Subgrade Characterization

Pavement Design Factors

Wheel Loads Applied to Pavement

Magnitude of Wheel Loads

Type of Wheel Loads (Single or Tandem Axles)

Number of Wheel Load Applications

Changes over Time

Subgrade Support Provided

Seasonal Changes in Subgrade Support

Subgrade Support

~~AASHTO Group Index~~

California Bearing Ratio (CBR)

Modulus of Subgrade Reaction (k)

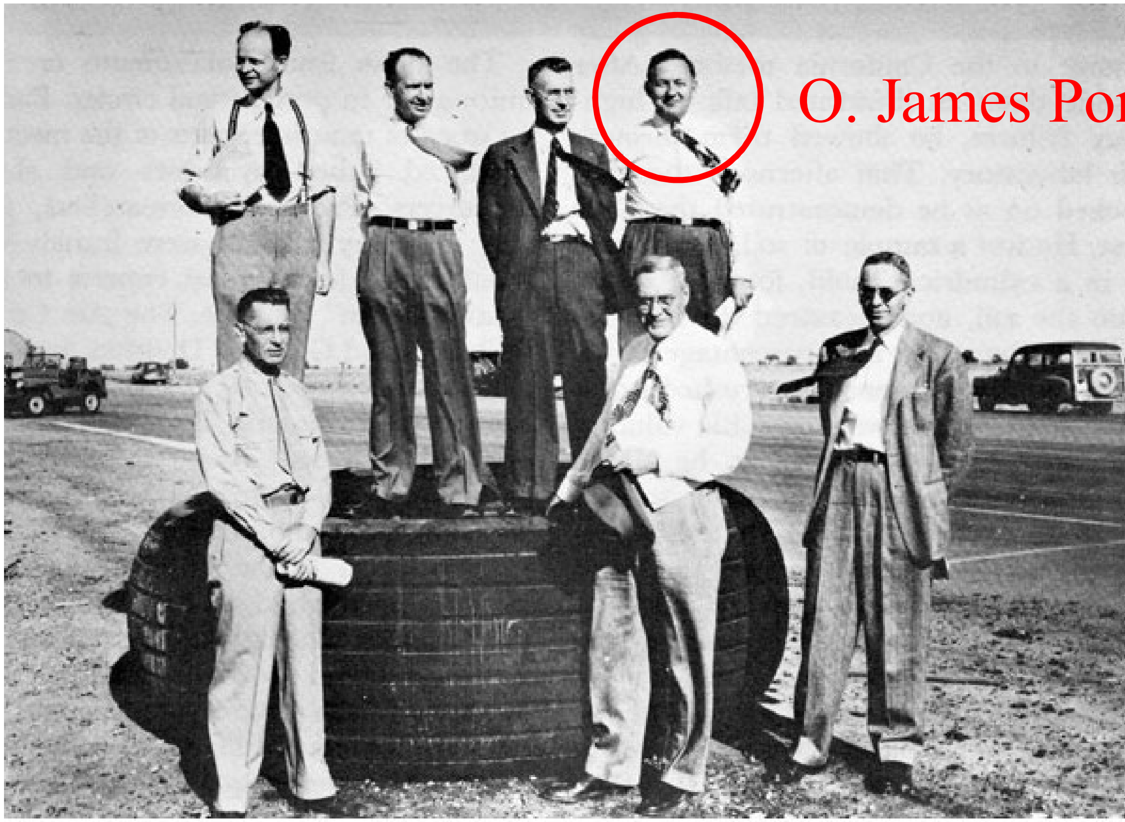
~~Hveem Resistance Value (R)~~

Resilient Modulus (M_R)

California Bearing Ratio

The CBR test measures the of resistance of a material to penetration of cylindrical plunger under controlled density and moisture conditions. It was developed by the California Division of Highways as a method of classifying and evaluating subgrade and base course materials for flexible pavements. The test produces a measure of strength relative to that of a high-quality crushed stone base course, which has a CBR value of 100%.

CBR Inventor



CBR Conference at Stockton Test Track,California. Front row (left to right): Colonel Henry C. Wolfe, Harald M. Westergaard, Philip C.Rutledge. Back row (left to right): Arthur Casagrande, Thomas A. Middlebrooks, James L. Land, O. James Porter

Source: http://gsl.erdc.usace.army.mil/gl-history/images/gl_img_25r.jpg

California Bearing Ratio

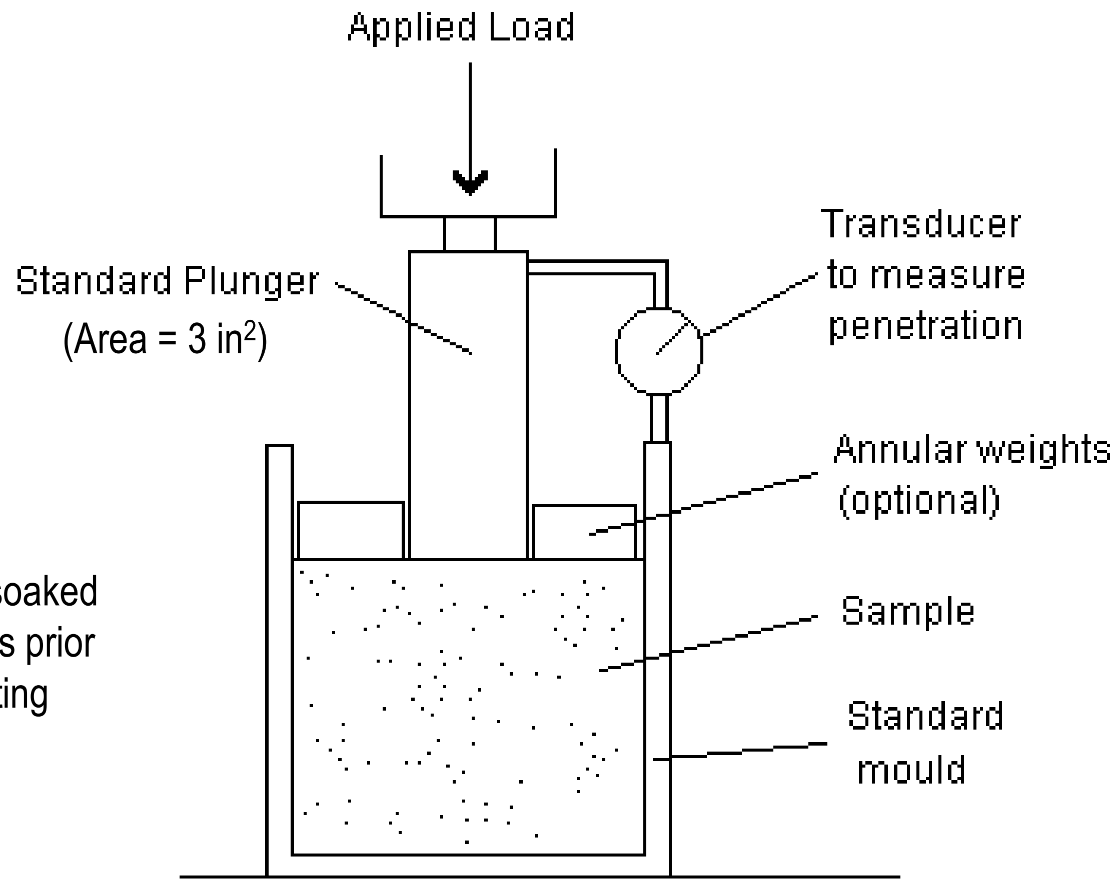
Typically, a sample of the material to be tested is compacted into a cylindrical mold to the same density to which it will be compacted in the field. Annular weights are then added to simulate the weight of the overlying pavement system. At the discretion of the engineer, the specimen is then inundated in water for four days to simulate the worst-case environmental conditions.

California Bearing Ratio

The actual test is conducted by pressing a cylindrical metal plunger with a cross-sectional area of 3 in^2 into the surface of the still-confined specimen at a rate of 0.1 in/min while measuring the penetration force.

A high-quality crushed stone base course is deemed to resist 3000 lb. of load at a displacement of 0.1 in. and 4500 lb. of load at a displacement of 0.2 in. The CBR value is the measured penetration resistance expressed as a percentage of those ideal values.

