Thi_ Qar University
College of Engineering/Civil Engineering Department

Highway Lectures

Fourth Class

Part #1: - Subgrade Soil

Lecture #3
Soil Test (CBR and K_Value)

Prepared By
Dr. Haider Habeeb Aodah

2014-2015

Purpose

- This test method covers the determination of the CBR of pavement subgrade, subbase, and base course materials from laboratory compacted specimens. CBR value obtained in this test forms an integral part of several flexible pavement design methods.

- California Bearing Ratio (CBR) test is the ratio of force per unit area required to penetrate in to a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min

- If a layer has a low CBR, the above layer shall has a larger thickness so it can reduce the load concentration, also higher CBR value means higher shear strength resistance value.

Purpose

- **California Bearing Ratio (CBR) :** is computed as the ratio of load required to achieving 2.5 or 5.0 mm to that required to achieving the same penetration of standard crushed stone
- In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR.
- In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used.

Apparatuses

i. ***Loading Machine***—The loading machine shall be equipped with a movable head or base that travels at a uniform rate of 1.25 mm/min for use in forcing the penetration piston into the specimen.

ii. ***Mold***— (152.4 ± 0.66 mm) and a height of (177.8 ± 0.46 mm). It shall be provided with a metal extension collar at least (50.8 mm) in height and a metal base plate having at least twenty eight 1.59 mm diameter holes uniformly spaced over the plate within the inside circumference of the mold.

iii. ***Spacer Disk***—A circular metal spacer disc having a minimum outside diameter of 150.8 mm but no greater than will allow the spacer disc to easily slip into the mold. The spacer disc shall be 2.416 ± 0.005 in. (61.37 ± 0.127 mm) in height.

iv. ***Rammer***—If a mechanical rammer is used it must be equipped with a circular foot, and when so equipped, must provide a means for distributing the rammer blows uniformly over the surface of the soil when compacting in a 6-in. (152.4-mm) diameter mold.

Apparatuses

i. ***Penetration Piston*—A** metal piston 1.954 ± 0.005 in. (49.63 ± 0.13 mm) in diameter and not less than 4 in. (101.6 mm) long .

ii. ***Balance***

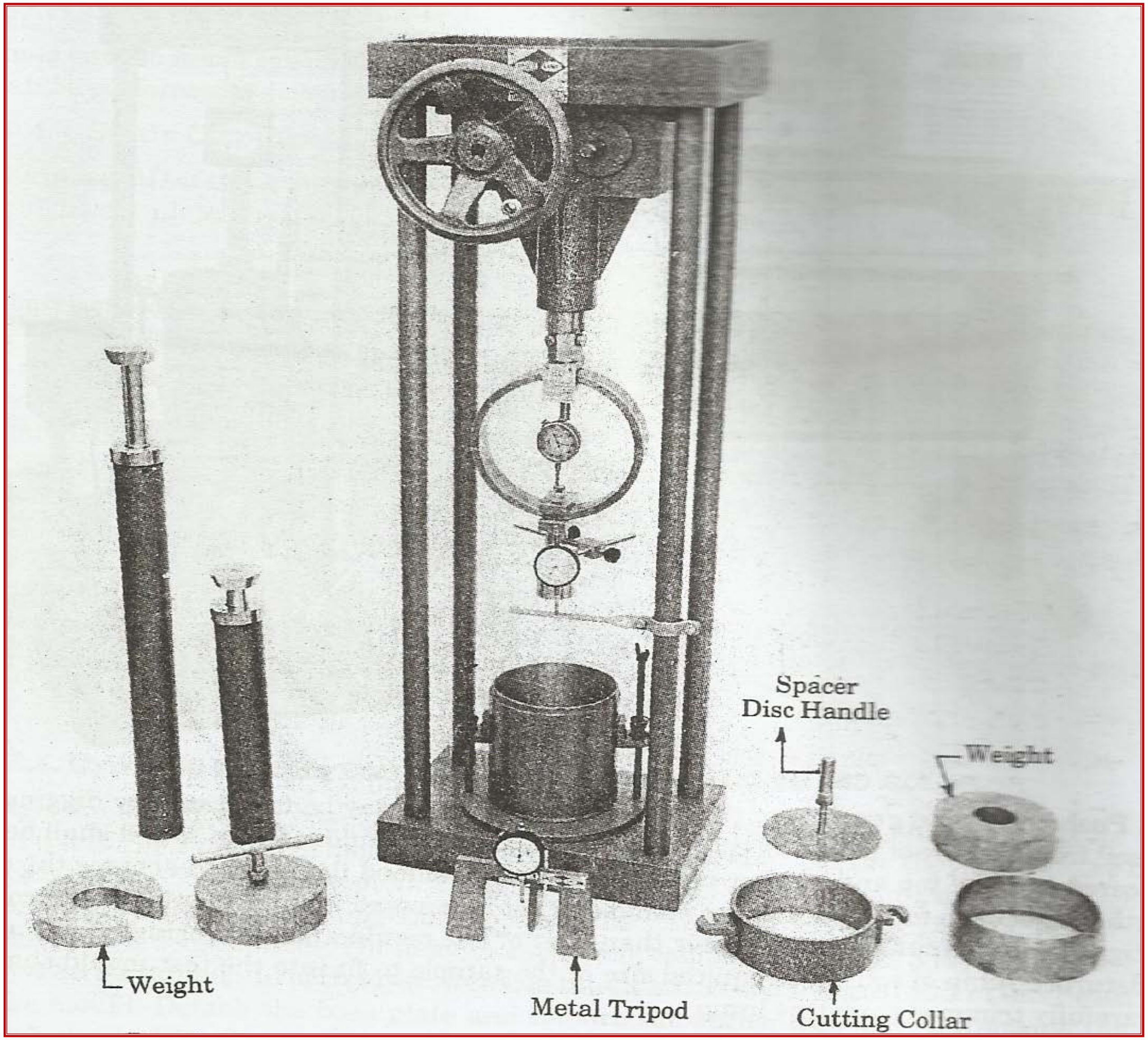
iii. ***Drying Oven*—**

iv. ***Sieves*—**3/4 in. (19 mm) and No. 4 (4.75 mm).

