearing Ratio)

Determination

- The CBR value is **usually based** on the load ratio for a penetration **of 2.5 mm (0.1 in).**
- However,
  - *If the CBR value at a penetration of 5.0 mm (0.2 in) is higher than the CBR value at a penetration of 2.5 mm*
    - The test should be repeated.
    - If the repeated test also yields a larger value, then the CBR at 5.0 mm (0.2 in) penetration should be used.

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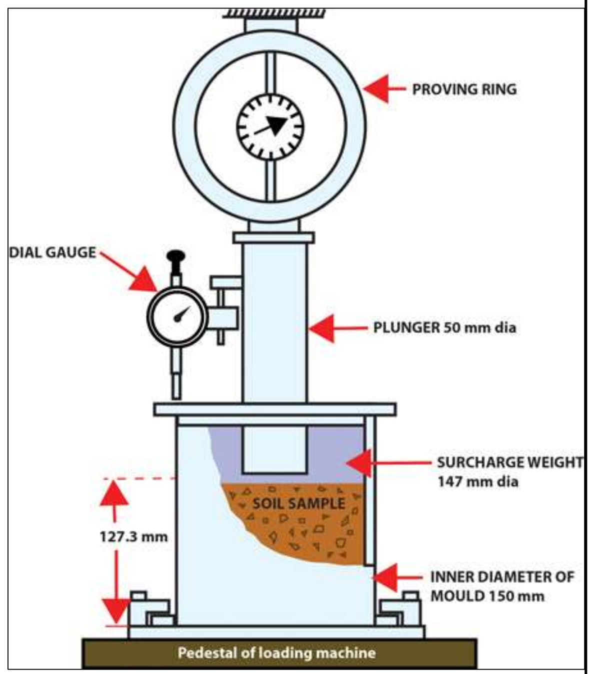
CBR (California Bearing Ratio)

Test Outputs

CBR test results	
Penetration (in)	Load on piston (psi)
0.025	70
0.05	115
0.1	220
0.2	300
0.4	320



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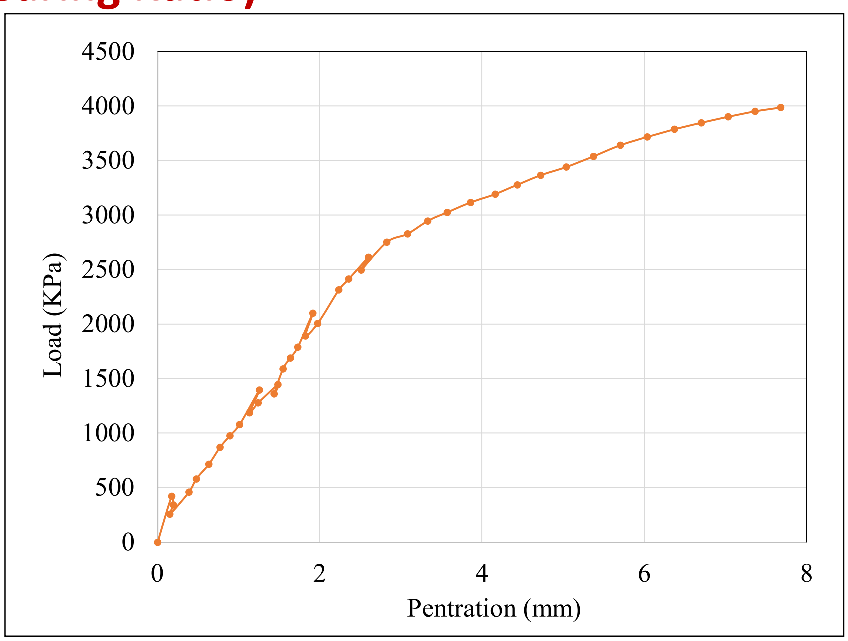
CBR (California Bearing Ratio)

Plotting

- The curve is normally concave downward,



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Example -1

- ❑ Find the CBR value at 2.5 mm (0.1 in) and 5.00 mm (0.2)

CBR test results	
Penetration (in)	Load on piston (psi)
0.025	70
0.05	115
0.1	220
0.2	300
0.4	320