California Bearing Ratio

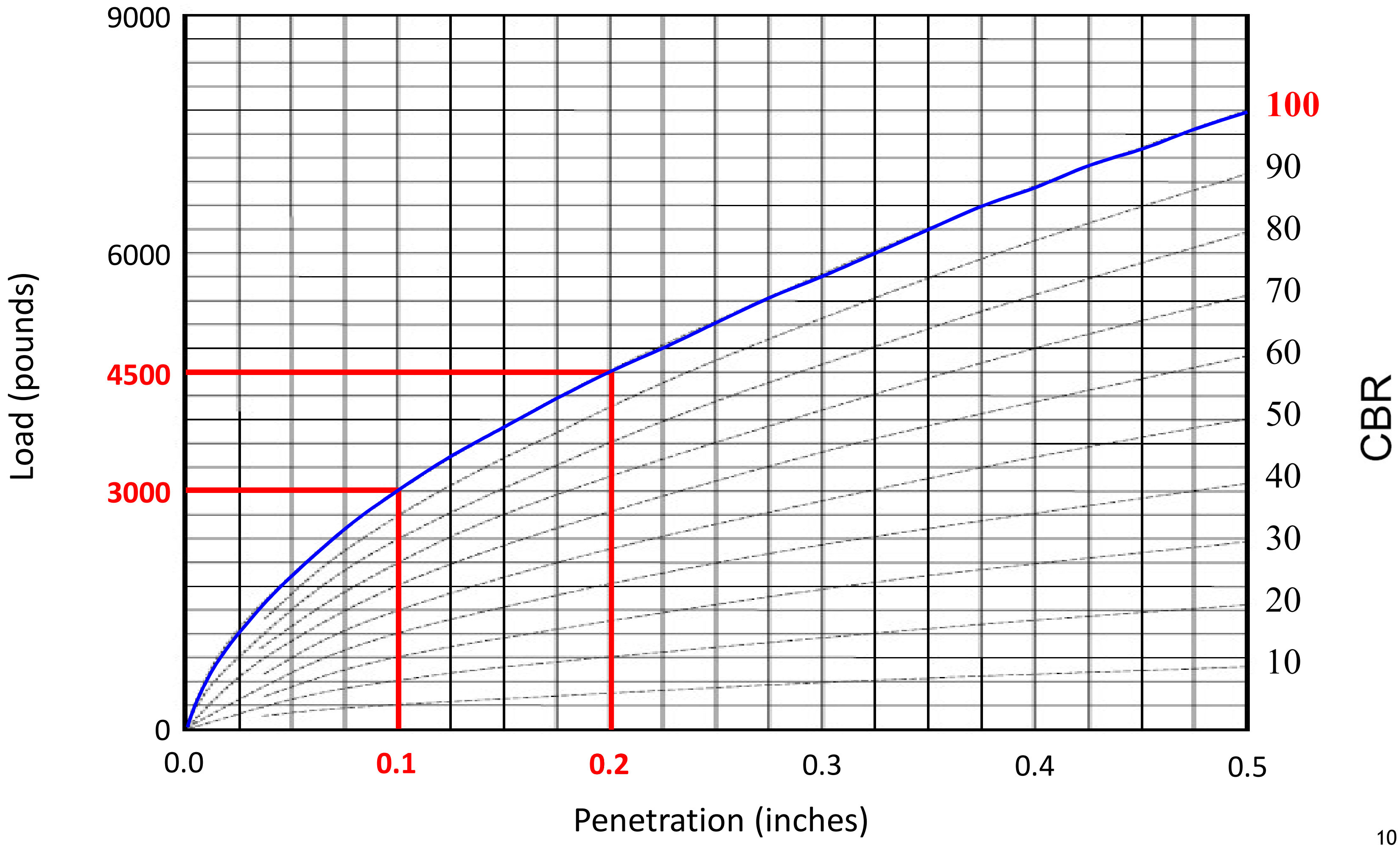


(Area = 3 in^2)