v. ***Filter Paper*—**Fast filtering, high wet strength filter paper, 15-cm diameter.

vi. ***Soaking Tank***

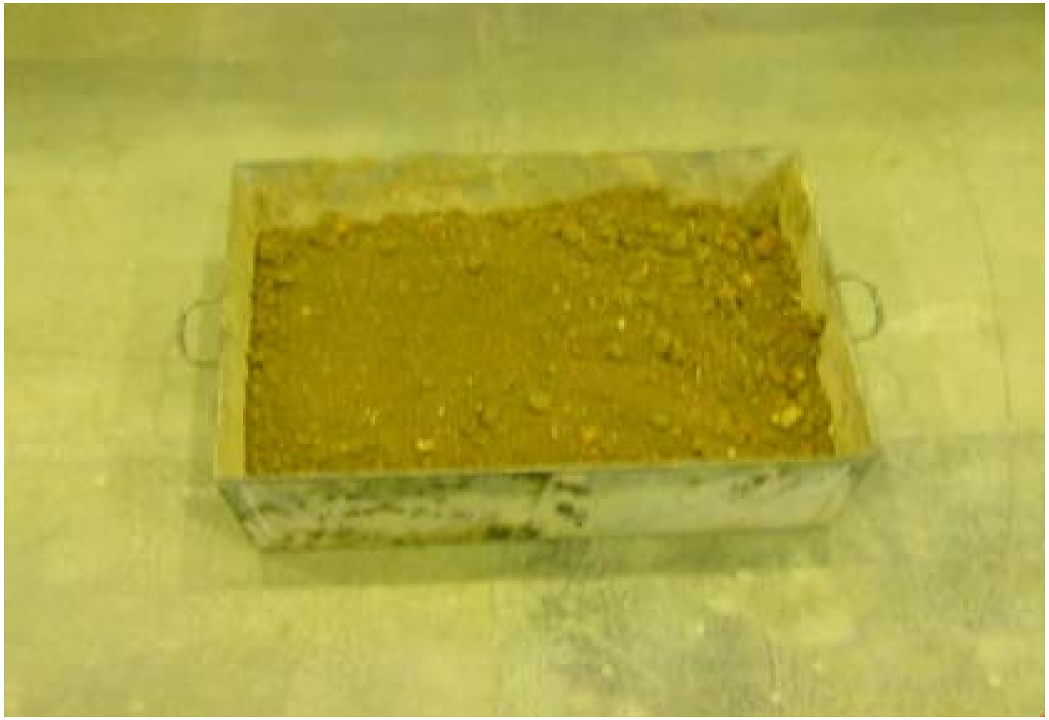
Apparatuses



Procedure

1- Sample Preparing

✓ The soil passed ¾ inches sieve size was mixed altogether to obtain more uniform soil (use optimum moisture content).



Soil portion passed than ¾

Procedure

1- Sample Preparing

✓Sufficient quantity of water was added to achieve optimum water content and mixed thoroughly to achieve uniform mix.

Mix water with the soil to obtain the optimum water content .

✓If material is retained on the 3⁄4-in. (19-mm) sieve, this material shall be removed and replaced by an equal mass of material passing the 3⁄4-in. (19-mm) sieve and retained on the No. 4 sieve.

Procedure

1- Sample Preparing

✓Insert a spacer disc over the base plate and place a coarse filter paper on the top of the spacer disc.

✓Place the mould on a solid base such as a concrete floor or plinth and compact the wet soil in to the mould in five layers of approximately equal mass each layer being given 56 blows with 4.90 kg hammer equally distributed and dropped from a height of 450 mm above the soil.

Each specimen was compacted at five layers using 56 blows .

Procedure

1- Sample Preparing

✓Remove the extension collar and carefully level the compacted soil to the top of the mould by means of a straight edge.

✓Place a filter paper between the base plate and the inverted mould.

✓Place the weights to produce a surcharge equal to the weight of base material and pavement to the nearest 4.5kg on the perforated plate.

✓Immerse the whole mould and weights in a tank of water allowing free access of water to the top and bottom of specimen for 96 hours.

✓After 96 hours of soaking take out the specimen from the water and drain off the excess water by placing the mould inclined for about 15 minutes.

Procedure

1- Sample Preparing

Stabilized soils were soaked for 96 hrs in water

Stabilized soils were drained for15 minutes before Testing .

Procedure

2- Test Procedure

i. Place the mould on the lower plate of the testing machine with top face exposed

ii. To prevent upheaval of soil in to the hole of surcharge weights, place 2.5kg annular weights on the soil surface prior to seating the penetration plunger after which place the reminder of the surcharge weights.

iii. Set the plunger under a load of 4 kg so that full contact is established between the surface of the specimen and the plunger.