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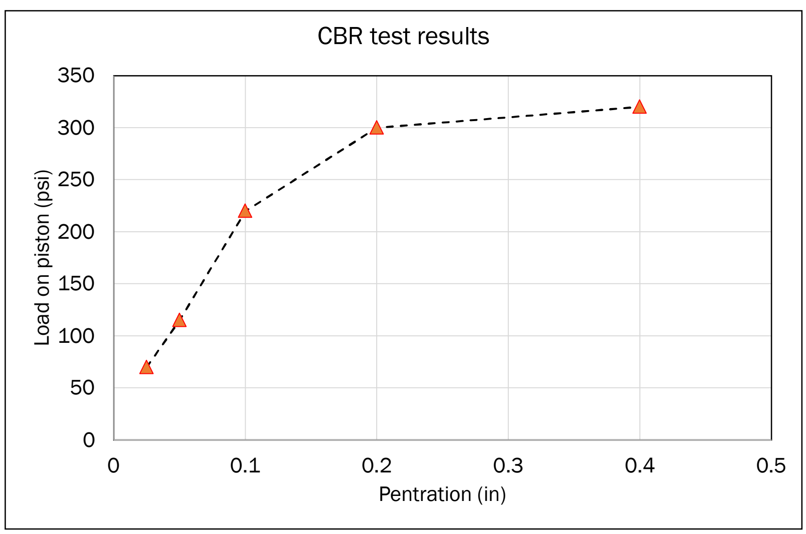
Example -1

Solution

CBR test results	
Penetration (in)	Load on piston (psi)
0.025	70
0.05	115
0.1	220
0.2	300
0.4	320



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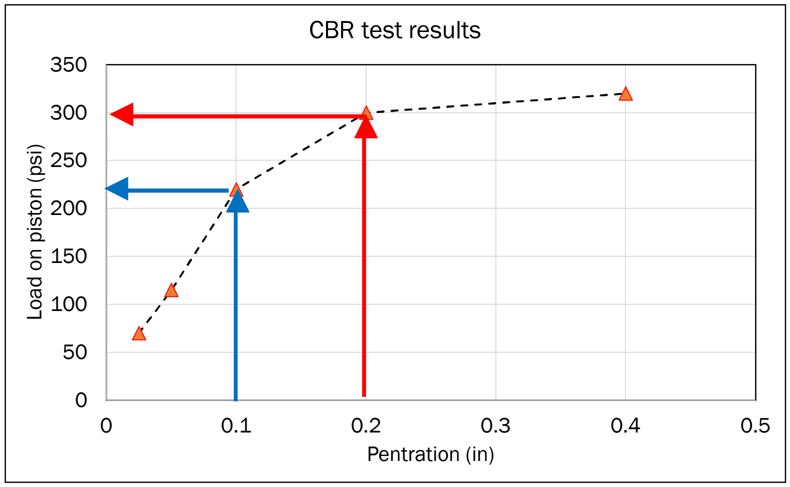
Example -1

Solution

Penetration (in)	Load on piston (psi)
0.1	220
0.2	300



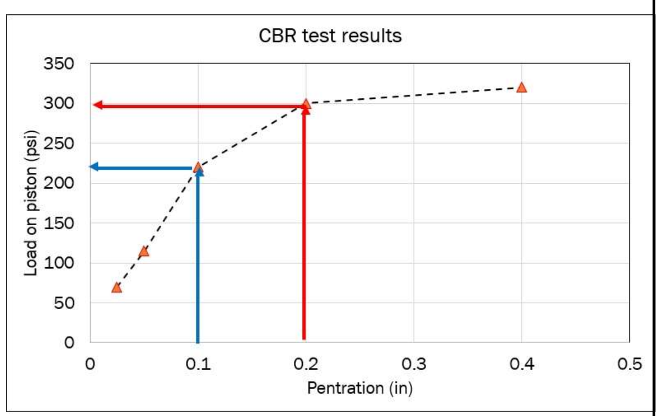
Example -1

Solution

$$CBR\,(\%) = \frac{\text{Stress at 0.1 in penetration (psi)}}{\text{1000 psi}} \times 100$$

$$CBR\ at\ 2.5\ mm(\%) = \frac{220\ psi}{1000\ psi} \times 100 = 22\ \%$$

$$CBR\,(\%) = \frac{\text{Stress at 0.2 in penetration (psi)}}{\text{1500 psi}} \times 100$$