Sample soaked for 4 days prior to testing

Source: http://www.archive.official-documents.co.uk/document/ha/dmrb/index.htm

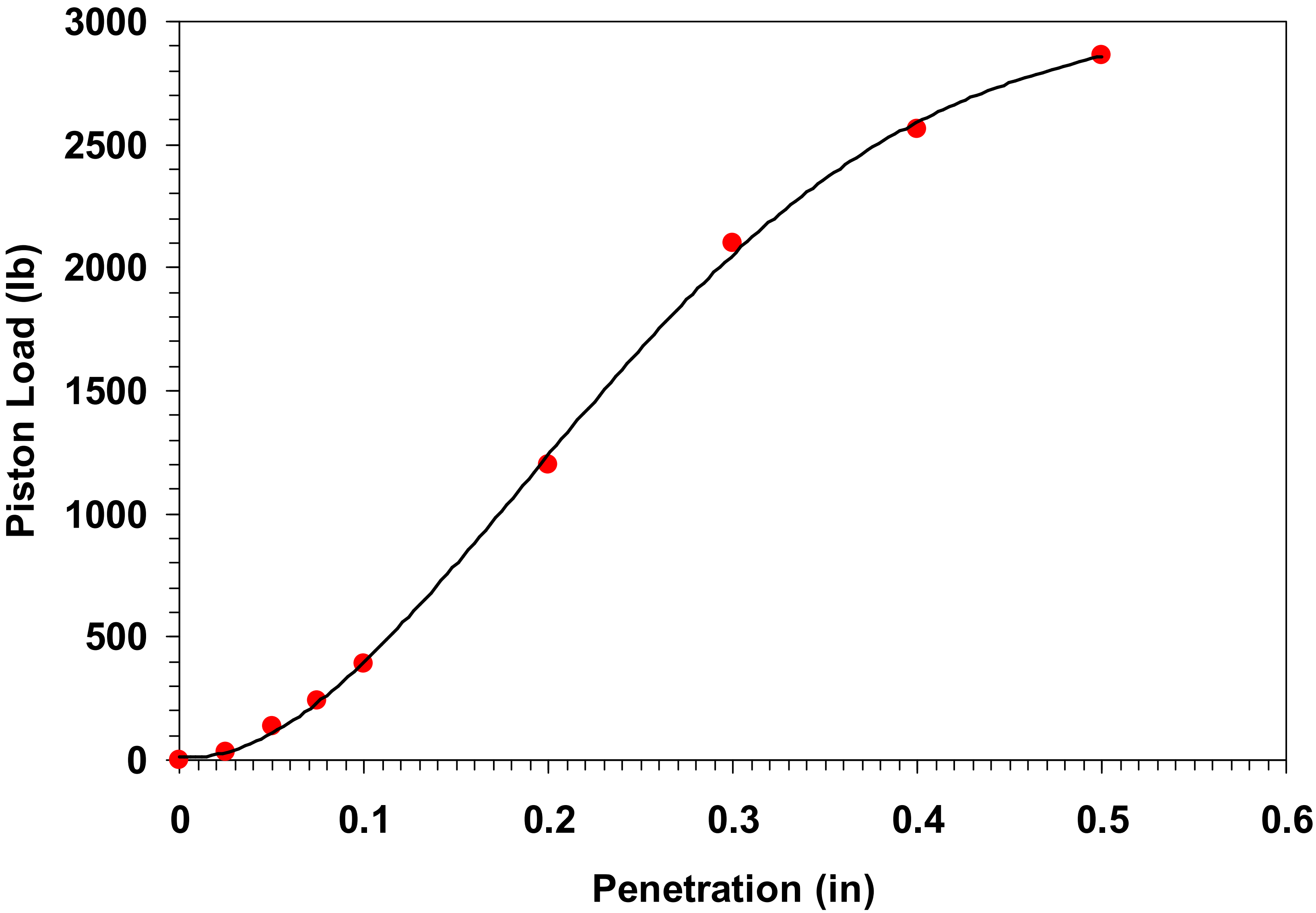
California Bearing Ratio

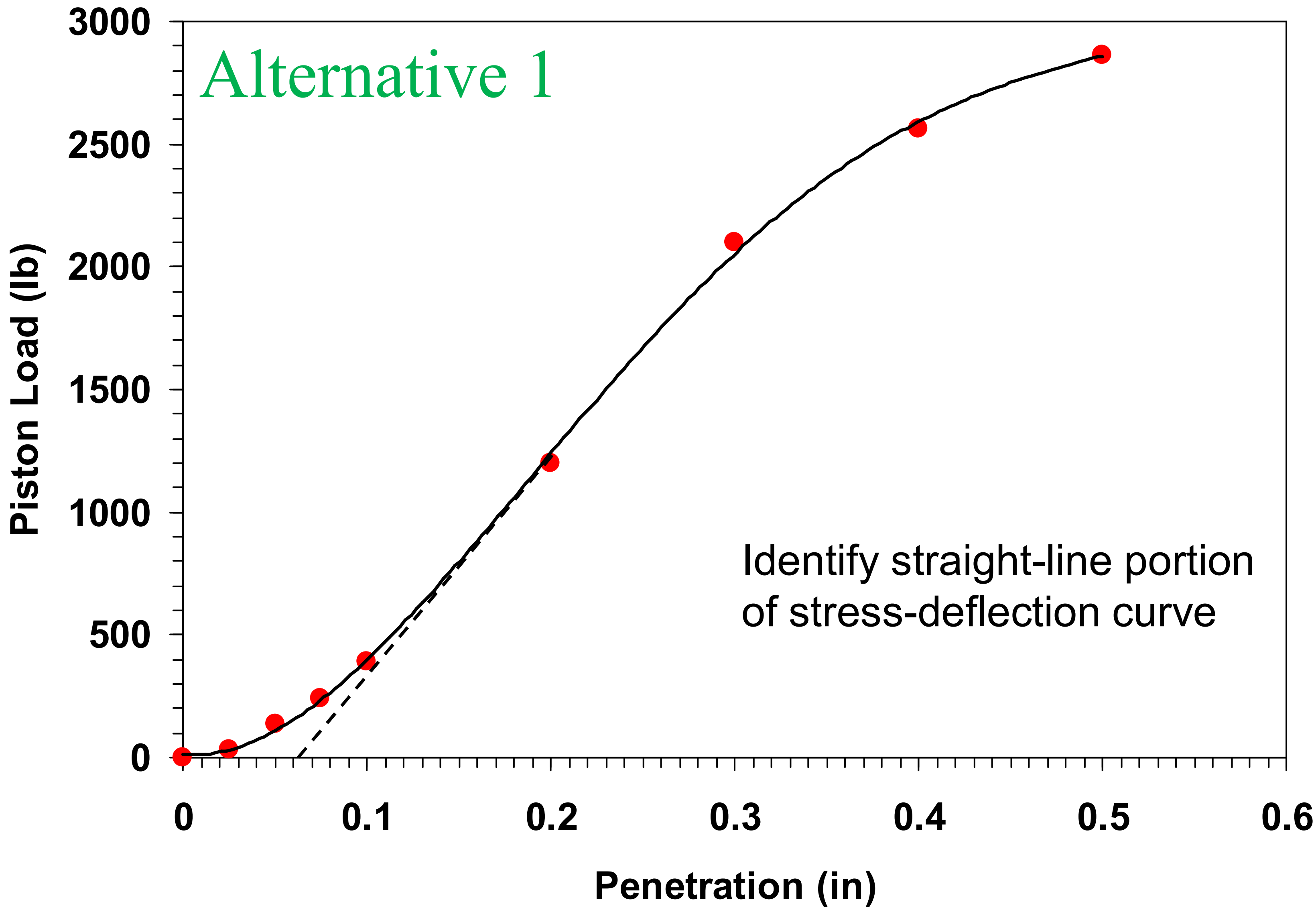


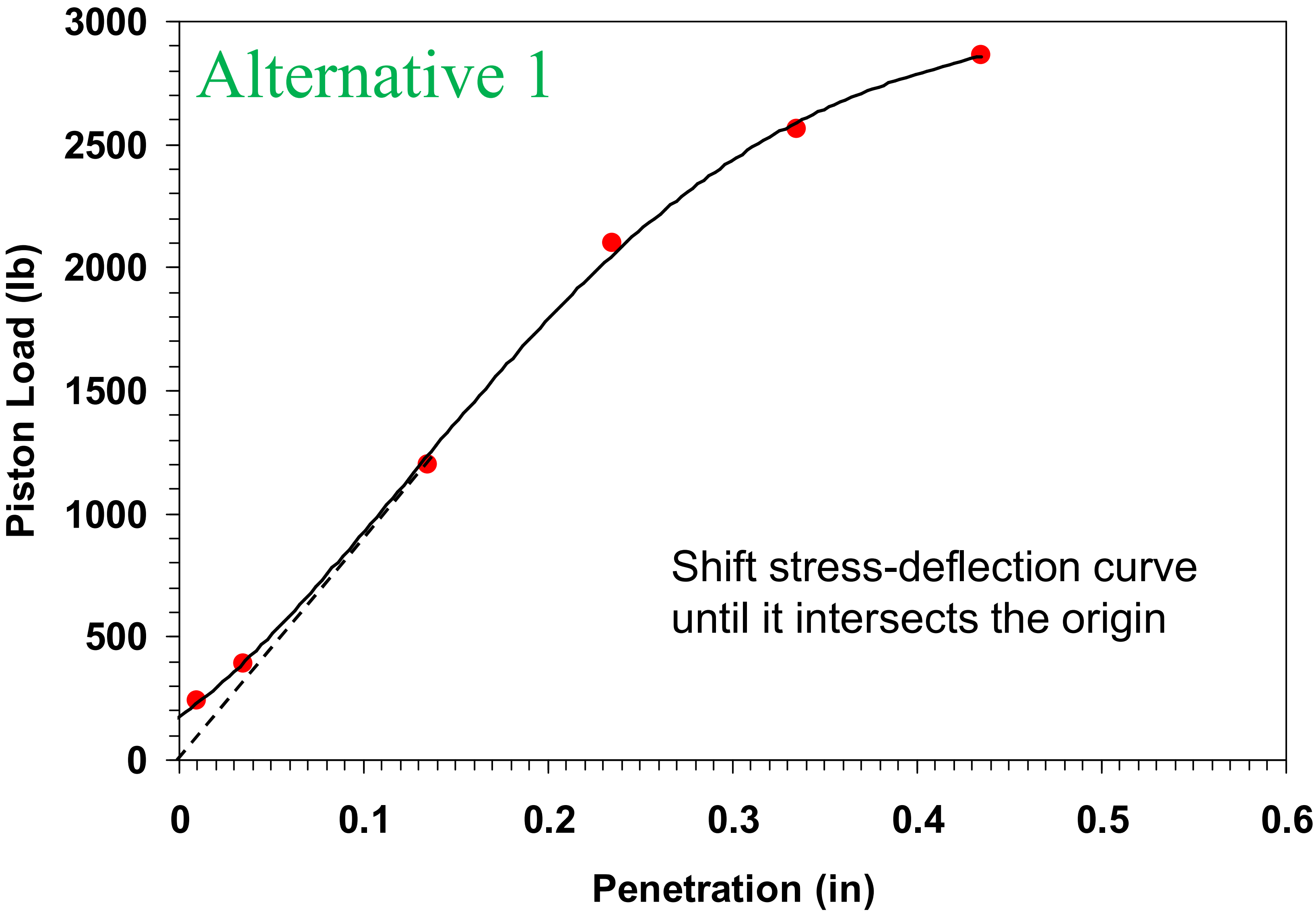
California Bearing Ratio

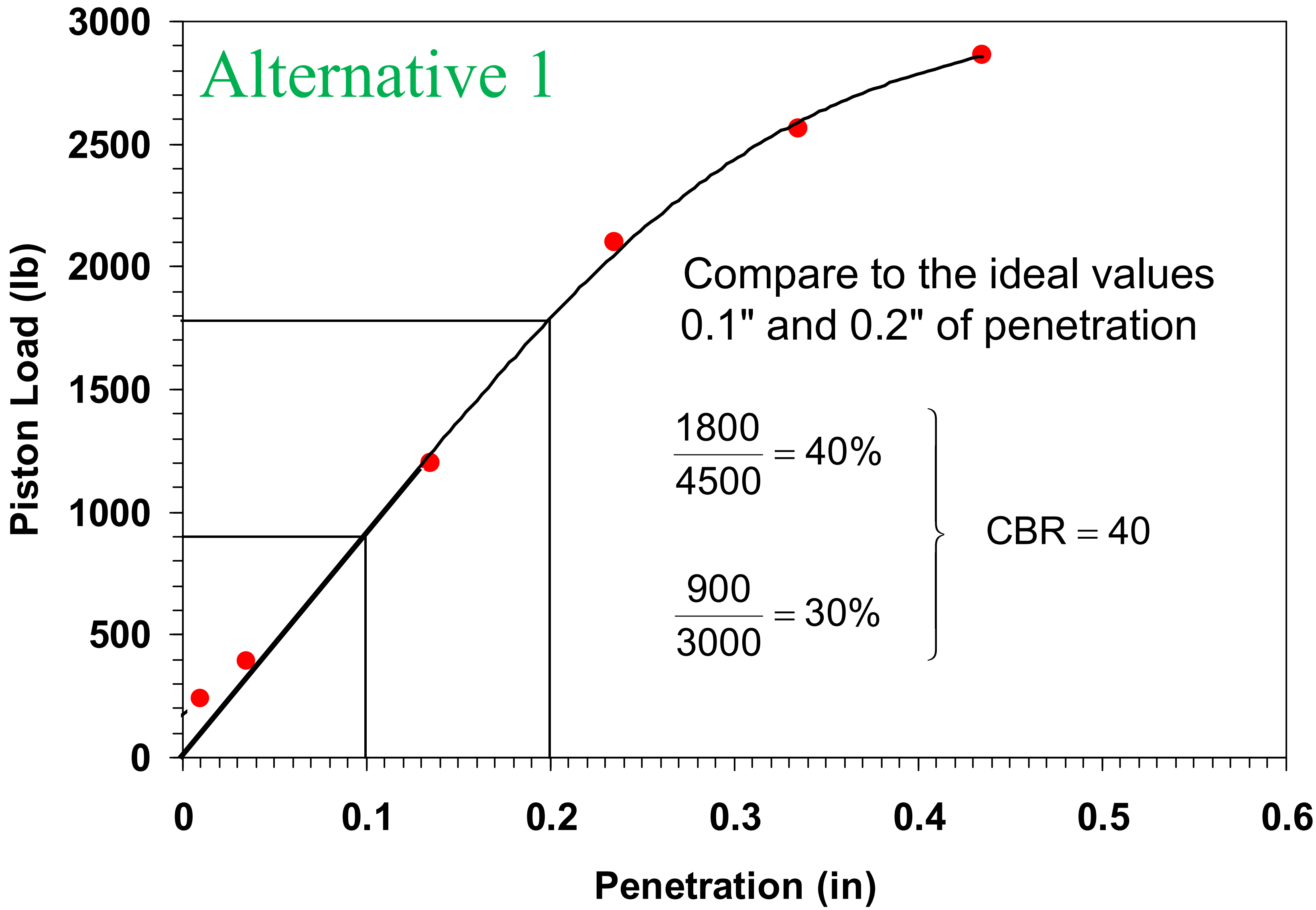
Actual measured results seldom have the same shape as the ideal load-penetration curves, so the first step in reducing the data is to eliminate any “slack” near the origin so the curve is monotonic.