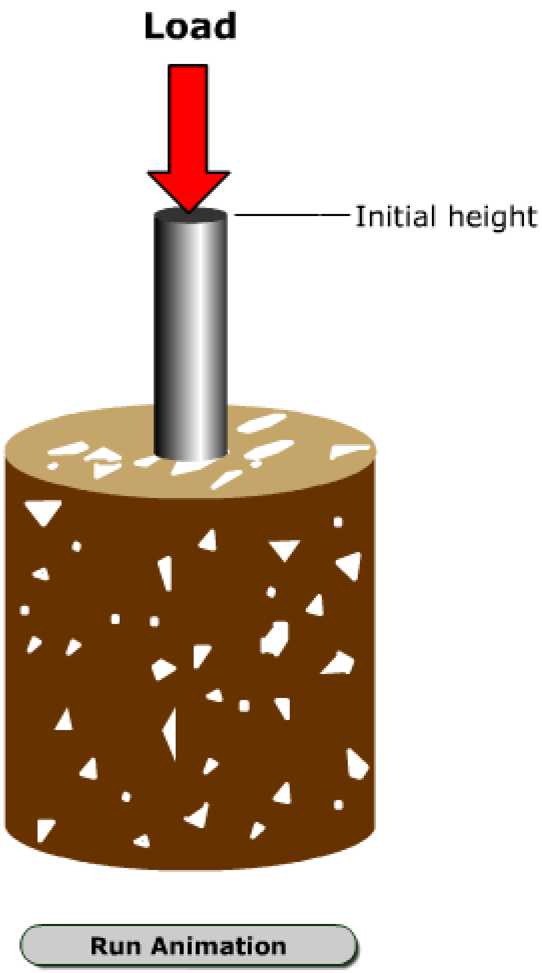
iv. Set the stress and strain gauges to zero.

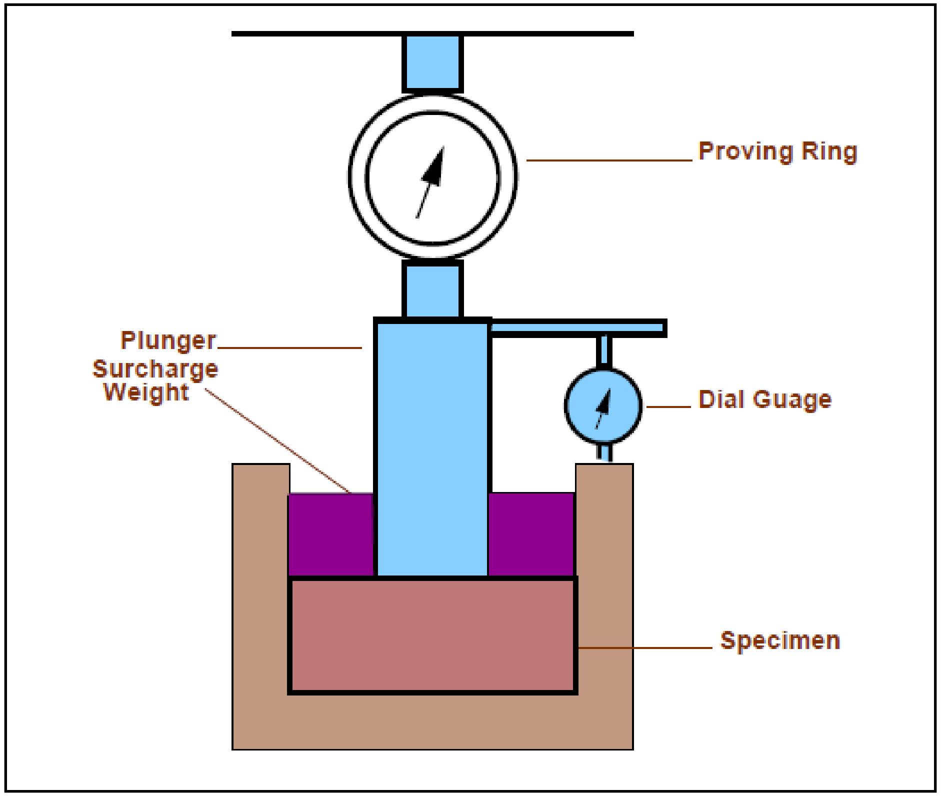
v. Consider the initial load applied to the plunger as the zero load.

vi. Apply the load at the rate of 1.25 mm / min.

vii. Take the readings of the load at penetration of 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4, 5, 7.5, 10 and 12.5 mm.

Procedure





- Load a piston at a constant rate
- See what load it takes to make it penetrate a known amount.

Calculations

i. Plot the penetration stress curve in natural scale, load on Y- axis an penetration on X-axis (pounds per square inch or megapascals).

ii. In some instances, the stress penetration curve may be concave upward initially, because of surface irregularities or other causes, and in such cases the zero point shall be adjusted as shown in Fig. 5.2 by drawing a tangent to the upper curve at the point of contra flexure as below