$$CBR\ at\ 5.0\ mm(\%) = \frac{300\ psi}{1500\ psi} \times 100 = 20\ \%$$

$Check:\ CBR\ at\ 2.5\ mm = 22\% > CBR\ at\ 5.0\ mm = 20\%$

CBR typical values

General Soil Type	USC Soil Type	CBR Range
Clean gravels	GW	40 – 80
	GP	30 – 60
Gravels with fines	GM	20 – 60
	GC	20 – 40
Clean sands	SW	20 – 40
	SP	10 – 40
Sands with fines	SM	10 – 40
	SC	5 – 20
Silts and clays	ML	15 or less
	CL	15 or less
	OL	5 or less
	MH	10 or less
	CH (LL>50%)	15 or less
	OH	5 or less

Table source: https://www.slideserve.com/nishi/california-bearing-ratio-cbr-method

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Field CBR

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Field CBR Test

Overview

- **Definition**: The **Field CBR Test** is a variation of the **California Bearing Ratio (CBR)** test conducted **on-site** to determine the **in-situ load-bearing capacity** of soil or granular materials under field conditions.
- **Purpose**: It helps assess the **compaction quality** and **strength** of **subgrade**, **subbase**, or **base layers** in real-time during constructio

Field CBR Test

Procedure

- **Step 1**: **Preparation**
  - *The test is typically conducted in a **compacted layer** in the field, with an excavation made to the desired depth.*
  - *A **circular plunger** is placed on the soil surface to apply pressure.*
- **Step 2**: **Loading**
  - *Apply a **vertical load** using a **loading machine** or **jack**, and record the force required for penetration at **2.5 mm** and **5.0 mm** depths.*
- **Step 3**: **Calculation**
  - *The **Field CBR value** is calculated as a percentage, comparing the measured load to a **standard load** for a given penetration depth.*

$$\text{Field CBR} = \left(\frac{\text{Measured Load}}{\text{Standard Load}}\right) \times 100$$

Field CBR

Determination

Video source: https://www.youtube.com/watch?v=ZaA3jaJFrsQ

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Modulus of resilience

Repeated load triaxial test

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Modulus of resilience (Mr)

- The **Modulus of Resilience** (Mr) is a measure of a material's ability to **absorb and recover energy** when subjected to **elastic deformation**
- MR is a measure of subgrade, base, and subbase material stiffness
  - *A material's stiffness*
    - indicates its ability to return to its original shape or form after an applied load is removed
- Purpose:
  - *It helps assess how well soils and aggregate layers can* ***bounce back*** *after being subjected to repeated loading, simulating* ***real-world traffic conditions.***

Images source: Chowdhury, Robinur, Evaluation of Resilient Modulus of Unbound Coarse Materials in Idaho ,Dissertation, Universität of Idaho, 2019

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Modulus of resilience (Mr)

Procedure

- **Step 1**: **Specimen Preparation**
  - *A* ***cylindrical soil sample*** *is compacted in the laboratory to a specified density and moisture content.*
- **Step 2**: **Loading**
  - *The soil specimen is subjected to a series of* ***cyclic loading*** *in a triaxial testing apparatus. These loads are applied repeatedly to simulate* ***traffic loading.***
- **Step 3**: **Measurement**
  - *The* ***resilient strain*** *(deformation under load) is recorded. The* ***Modulus of Resilience (Mr)*** *is calculated by dividing the* ***applied stress*** *by the* ***resilient strain.***

$$\text{Mr} = \frac{\text{Applied Stress}}{\text{Resilient Strain}}$$

Images source: Chowdhury, Robinur, Evaluation of Resilient Modulus of Unbound Coarse Materials in Idaho ,Dissertation, Universität of Idaho, 2019

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Modulus of resilience (M_r)

Preparation of specimen for resilient modulus test


(a) Split mold


(b) Membrane stretcher


(c) unmolded specimen after compaction


(d) specimen with rubber membrane

Image's source: Chowdhury, Robinur, Evaluation of Resilient Modulus of Unbound Coarse Materials in Idaho ,Dissertation, Universität of Idaho, 2019

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Modulus of resilience (M_r)

Deformation measurements


Internal LVDT


External LVDT

Image's source: Chowdhury, Robinur, Evaluation of Resilient Modulus of Unbound Coarse Materials in Idaho ,Dissertation, Universität of Idaho, 2019

