AF2903 Highway Construction and Maintenance

Royal Institute of Technology, Stockholm

Mechanical Properties of Aggregates

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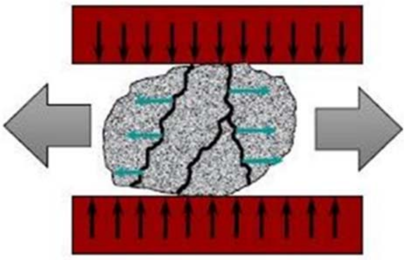

California Bearing ratio (CBR) Value

- Basically a penetration test
- Piston penetrates soil at constant rate 0.05 in/min
- Pressure is recorded
- Take the ratio to the bearing capacity of a standard rock
- Range: 0 (worst) –100 (best) Type equation here.

$$CBR = \frac{\text{Pressure to cause 0.1'' penetration to the sample}}{\text{Pressure to cause 0.1'' penetration for standard rock}}$$

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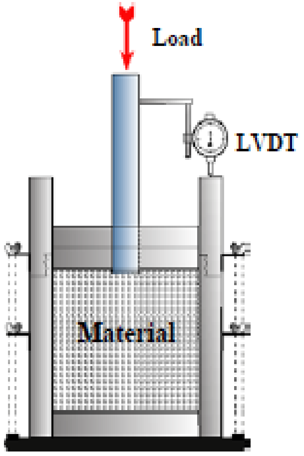
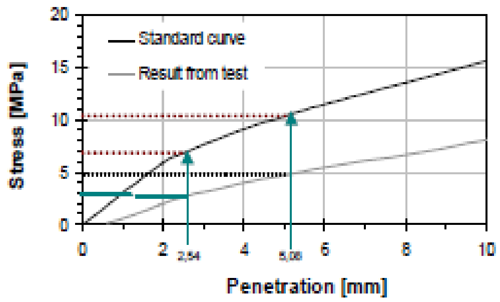
California Bearing ratio (CBR) Value





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California Bearing ratio (CBR) Value

General Soil Type	USC Soil Type	CBR Range
Coarse-grained soils	GW	40 - 80
	GP	30 - 60
	GM	20 - 60
	GC	20 - 40
	SW	20 - 40
	SP	10 - 40
	SM	10 - 40
	SC	5 - 20
Fine-grained soils	ML	15 or less
	CL LL < 50%	15 or less
	OL	5 or less
	MH	10 or less
	CH LL > 50%	15 or less
	OH	5 or less

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Stress and Strain

- Stress

$$Stress = \frac{Load}{Area}$$

- Strain

$$Strain = \frac{Deformation}{Original\_length}$$

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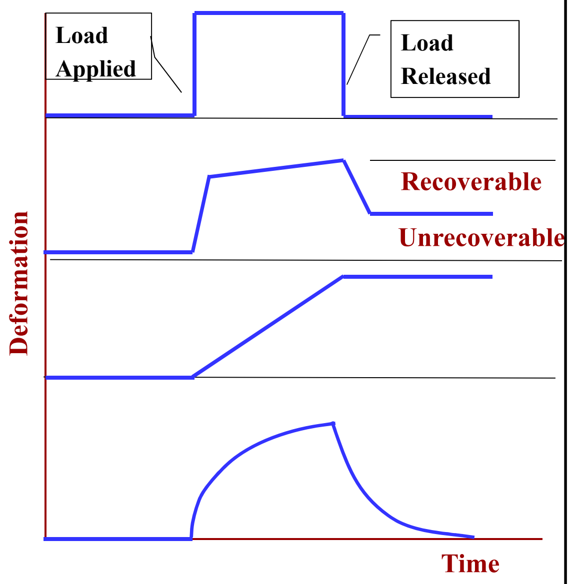
Types of materials responses

- Elastic
- Elasto-Plastic
- Viscous
- Visco-elastic



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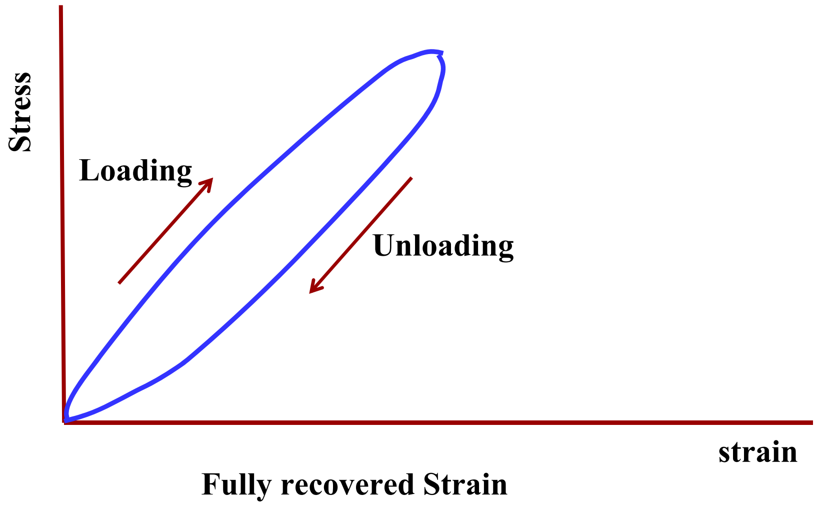
Elastic Stress – strain behavior