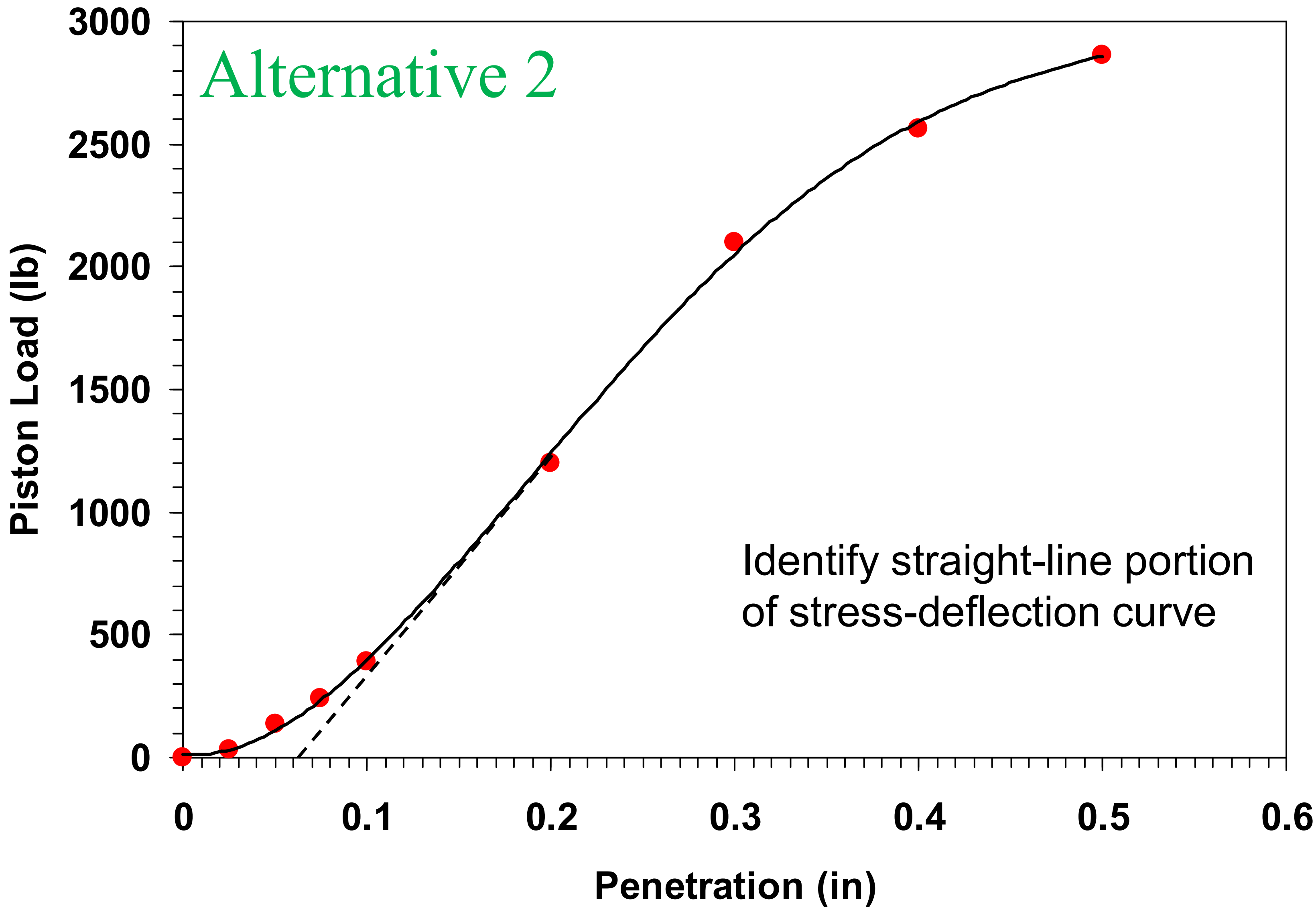
Then, the loads at 0.1" and 0.2" of penetration are divided by 3000 lb. and 4500 lb., respectively, and the larger of the two ratios is reported as the CBR.

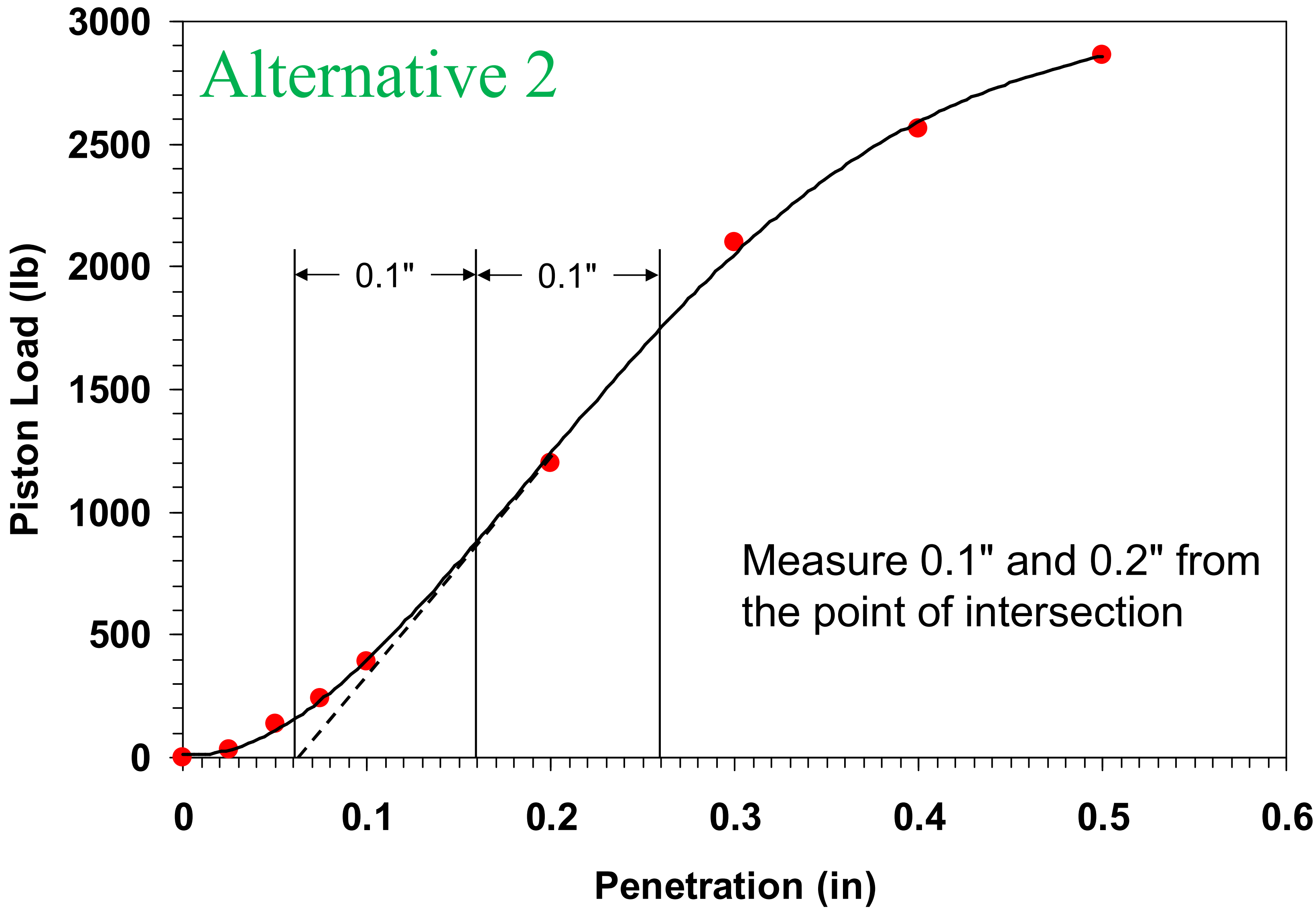

3000
2500
2000
1500
1000
500
0
Piston Load (lb)
0
0.1
0.2
0.3
0.4
0.5
0.6
Penetration (in)

