California Bearing Ratio (CBR)

- ***California Bearing Ratio (CBR) is a penetration test for evaluation of the mechanical strength of road subgrades, sub-base and base courses. It was developed by the California Department of Transportation.***

- *The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material.*

or

- *The test is performed by measuring the load required to penetrate a soil sample with a plunger of standard area. The measured load is then divided by the load required to achieve an equal penetration on a standard crushed rock material.*

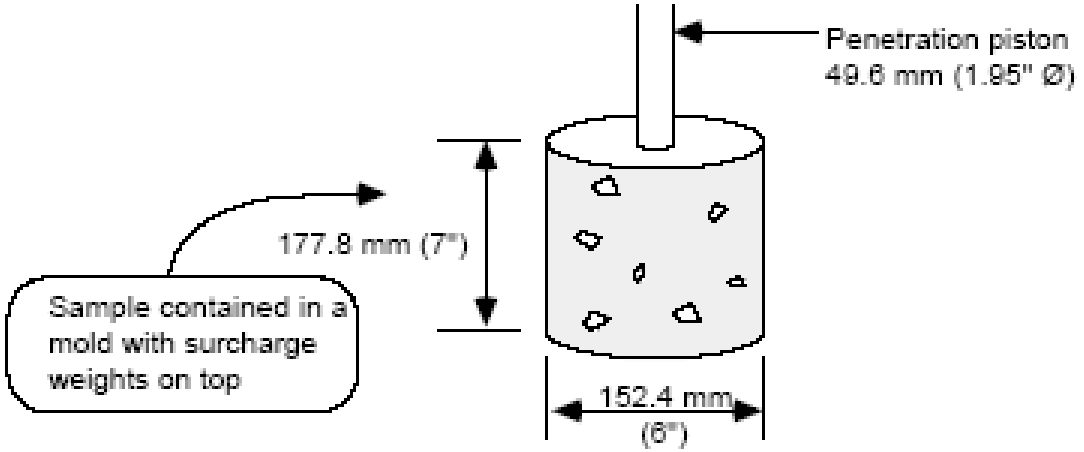
California Bearing Ratio (CBR)

(a) Developed by the California Division of Highways around 1930

(b) Subsequently adapted by numerous states, counties and U.S. federal agencies. Adopted by the U.S. Army Corps of Engineers during early 1940's (WW II use).

(c) This test is a comparative measure of the shearing resistance of a material and is used with empirically derived curves to design flexible pavement structures.

(d) This test can be used for base, subbase, and subgrade materials.



California Bearing Ratio = (Load required for a certain penetration of plunger) x 100
Standard Load for same penetration

- **Surcharge plates are used on the mould to simulate the field conditions**
  - ***One surcharge plate represents 2.5" thick pavement***
  - ***Two surcharge plates represent 5" thick pavement***

(f) Apply load to piston at a rate of 1.3 mm (0.05") per minute. Record total load readings at penetrations ranging from 0.64 mm (0.025 in.) up to 7.62 mm (0.300 in.)

CBR(%) = (100) (x/y)

where x = material resistance or the unit load on the piston (pressure)— for 2.54 mm (0.1") or 5.08 mm (0.2") of penetration

y = standard unit load (pressure) for well graded crushed stone

= for 2.54 mm (0.1") penetration = 6.9 MPa (1000 psi)

= for 5.08 mm (0.2") penetration = 10.3 MPa (1500 psi)

Thus CBR compares the material being tested with the bearing of a well-graded crushed stone. Thus, a high quality crushed stone base material should have a CBR ≈ 100%.