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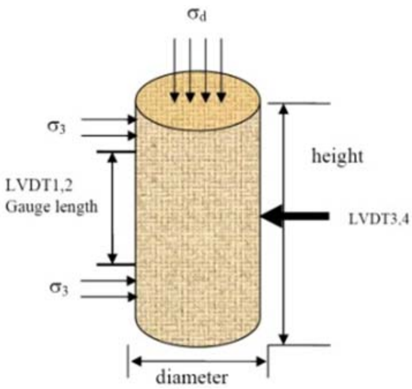
Cyclic Loading Behavior



- Triaxial loading cell is used to test the cyclic loading behavior

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Cyclic Loading Behavior

- The response of the materials is elasto-plastic
- Under cyclic load application the aggregates experience:-
  - recoverable (resilient) strain
  - non-recoverable (permanent) strain
- The stable resilient behavior obtained after a large number of load cycles.
- The accumulation of permanent strains, which is more complex to describe

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Stresses

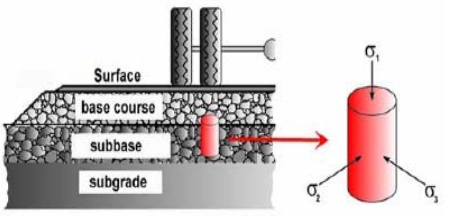
- Deviator Stress

$$q = \sigma_d = \sigma_1 - \sigma_3$$

- Mean principal stress

$$p = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3} = \frac{\sigma_1 + 2\sigma_3}{3}$$

$$\sigma_2 = \sigma_3$$



- Bulk stress

$$\theta = \sigma_1 + 2\sigma_3$$

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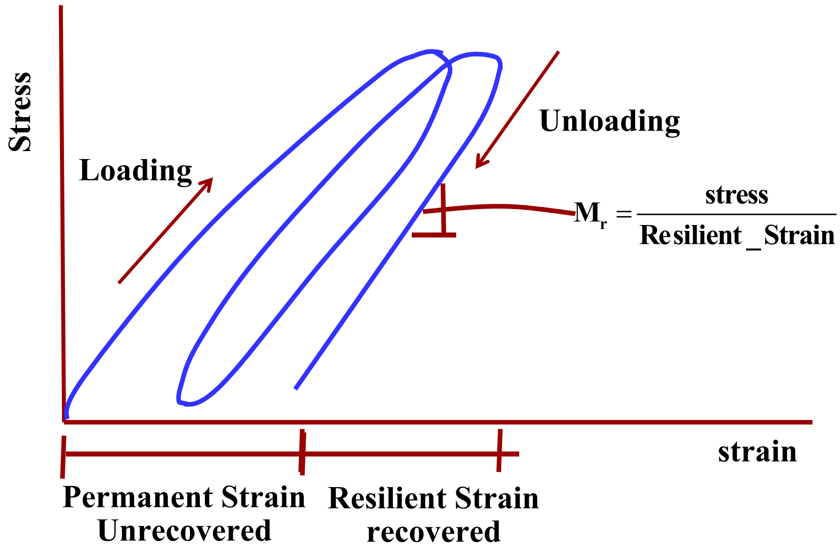
Elasto-Plastic Stress – strain behavior



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Resilient Modulus (M_r)

- Important mechanical property for pavement design
- is the elastic properties of aggregate recognizing certain non-linear characteristics (AASHTO T 307)
- Defined as applied stress divided by recoverable strain

$$M_r = \frac{\sigma_d}{\varepsilon_r}$$

- Deviator stress σ_d
- Resilient strain ε_r
- Resilient modulus ≠ Strength

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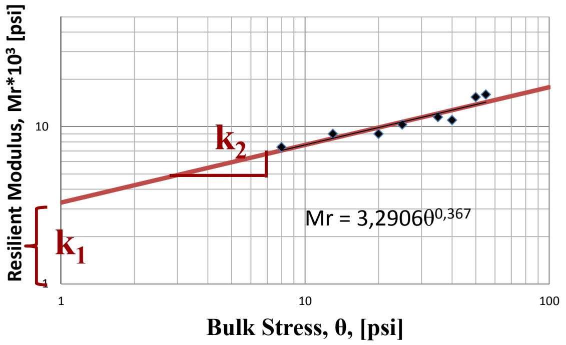
K-θ Model for Resilient Modulus (M_r)

- k_1 and k_2 are constants that represent the intercept and slope of resilient modulus against the bulk stress on logarithmic scales.
- Psi (Pounds per square inch)

$$M_r = k_1 \theta^{k_2}$$



k_1= 3290.6 psi (22.68Mpa)

k_2=0.367

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Example

- The Table below shows the result of resilient modulus tests on an aggregate materials. Determine the nonlinear coefficient k_1 and k_2.