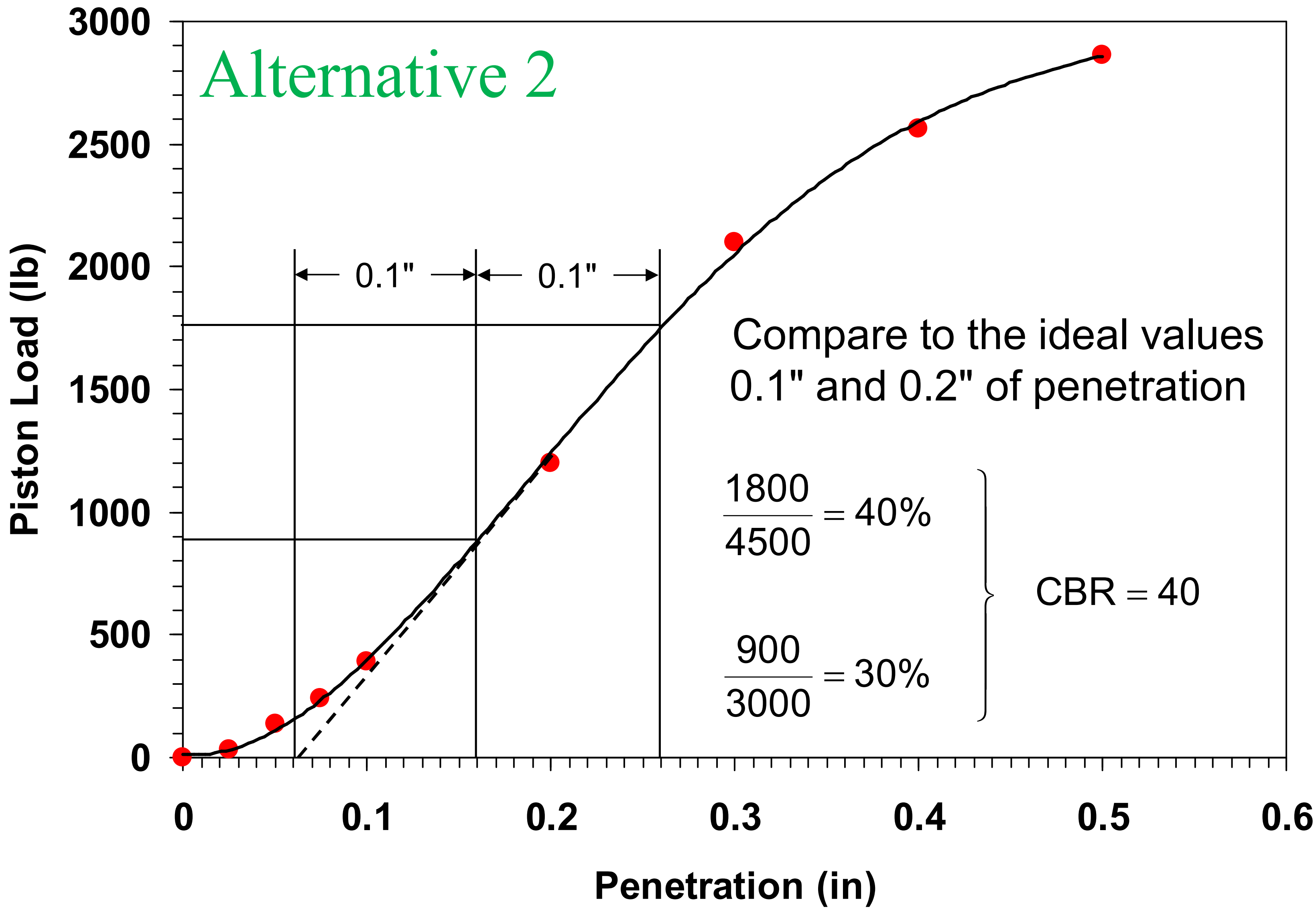

Alternative 1
Identify straight-line portion of stress-deflection curve
Piston Load (lb)
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Penetration (in)


Alternative 1
Shift stress-deflection curve
until it intersects the origin
Piston Load (lb)
Penetration (in)
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6


Alternative 1
Piston Load (lb)
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Penetration (in)
Compare to the ideal values
0.1" and 0.2" of penetration
1800/4500 = 40%
900/3000 = 30%
CBR = 40


Alternative 2
Identify straight-line portion
of stress-deflection curve
Piston Load (lb)
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Penetration (in)


Alternative 2
3000
2500
2000
1500
1000
500
0
Piston Load (lb)
0.1"
0.1"
Measure 0.1" and 0.2" from the point of intersection
0
0.1
0.2
0.3
0.4
0.5
0.6
Penetration (in)

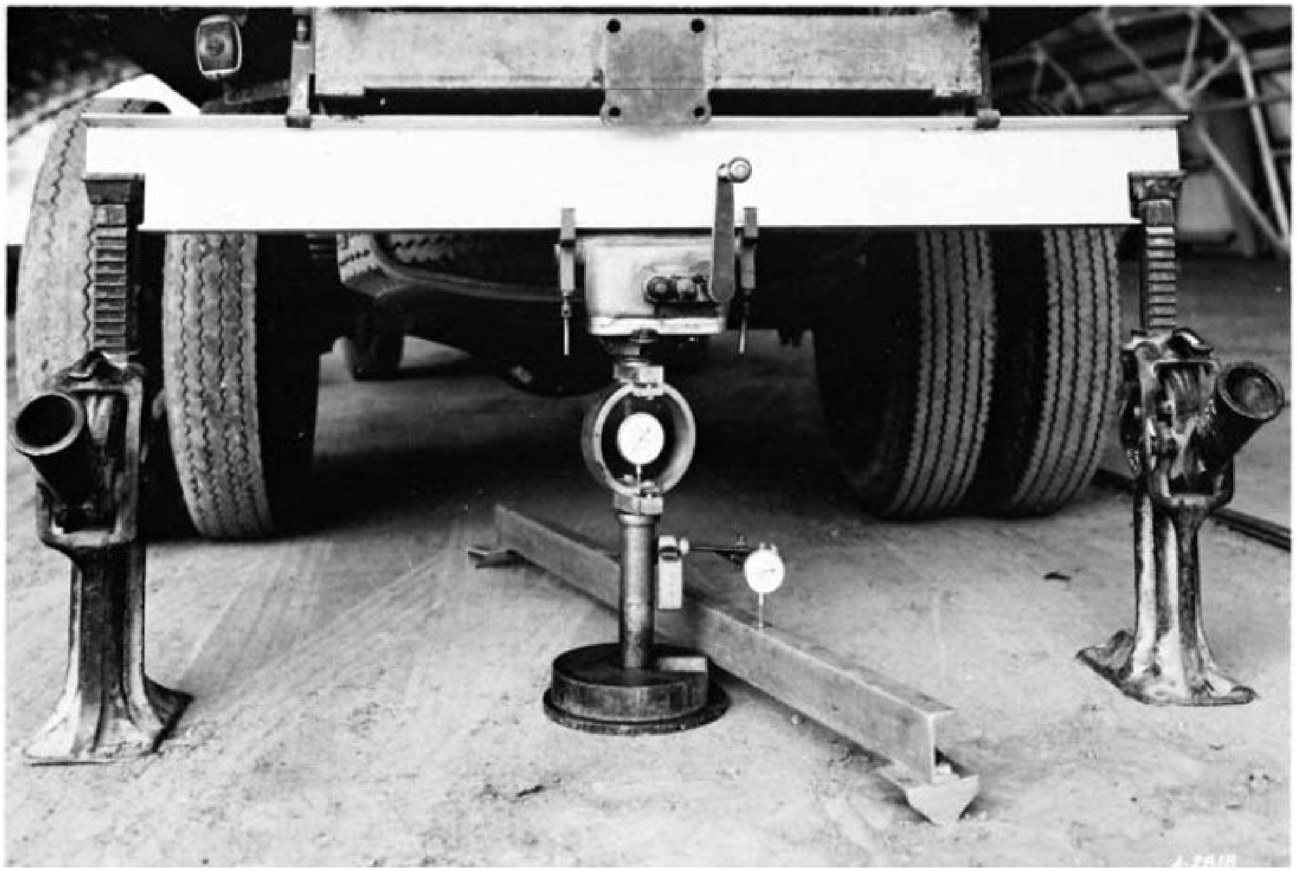


Alternative 2
3000
2500
2000
1500
1000
500
0
Piston Load (lb)
0
0.1
0.2
0.3
0.4
0.5
0.6
Penetration (in)
0.1"
0.1"
Compare to the ideal values
0.1" and 0.2" of penetration
1800/4500 = 40%
900/3000 = 30%
CBR = 40

California Bearing Ratio

The CBR test can also be conducted in the field by jacking against the bumper of a truck and measuring the penetration of the plunger against a reference beam anchored outside of the zone of influence of the plunger (typically an area 3-4 ft in diameter).