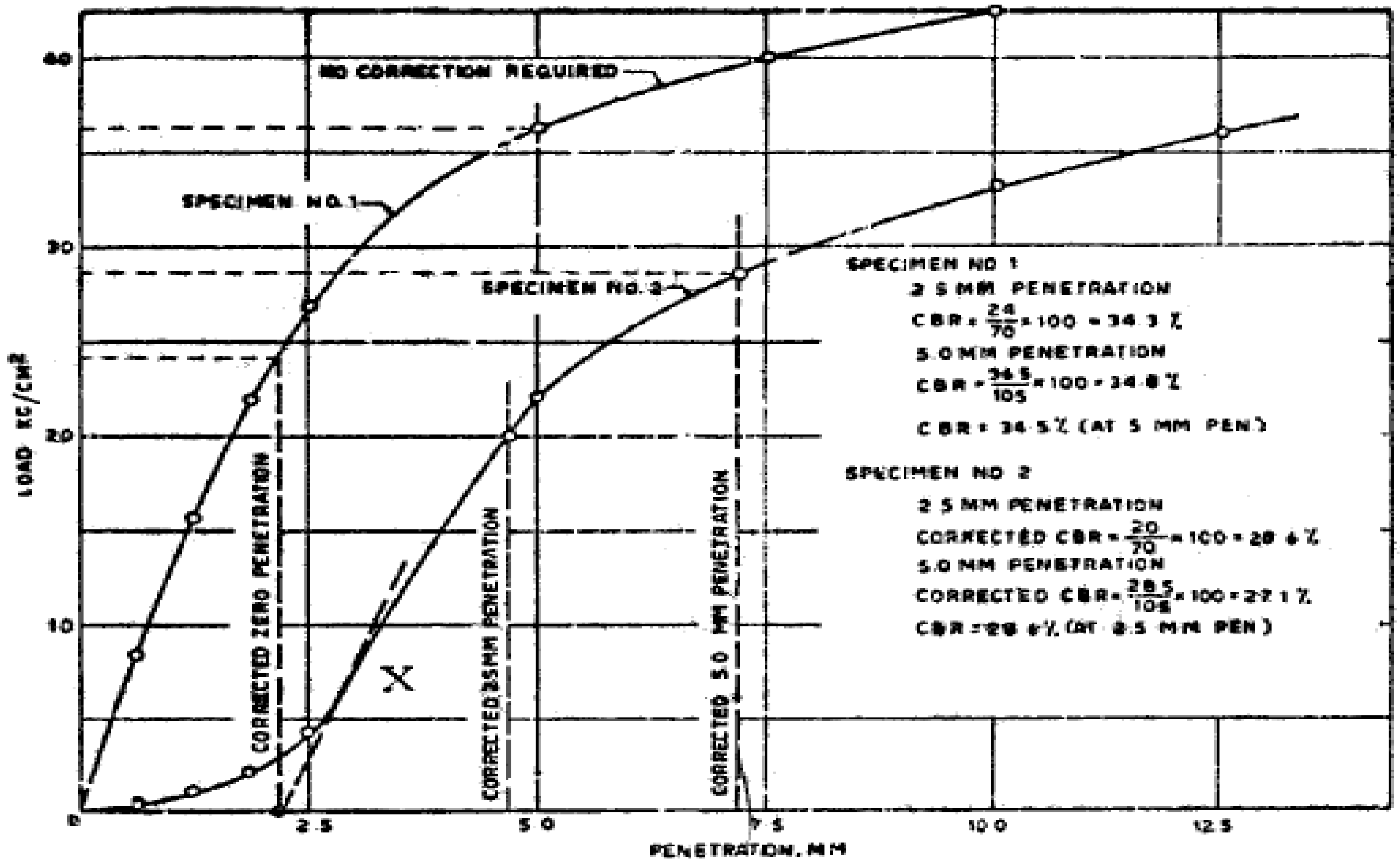
iii. Take the intersection point of the tangent and the X – axis as the origin.

iv. Correction all the data according to new origin.

v. Calculate the CBR values for penetration of 2.5 mm (0.1 in.) and 5.0 mm (0.2 in.) from Equations below.

vi. The CBR reported for the soil mixture is normally the bearing ratio at 2.54-mm penetration. When the bearing ratio at 5.0-mm penetration is greater, rerun the test. If the check test gives a similar result, the CBR is then taken as the bearing ratio determined 5.0 mm.

Calculations



Load-Penetration Curve in C.B.R Test

شكل (١١،٢) منحنى الغرز لقياس نسبة كاليفورنيا للتحميل.

Calculations

$$CBR_{0.1} = \frac{Unit\ load\ @\ 0.1\ in.\ pentration\ for\ the\ sample}{Standard\ unit\ load\ @\ 0.1\ in.pentration} \times 100 \ldots\ldots\ldots (1)$$

$$CBR_{0.2} = \frac{Unit\ load\ @\ 0.2\ in.\ pentration\ for\ the\ sample}{Standard\ unit\ load\ @\ 0.2\ in.pentration} \times 100 \ldots\ldots\ldots (2)$$

- The standard unit load can be taken from the table below.

Penetration depth (mm)	Load (kg)	Load (Ib)
2.5	1370	3044
5	2055	4566
7.5	2630	5844
10	3180	7066