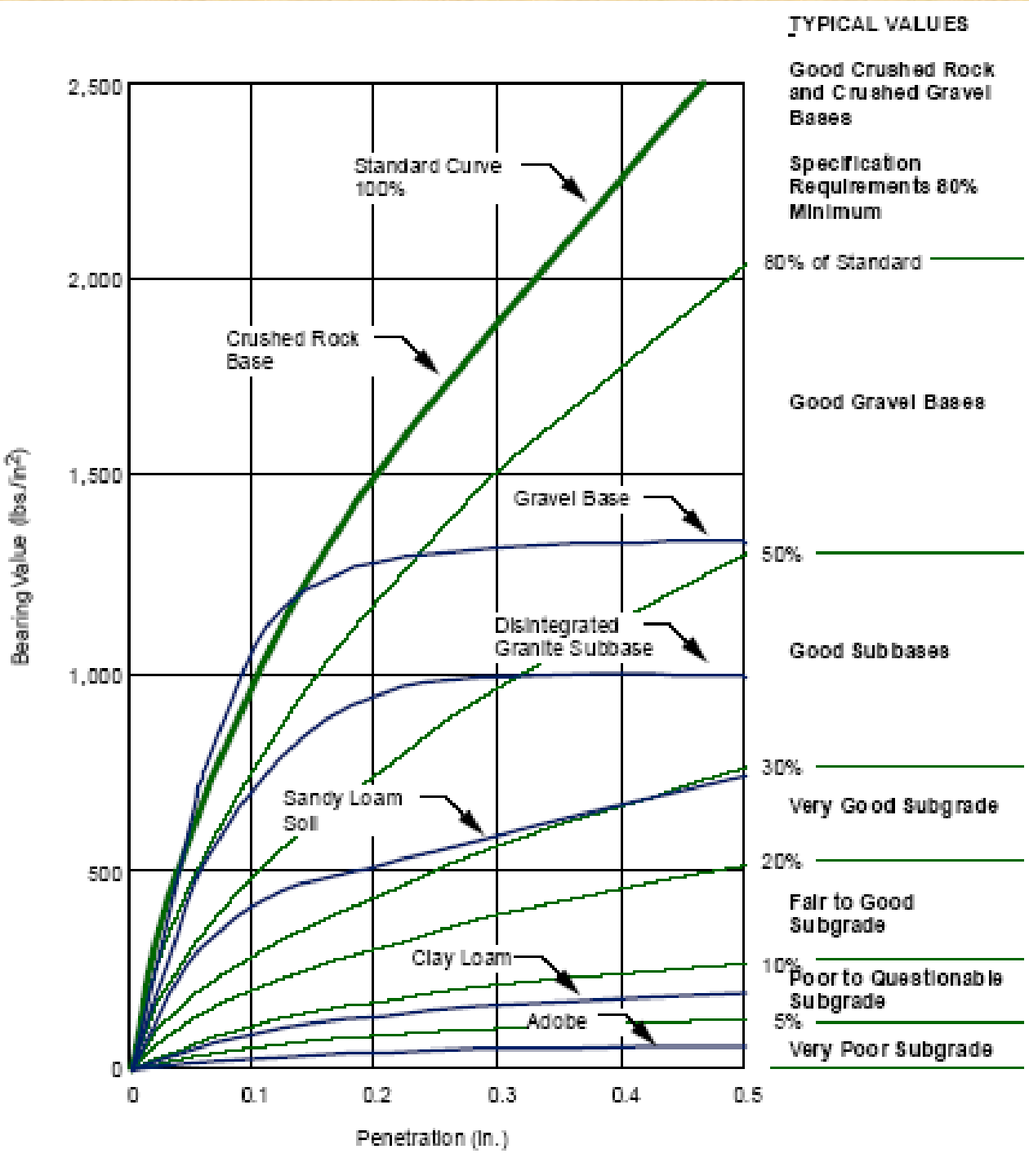
Standard Test Methods

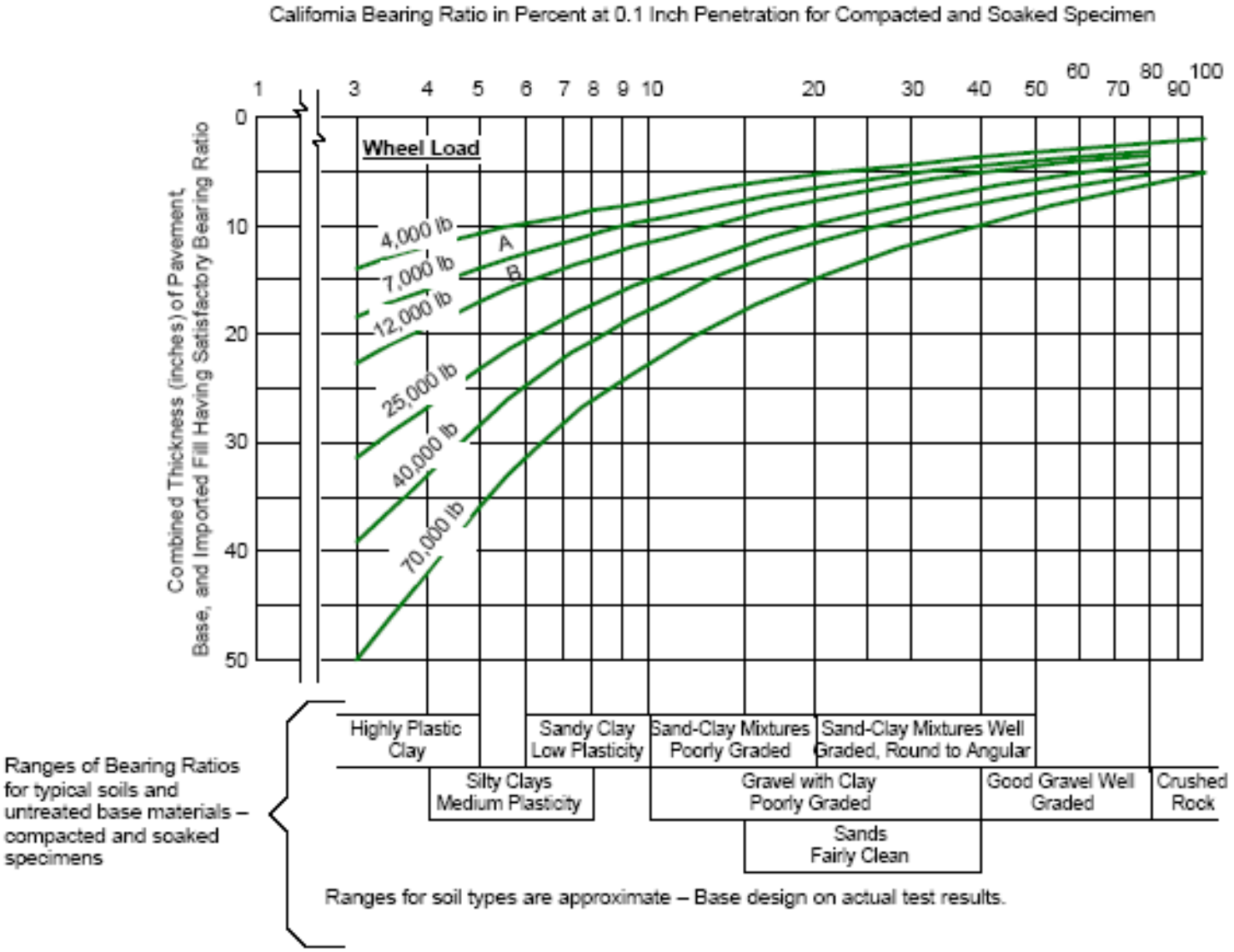
- AASHTO T193: The California Bearing Ratio
- ASTM D1883: Bearing Ratio of Laboratory Compacted Soils