Field CBR Test



Source: *ASTM Standards on Disc*, Vol. 04.03, Designation D 4429 - 04, June 2007

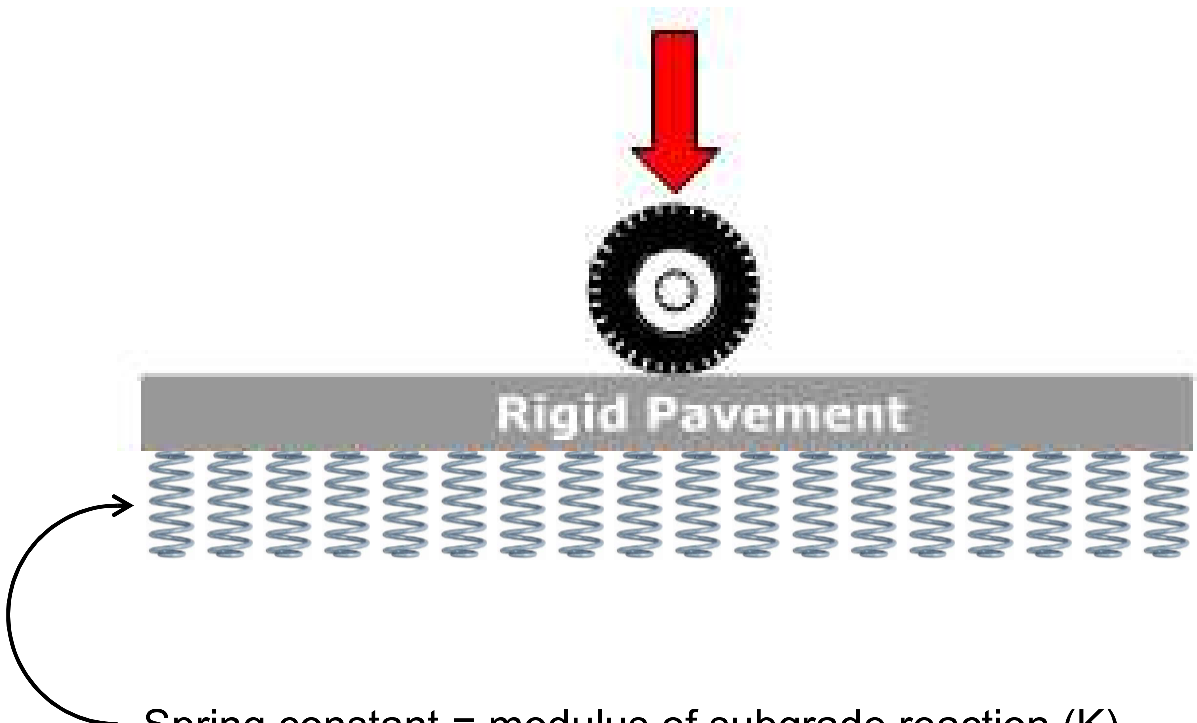
Typical CBR Values

Description of Material	**CBR**
Well-graded crushed aggregates	100
Well-graded natural gravels	80
Silty gravel or silty, sandy gravel	40-80
Well-graded sands, gravelly sands	20-50
Clayey gravel or sandy, clayey gravel	20-40
Silty or clayey sands	10-40
Fine clean sands	10-20
Lean (low-plasticity) clays, sandy clays	5-15
Silts, sandy silts	5-15
Organic silts, lean organic clays	4-8
Fat (high-plasticity) clays	3-5

Modulus of Subgrade Reaction

We often model the subgrade and subbase materials beneath rigid pavements as a series of elastic springs. The modulus of subgrade reaction (K) represents the spring constant for those springs.

Rigid Pavements



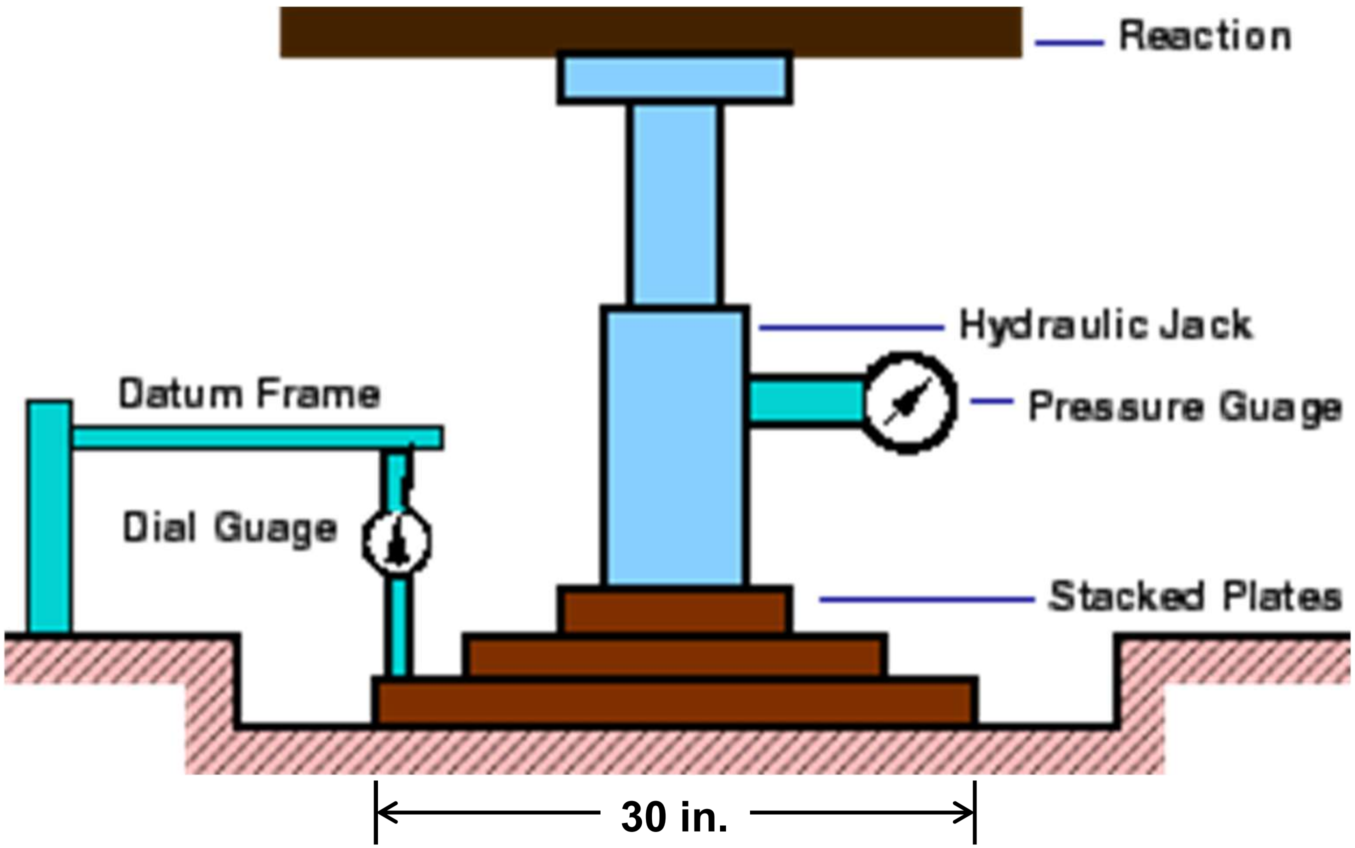
Spring constant = modulus of subgrade reaction (K)

Modulus of Subgrade Reaction

The modulus of subgrade reaction is measured in the field by conducting a ***plate load test***, which measures the force needed to push a circular metal plate into the surface of the roadbed material.

Depending on the strength of the material, plates up to 30" in diameter can be used to obtain an accurate result.