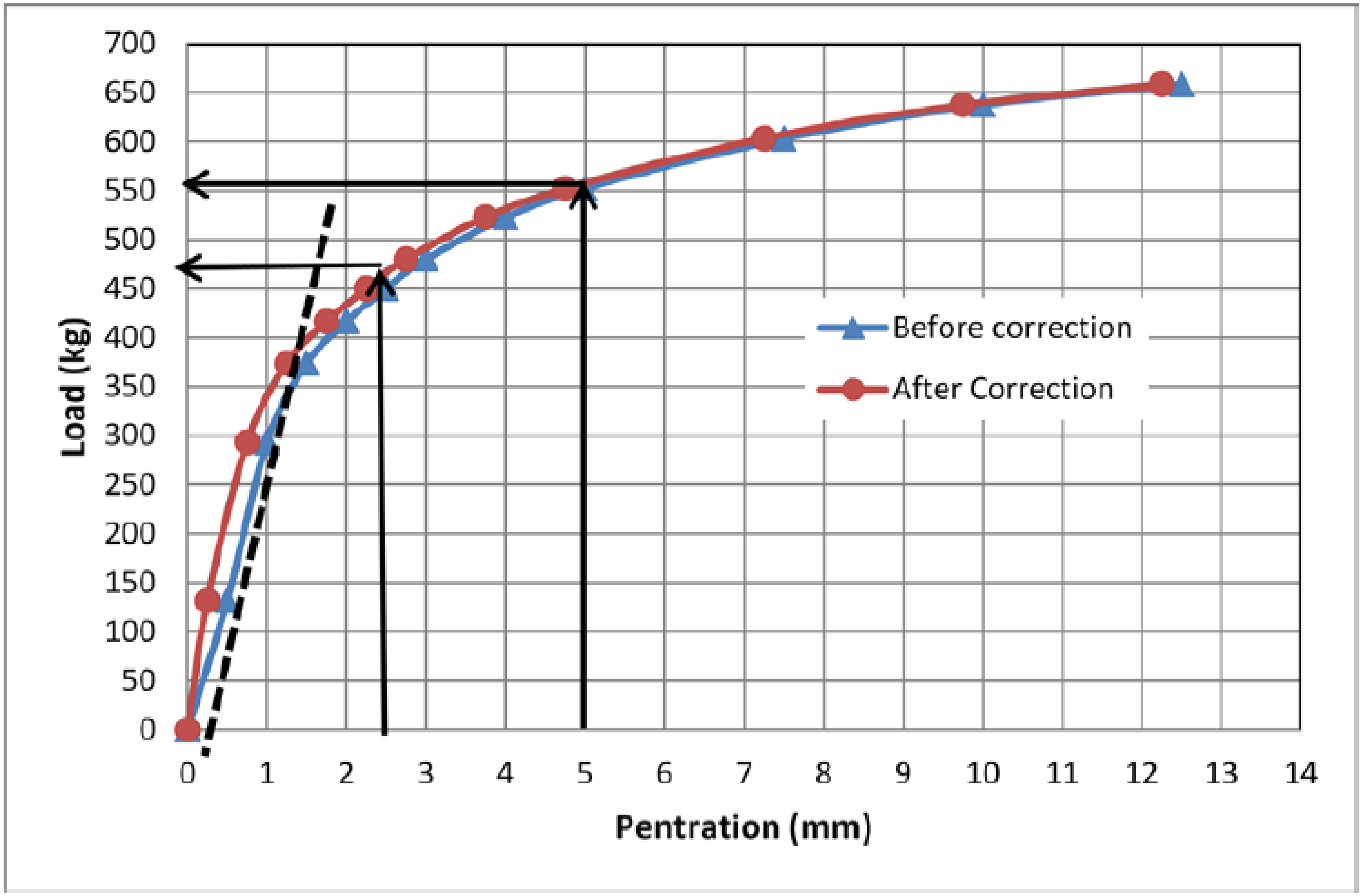
Example

i. Proving ring constant 1 Div of dial gage = 4.25kg
ii. Surcharge weight =5 kg
iii. Plunger diameter=50 mm

Table 5.3: Compaction test results

Penetration (mm)	Proving ring Division	Load (kg)	Correction load (Fig.5.3)	Standard load (Table 5.1)	CBR % value
0	0	0.00			
0.5	31	131.75			
1	69	293.25			
1.5	88	374.00			
2	98	416.50			
2.5	**106**	**450.50**	**470**	**1370**	**34**
3	113	480.25			
4	123	522.75			
5	**130**	**552.50**	**560**	**2055**	**27**
7.5	142	603.50			
10	150	637.50			
12.5	155	658.75			

Example



700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Load (kg)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Pentration (mm)
Before correction
After Correction

Specification

➢The Minimum allowable CBR values of a pavement structure layers as per the Iraqi standard specification for roads and bridges are given in Table below:-

No.	*Type of pavement layer*	*CBR Value, Minimum %*
1	Subgrade	The minimum CBR value shall be 4% at 95% compaction, otherwise the soil shall not be regarded as suitable to be used for subgrade.
2	Subbase	The CBR values of the subbase course (granular materials) shall not be less than 45% for type A, not less than 35% for type B and not less than 30% for type C at 95% compaction.
3	Base	

Modulus of Subgrade Reaction (K_ Value)

.

Modulus of Subgrade Reaction (K-Value) - Ratio of load per unit area (applied through a centrally loaded rigid body) of horizontal surface of a mass of soil to corresponding settlement of the surface. It is determined as the slope of the secant drawn between the point corresponding to zero settlement and the point of 1.25 mm settlement (Figure 7.1), of a load-settlement curve obtained from a plate load test on a soil using a 75 cm diameter or smaller loading plate with corrections for size of plate used.