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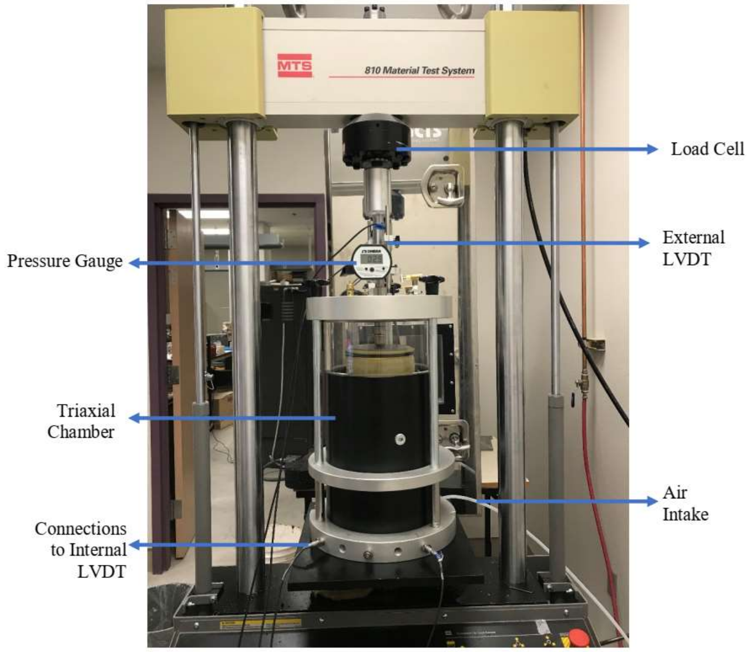

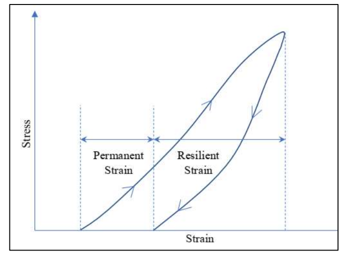

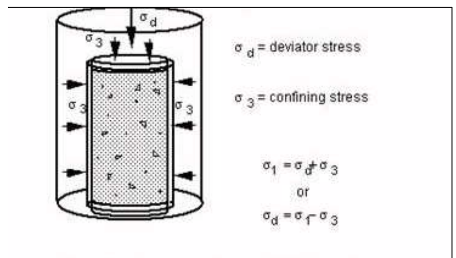

Figure 2a: Stresses Acting on Triaxial Specimen

Images source: Chowdhury, Robinur, Evaluation of Resilient Modulus of Unbound Coarse Materials in Idaho ,Dissertation, Universität of Idaho, 2019

Image source: https://pavementinteractive.org/reference-desk/testing/aggregate-tests/triaxial-test/

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Modulus of resilience (M_r)

Video source: https://www.youtube.com/watch?v=k22dLtIDcbo

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Modulus of resilience (M_r)

Importance

- Measure of fundamental material property
- Dynamic load testing similar to traffic loading
- Essential input in mechanistic-empirical pavement design
- Mr values are critical for designing **flexible pavements (THICKNESS determination)**, ensuring that the materials can **withstand traffic loads** and maintain their structural integrity over time.

Images source: Chowdhury, Robinur, Evaluation of Resilient Modulus of Unbound Coarse Materials in Idaho ,Dissertation, Universität of Idaho, 2019

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Mr Typical range

AASHTO Soil Classification	Base/Sub base for Flexible and Rigid Pavements	Embankment and Subgrade for Flexible Pavements	Embankment and Subgrade for Rigid Pavements
A-1-a	40,000	29,500	18,000
A-1-b	38,000	26,500	18,000
A-2-4	32,000	24,500	16,500
A-2-5	28,000	21,500	16,000
A-2-6	26,000	21,000	16,000
A-2-7	24,000	20,500	16,000
A-3	29,000	16,500	16,000
A-4	24,000	16,500	15,000
A-5	20,000	15,500	8,000
A-6	17,000	14,500	14,000
A-7-5	12,000	13,000	10,000
A-7-6	8,000	11,500	13,000