Modulus of Subgrade Reaction



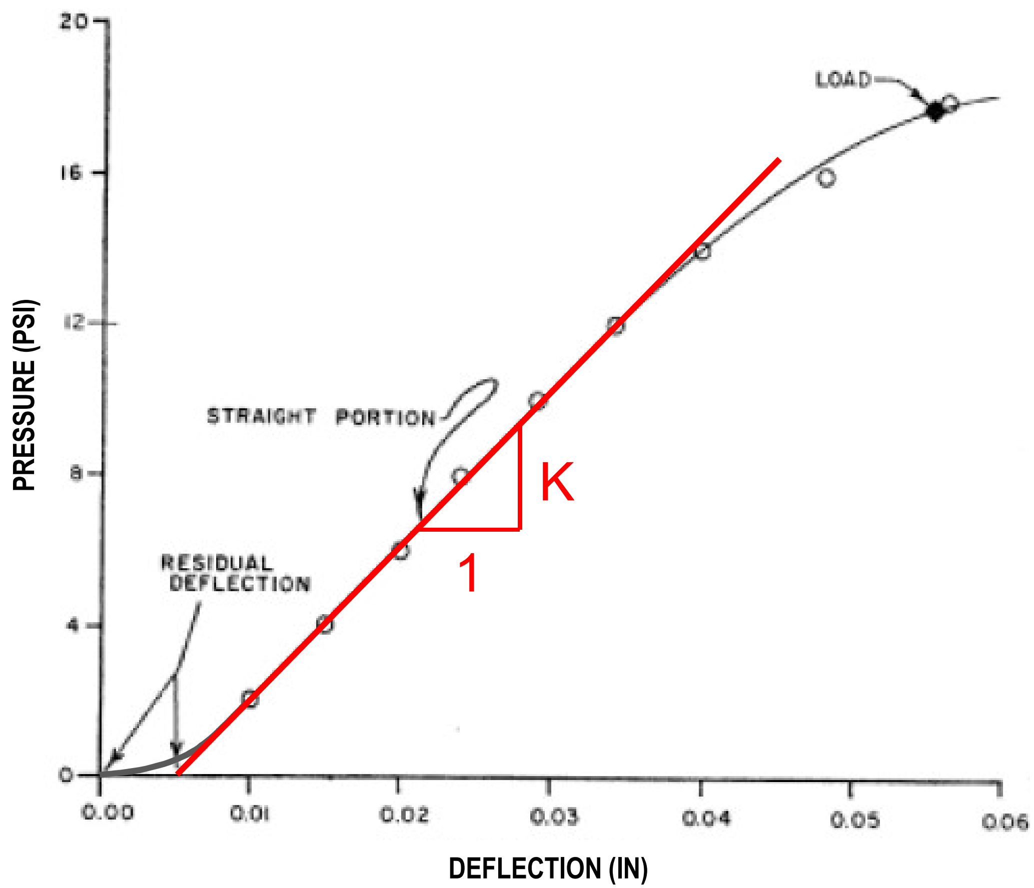
Modulus of Subgrade Reaction

Modulus of Subgrade Reaction

As the vertical load is being applied to the plate, the resulting deformation of the soil surface is measured. The modulus of subgrade reaction is the slope of the initial linear portion of the load-deformation curve.

The ideal load-deformation curve is initially linear, but real field curves often contain some “slack” near the origin, so the engineer has to use some judgement to determine where the linear portion is.

Modulus of Subgrade Reaction



Typical K Values

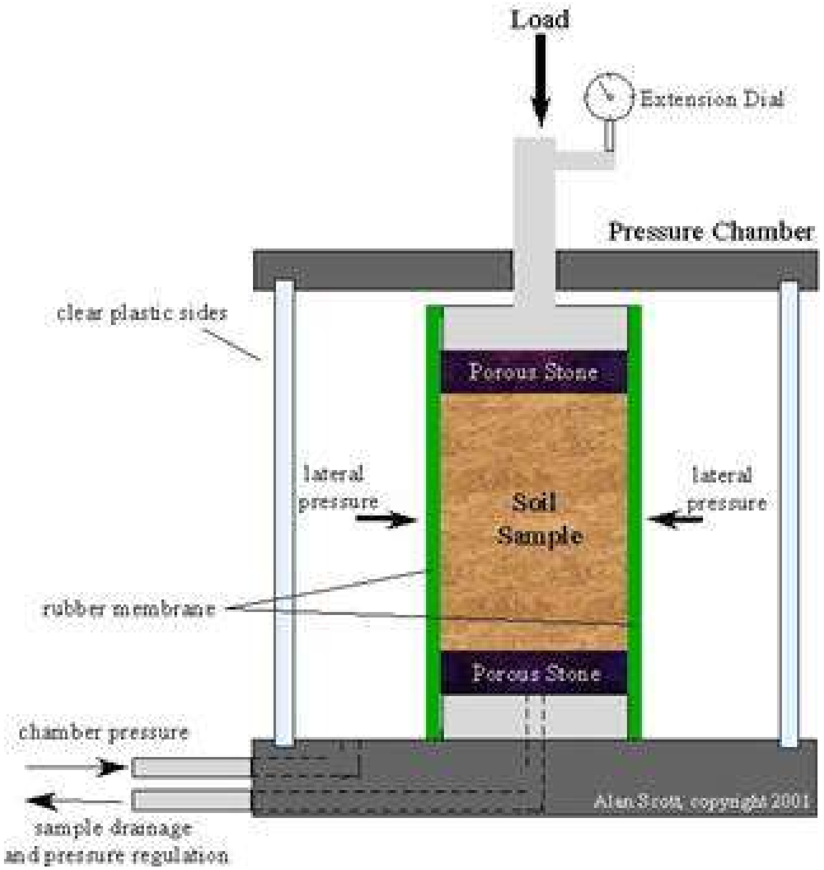
Description of Material	**K (psi/in)**
Well-graded gravel	300-450
Silty sands	300-400
Well-graded sands, gravelly sands	200-400
Fine sand (e.g. beach sand)	150-350
Clayey sands	150-350
Fat (high-plasticity) clays	40-225
Lean (low-plasticity) clays, sandy clays	25-225
Silts, sandy silts	25-200

Resilient Modulus

The resilient modulus is a measure of the stiffness of a roadbed material. It is the modulus of elasticity of the material under rapidly applied cyclic loads that simulate vehicle axle loads on a pavement.

The resilient modulus test is a form of triaxial test in which a cylindrical specimen is subjected to a lateral confining pressure then loaded with a series of fixed axial loads of constant magnitude and duration.