$$K = \frac{\rho}{\Delta} = \frac{\rho}{0.125} \dots\dots$$

Where:-

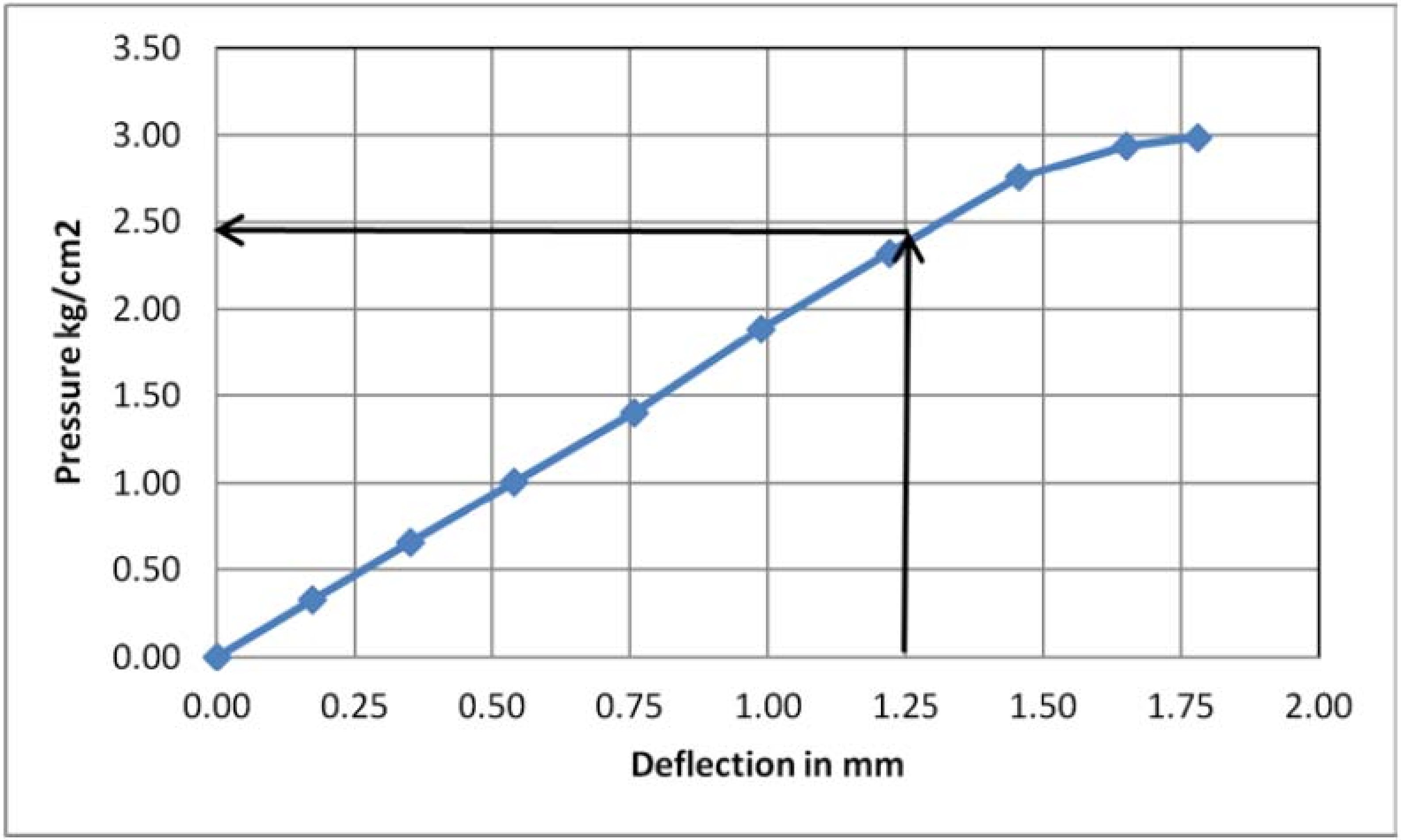
K: Modulus of subgrade reaction (K-Value) in kg/cm^3.

ρ: Pressure in kg/cm^2.

Δ: Deflectio (0.125 cm).

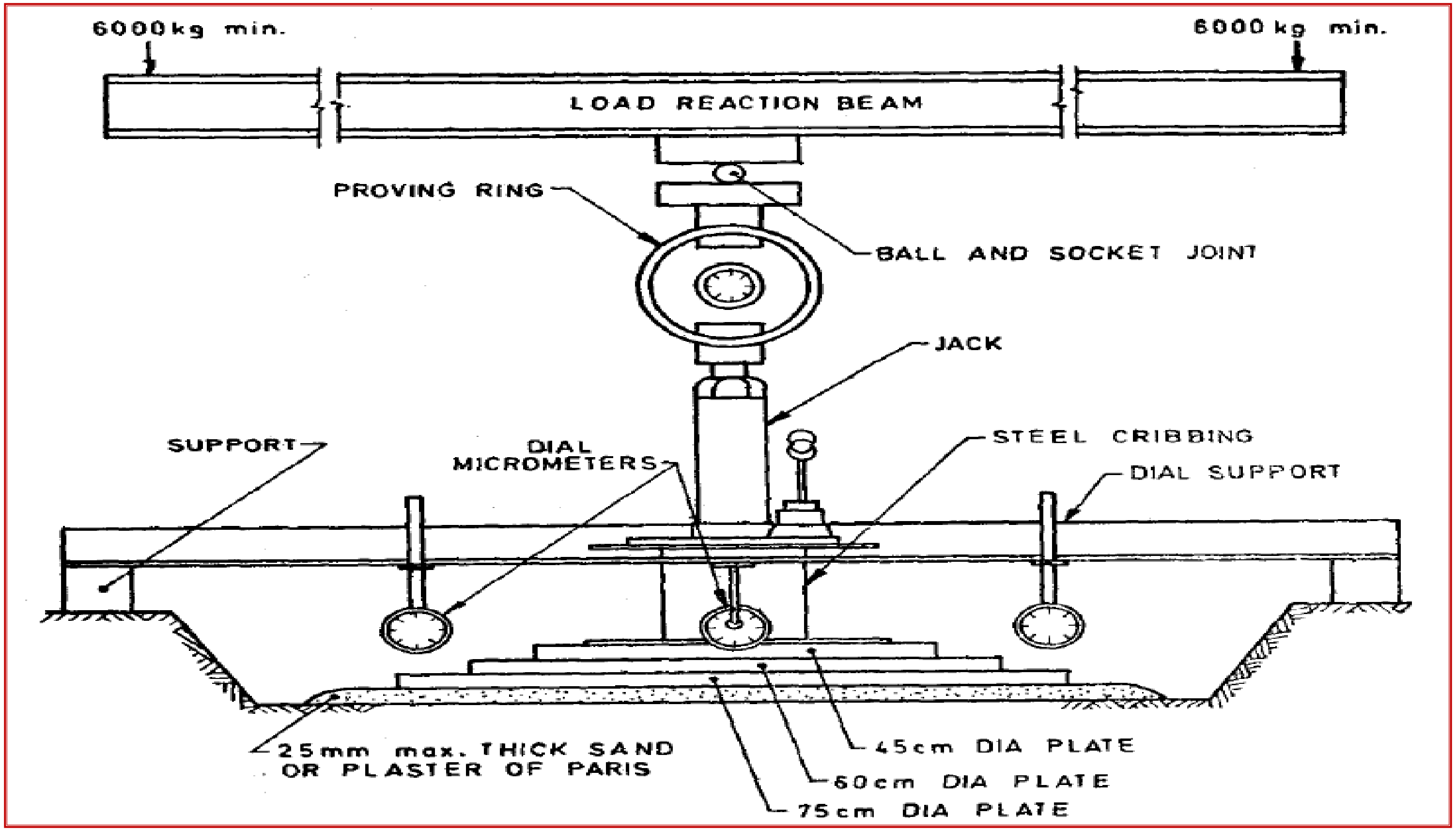
Modulus of Subgrade Reaction (K_ Value)

.