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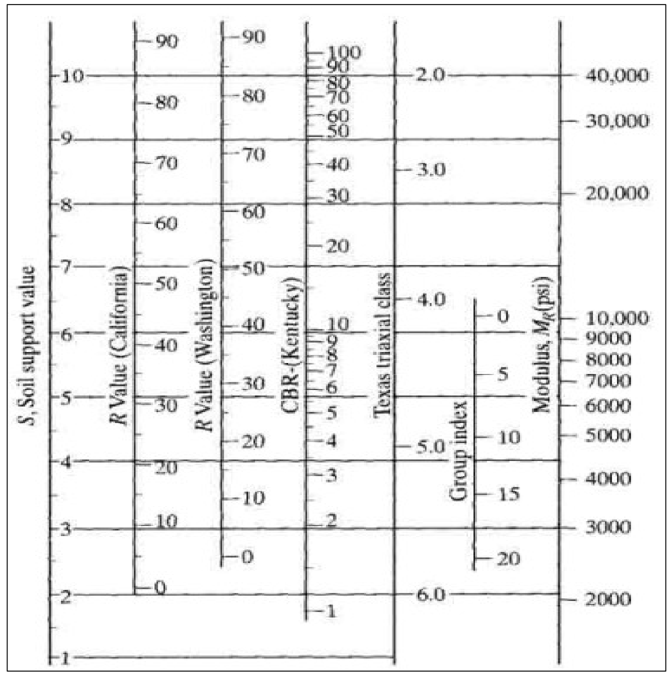
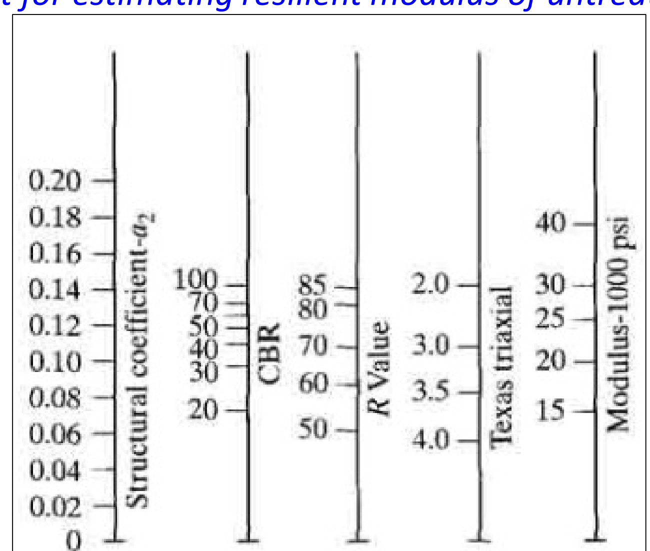
- Correlation chart for estimating resilient modulus of subgrade soils

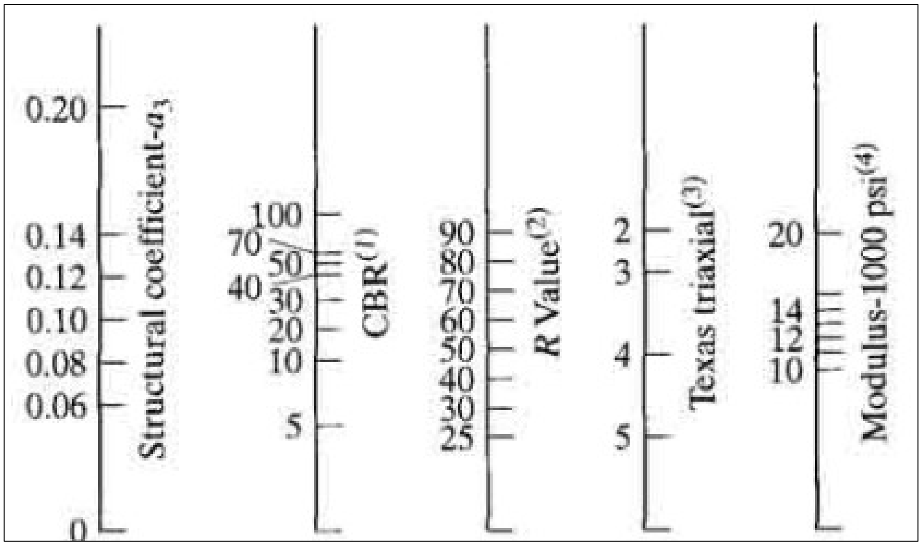


Correlation chart for estimating resilient modulus of untreated bases



(a) Untreated

Correlation charts for estimating resilient modulus of Subbase



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