Resilient Modulus

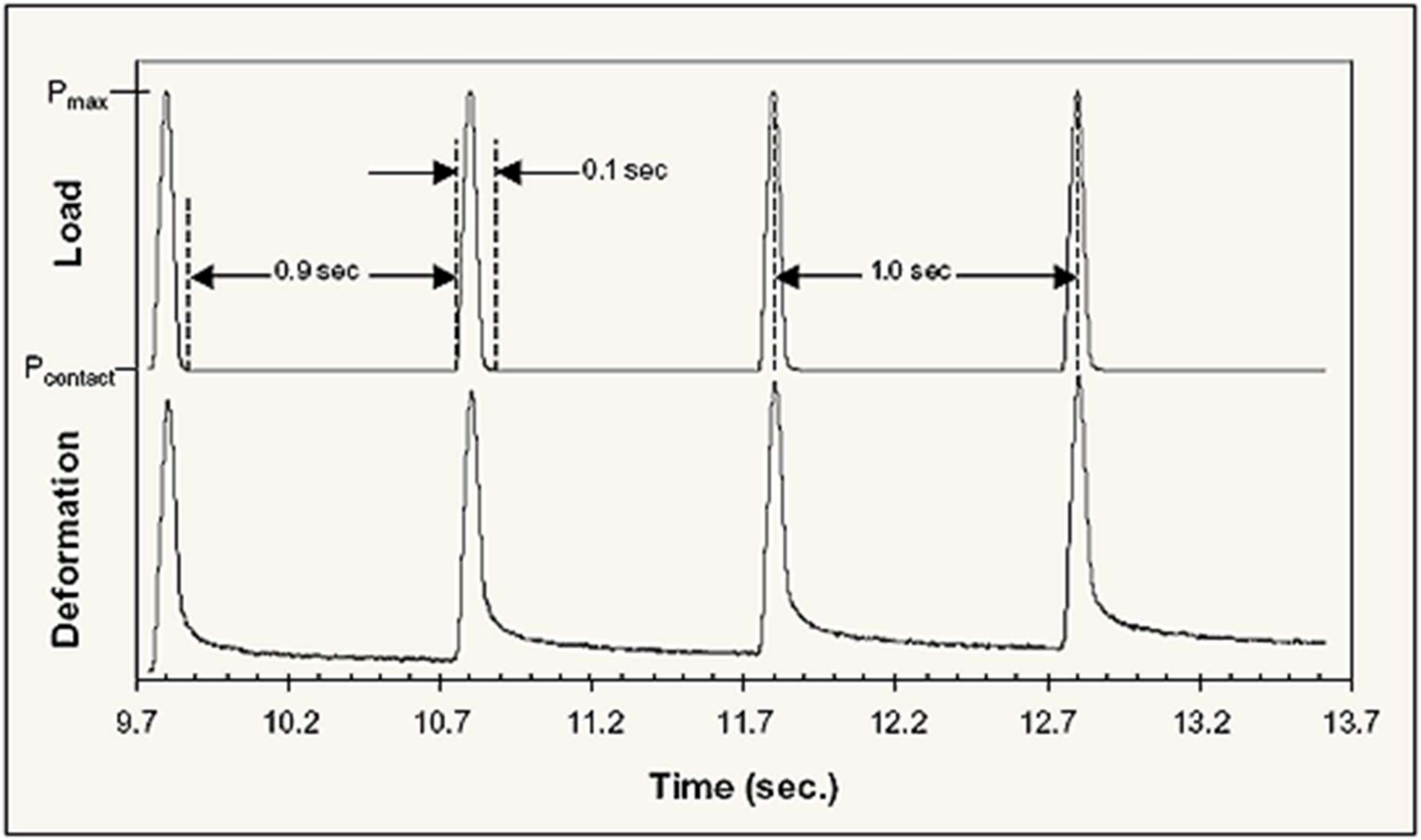


Resilient Modulus

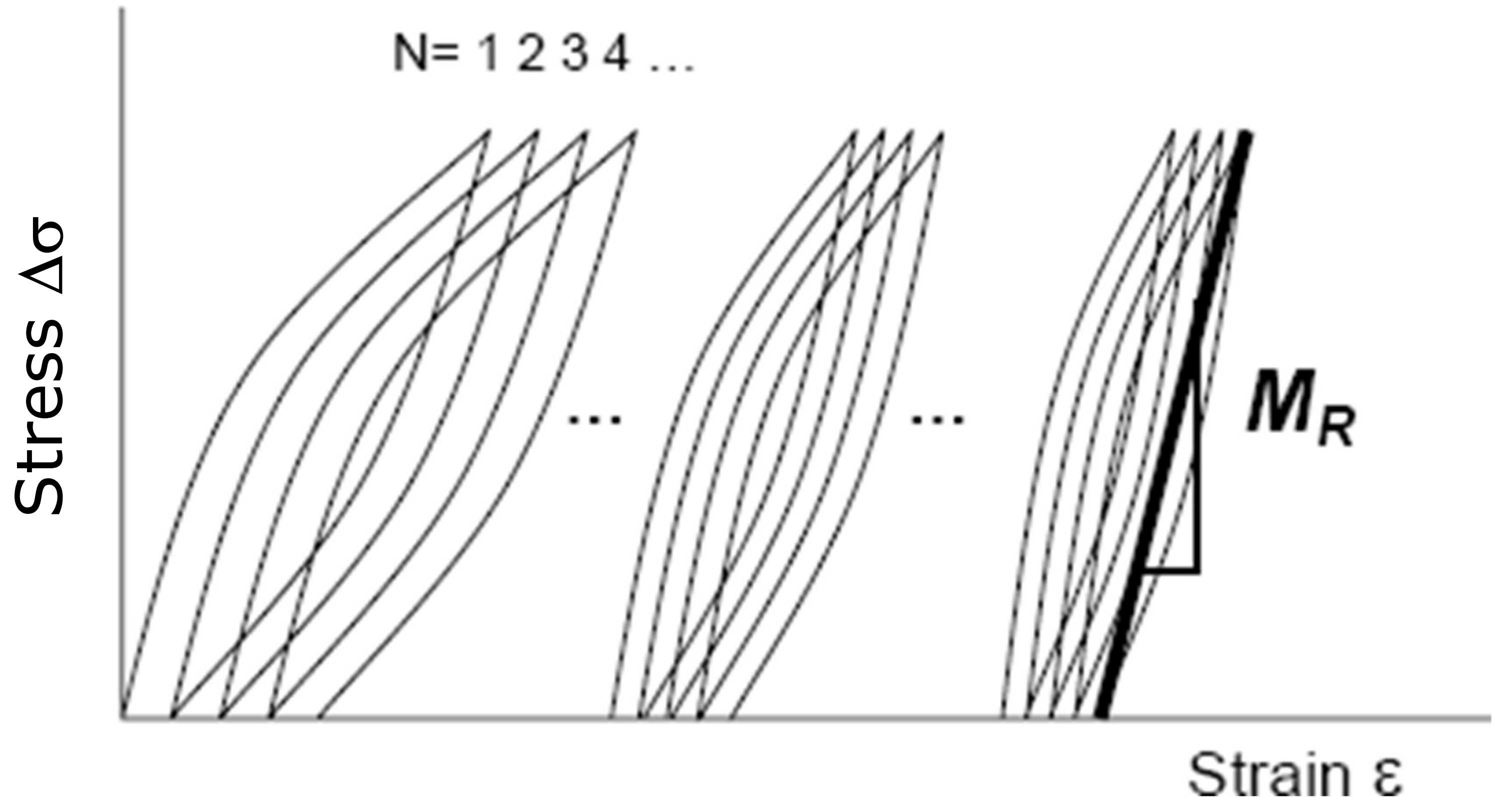
The cyclic axial loads are applied at a rate of one per second. Each load consists of a 0.1-second load pulse followed by a 0.9-second rest.

Typically, hundreds of load pulses are applied before the resilient modulus is measured to ensure that you are measuring the long-term stiffness of the material under repeated loading.

Resilient Modulus



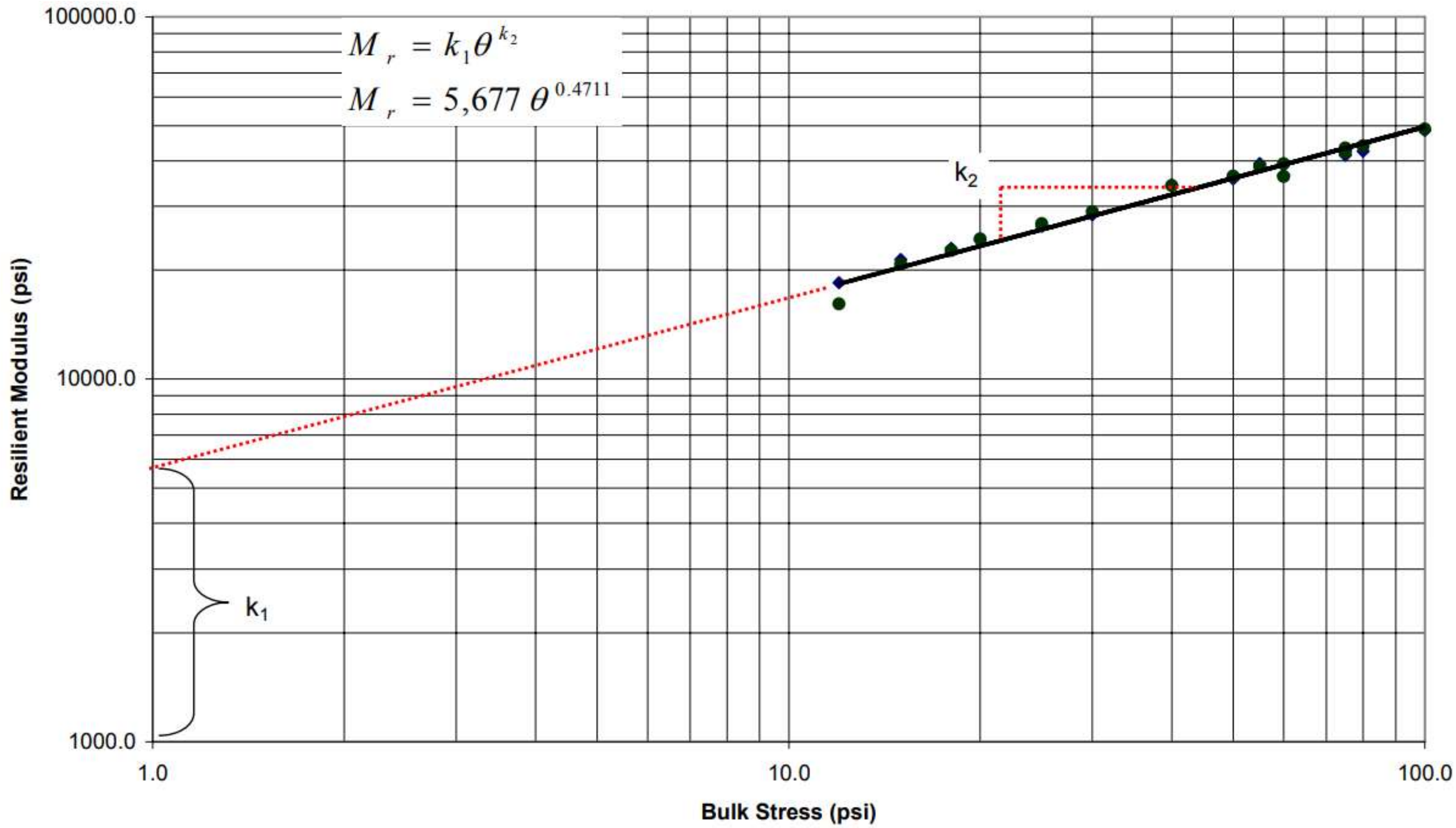
Resilient Modulus



Resilient Modulus

The resilient modulus test is typically run at 3 to 5 different confining pressures and, for each confining pressure, 3 to 5 different axial loads are applied. At the end of the test, the bulk stress can be calculated ($\theta = \sigma_{axial} + 2\sigma_{lateral}$) and the results plotted as a function of the bulk stress. This allows the designer to choose a resilient modulus corresponding to the stresses present in the pavement system.

Resilient Modulus



Typical M_R Values

Description of Material	M_R (psi)
Crushed Stone	20,000 – 50,000
Sandy Subgrade	15,000 – 30,000
Silty Subgrade	5000 – 20,000
Clayey Subgrade	5000 – 15,000