Modulus of Subgrade Reaction (K_ Value)

- To calculate the Modulus of Subgrade Reaction, *Plate Bearing Test* is conducted.



Modulus of Subgrade Reaction (K_ Value)

.

Test Procedures

i. Carefully center a bearing plate of the selected diameter under the jack assembly.
ii. Use three gages, they shall be set at an angle of 120° from each other, and equidistant from the circumference of the bearing plate. Each individual set of readings shall be averaged, and this value is recorded as the average settlement reading.
iii. After the equipment has been properly arranged, the load is then increased till the average settlement of gages increase to a further amount of about 0.25 mm and the load and the settlement dial reading are recorded.

Modulus of Subgrade Reaction (K_ Value)

.

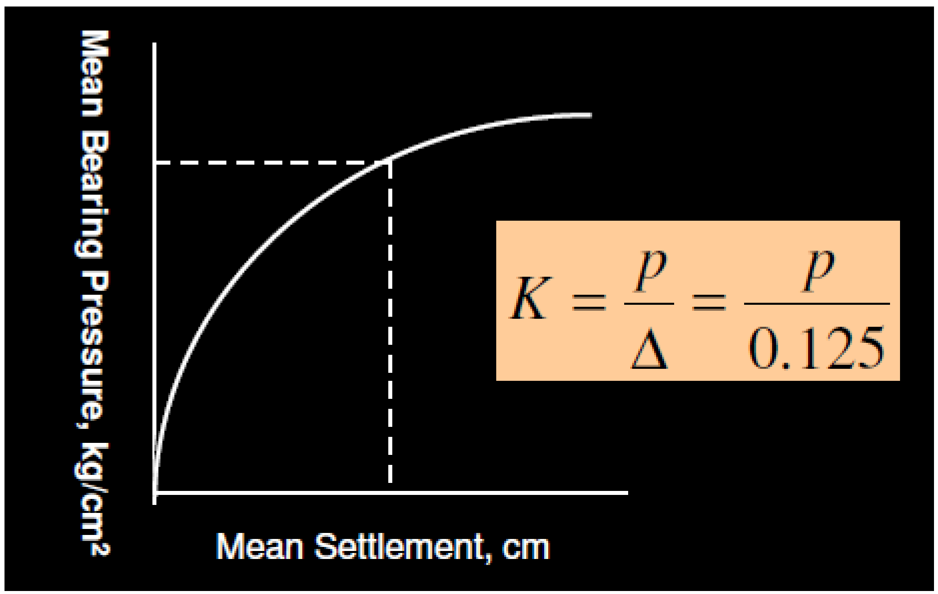
Test Procedures

i. The average of the three or four settlement dial readings is taken as the average settlement of the plate corresponding to the applied load.
ii. The procedure is repeated till the total average settlement of the plate is not less than 1.75 mm.

Modulus of Subgrade Reaction (K_ Value)

Calculations

➢A graph is plotted with the mean settlement values of the plate on the X-axis versus with the pressure on the Y-axis. The modulus of subgrade reaction, K is calculated from the Equation below.



Where:-

K: Modulus of subgrade reaction (K-Value) in kg/cm^3.

ρ: Pressure in kg/cm^2.

Δ: Deflectio (0.125 cm).

Modulus of Subgrade Reaction (K_ Value)

.