$CBR_{0.1"}$ = Load required for 0.1" penetration of plunger (lb.) / 3000

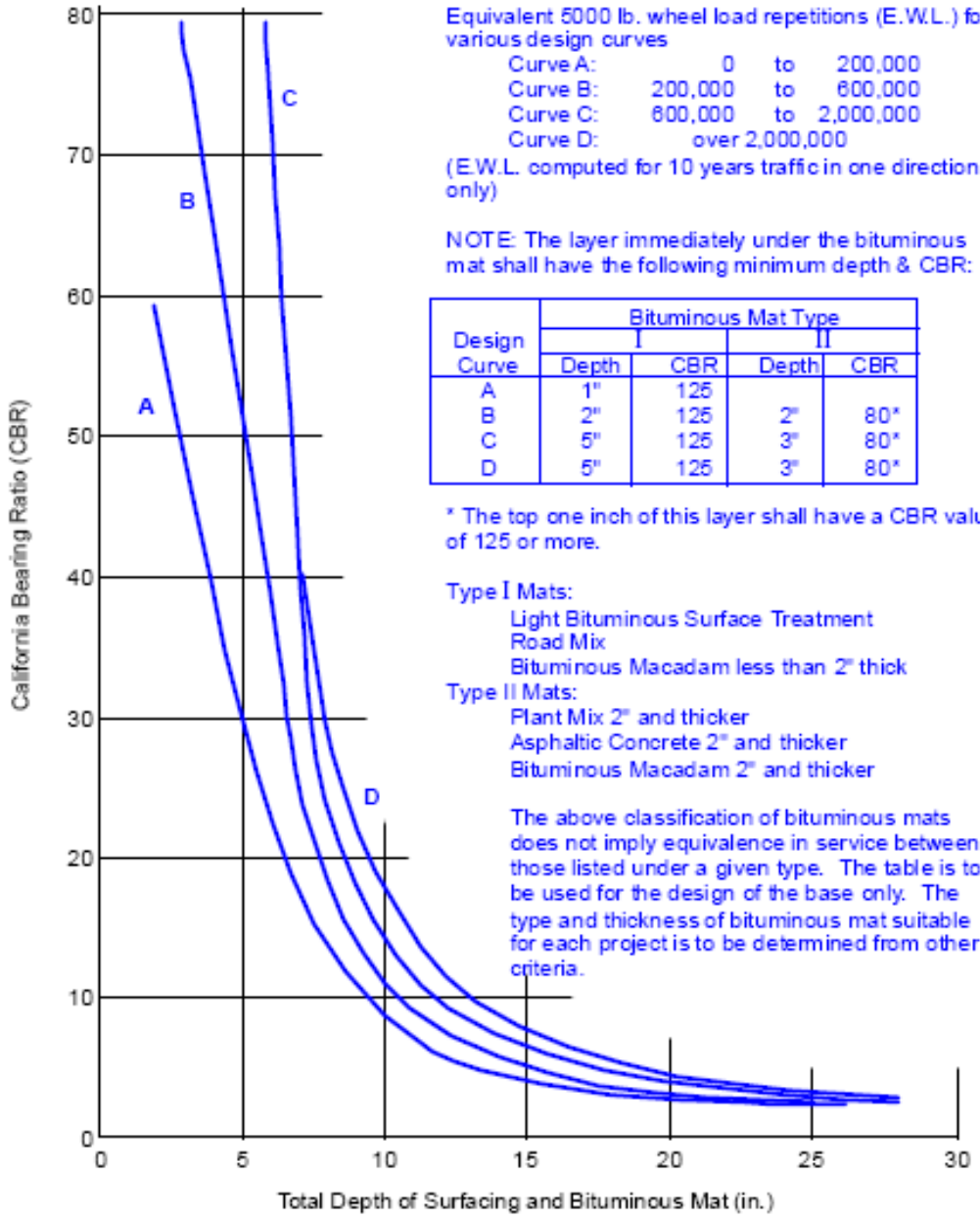
$CBR_{0.2"}$ = Load required for 0.2" penetration of plunger (lb.) / 4500

- Higher of the two values will be used for design
- Usually $CBR_{0.1"} > CBR_{0.2"}$


TYPICAL VALUES
Good Crushed Rock and Crushed Gravel Bases
Specification Requirements 80% Minimum
80% of Standard
Good Gravel Bases
50%
Good Subbases
30%
Very Good Subgrade
20%
Fair to Good Subgrade
10%
Poor to Questionable Subgrade
5%
Very Poor Subgrade
Standard Curve 100%
Crushed Rock Base
Gravel Base
Disintegrated Granite Subbase
Sandy Loam Soil
Clay Loam
Adobe
Bearing Value (lbs/in²)
2,500
2,000
1,500
1,000
500
0
0
0.1
0.2
0.3
0.4
0.5
Penetration (In.)