Confining Pressure (psi)	Deviatoric Stress (psi)	Recoverable Strain (x 10E-3)	Resilient Modulus (x 10E3)	Bulk Stress θ, (psi)
2	6	0,58	10,34	12
5	15	0,74	20,27	30
10	30	0,95	31,58	60
15	45	1,14	39,47	90
20	50	1,2	41,67	110

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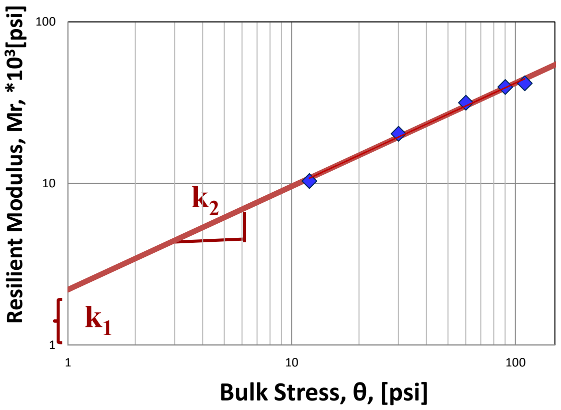
Example

$$Mr = 2{,}2015\theta^{0{,}639}$$



k_1= 2201,5 psi (15,2 Mpa)

k_2=0.639

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Deformation of Unbound Aggregate Materials

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Factors that influence the deformation and shear behavior

- Particle shape
- Particle size
- Angularity
- Grain size distribution
- Surface texture
- Packing (i.e. degree of compaction)
- Density
- Mineralogy

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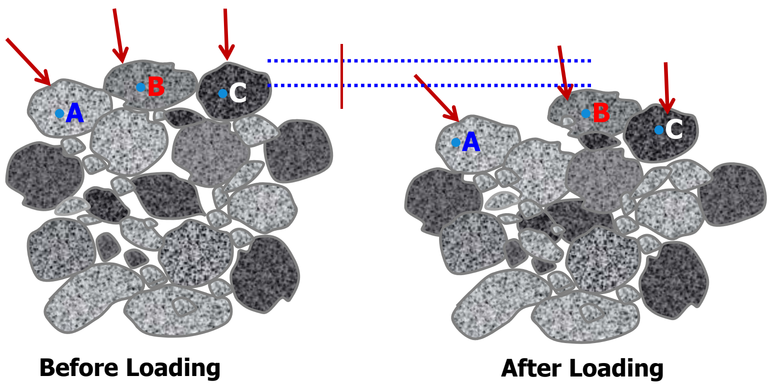
Mechanisms that contribute to deformation

- Relative motion of particles due to sliding or rolling
- Distortion and crushing of particles



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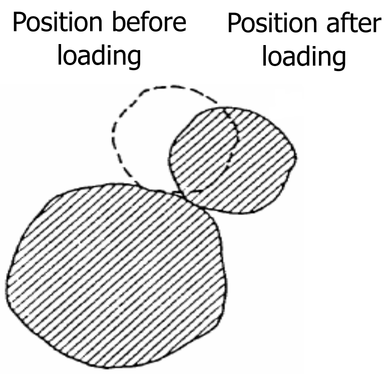
Mechanisms that contribute to deformation

- When the shear force becomes larger than the shear resistance at the contact:
  - Relative sliding between particles
- The overall deformation is partly from:
  - Individual particles, and
  - Relative sliding between particles



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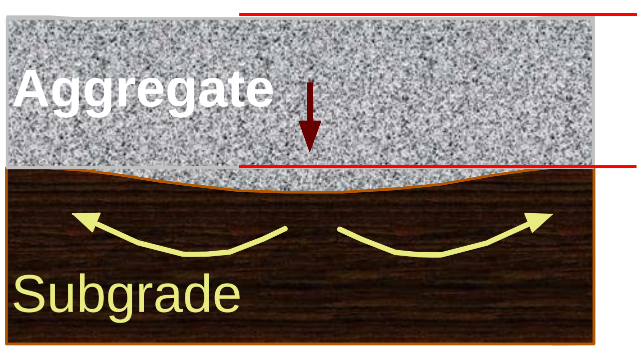
Unbound Base layer Deformation



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Unbound Base layer Deformation

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Present Approach

- Use a high quality aggregate for surface and base layers
  - Scandinavian countries

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Questions?