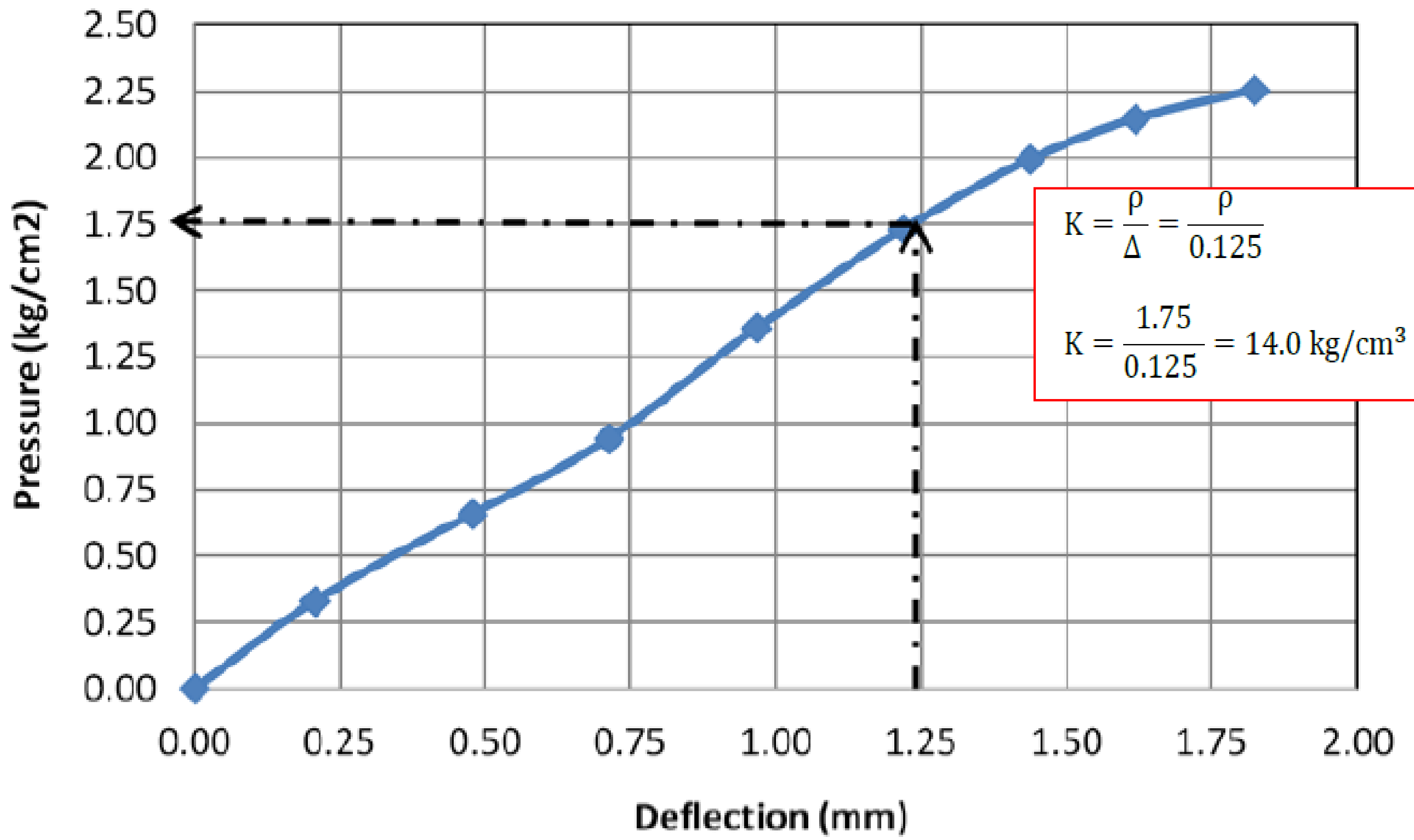
Example

- Location: IIT Roorkee Laboratory/Roorkee-india
- Soil Type: ....
- Depth of Test: 50 cm
- Moisture Content: 15%
- Density: 1.845 gm/cm^3
- Plate Diameter: 30 cm
- Area of Plate : 706.86 cm^2
- Date : 16/1/2013
- Settlement Dial, 1 Div.=0.01 mm
- Load proving ring Div= 15.48 kg

Approx. settlement (mm)	Actual dial gages Settlement				Average Settlement (mm)	Load dial reading	Pressure (kg/cm^2)
	#1	#2	#3	#4			
0.00	0	0	0		0	0	0
0.25	0.25	0.14	0.23		0.21	15	0.328
0.5	0.5	0.44	0.49		0.48	30	0.657
0.75	0.75	0.61	0.78		0.71	43	0.942
1.00	1.00	0.85	1.05		0.97	62	1.358
1.25	1.25	1.12	1.29		1.22	79	1.730
1.50	1.50	1.33	1.48		1.44	91	1.993
1.75	1.75	1.42	1.68		1.62	98	2.146
2.00	2.00	1.61	1.86		1.82	103	2.256

Modulus of Subgrade Reaction (K_ Value)

Example



$$K = \frac{\rho}{\Delta} = \frac{\rho}{0.125}$$

$$K = \frac{1.75}{0.125} = 14.0\ \text{kg/cm}^3$$

Modulus of Subgrade Reaction (K_ Value)

.

➢ ***Correction of K-Value to account for smaller plate size:***- It is expensive and difficult to carry out plate bearing test using 75 cm diameter plate and to provide adequate reaction load through heavily loaded truss to determine the subgrade modulus reaction, therefore smaller plate of diameter 30 cm is generally used for conducting the plate bearing test and the rear axle of a load truck is used as the reaction is equal to 30/75 or 0.4. That is mean:

$$K_{75} = 0.4 \times K_{30} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$K_{75} = 0.5 \times K_{30} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Modulus of Subgrade Reaction (K_ Value)

.

➢ Relations

The 1993 AASHTO Guide offers the following relationship between k-values from a plate bearing test and resilient modulus (M_R):

$$K = \frac{M_R}{19.4} \dots \quad (5)$$

Where M_R The Resilient modulus of soil. Also, the relation between resilient modulus of soil and the CBR value is given as:

$$M_R(MPa) = 10 \times CBR \quad For\ CBR \leq 5 \dots \quad (6)$$

$$M_R(MPa) = 17.6 \times (CBR)^{0.64} \quad For\ CBR > 5 \dots \quad (7)$$

Modulus of Subgrade Reaction (K_ Value)

.

➢ ***Relations :-*** Approximate K_ value corresponding CBR soaking value (Ref. IRC 58-2002).

Soaked CBR %	**2**	**3**	**4**	**5**	**7**	**10**	**15**	**20**	**50**	**100**
K-Value (kg/cm^3	**2.1**	**2.8**	**3.5**	**4.2**	**4.8**	**5.5**	**6.2**	**6.9**	**14.0**	**22.2**

References

1) AASHTO T 193-10, (2010), “Standard Method of Test for The California Bearing Ratio”.
2) ASTM D1883-2007,"Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils”.
3) Ministry of Iraqi housing and construction, (2003), “Standard Specification for Roads and Bridges”, Baghdad-Iraq.
4) Mittal, S. and Shukla, J., P., (2012), " Soil Testing for Engineers", Indian Institute of Technology Roorkee, India.
5) Indian Standard IS:9214, (2002) ,"Method of Determination of Modulus Subgrade Reaction (K-Value) of Soils in Field”.

References

6) Indian Road Congress IRC:58- 2002 ,“Guideline for the Design of the Plain Jointed Rigid Pavements for Highways”.