California Bearing Ratio in Percent at 0.1 Inch Penetration for Compacted and Soaked Specimen
1
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
Combined Thickness (inches) of Pavement, Base, and Imported Fill Having Satisfactory Bearing Ratio
Wheel Load
4,000 lb
7,000 lb
12,000 lb
25,000 lb
40,000 lb
70,000 lb
A
B
Highly Plastic Clay
Sandy Clay Low Plasticity
Sand-Clay Mixtures Poorly Graded
Sand-Clay Mixtures Well Graded, Round to Angular
Silty Clays Medium Plasticity
Gravel with Clay Poorly Graded
Good Gravel Well Graded
Crushed Rock
Sands Fairly Clean
Ranges of Bearing Ratios for typical soils and untreated base materials – compacted and soaked specimens
Ranges for soil types are approximate – Base design on actual test results.

SURFACING DESIGN CURVES



Equivalent 5000 lb. wheel load repetitions (E.W.L.) for various design curves

Curve A:	0	to	200,000
Curve B:	200,000	to	600,000
Curve C:	600,000	to	2,000,000
Curve D:	over 2,000,000		

(E.W.L. computed for 10 years traffic in one direction only)

NOTE: The layer immediately under the bituminous mat shall have the following minimum depth & CBR:

Design Curve	Bituminous Mat Type I		Bituminous Mat Type II	
	Depth	CBR	Depth	CBR
A	1"	125		
B	2"	125	2"	80*
C	5"	125	3"	80*
D	5"	125	3"	80*

* The top one inch of this layer shall have a CBR value of 125 or more.

Type I Mats:
- Light Bituminous Surface Treatment
- Road Mix
- Bituminous Macadam less than 2" thick

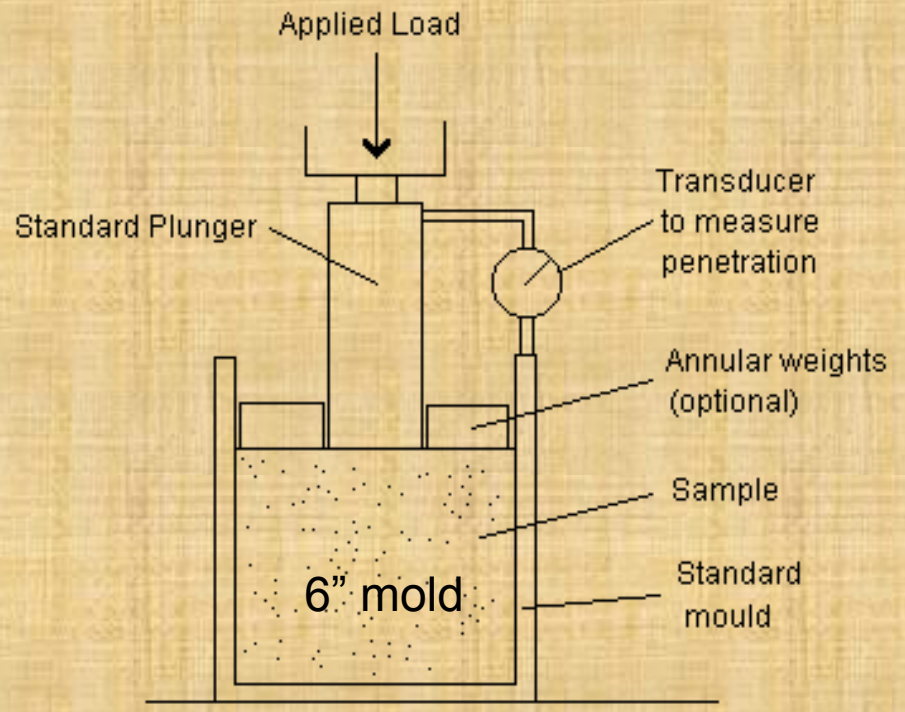
Type II Mats:
- Plant Mix 2" and thicker
- Asphaltic Concrete 2" and thicker
- Bituminous Macadam 2" and thicker

The above classification of bituminous mats does not imply equivalence in service between those listed under a given type. The table is to be used for the design of the base only. The type and thickness of bituminous mat suitable for each project is to be determined from other criteria.

Pavement Design

California Bearing Ratio (CBR)

"The Test"



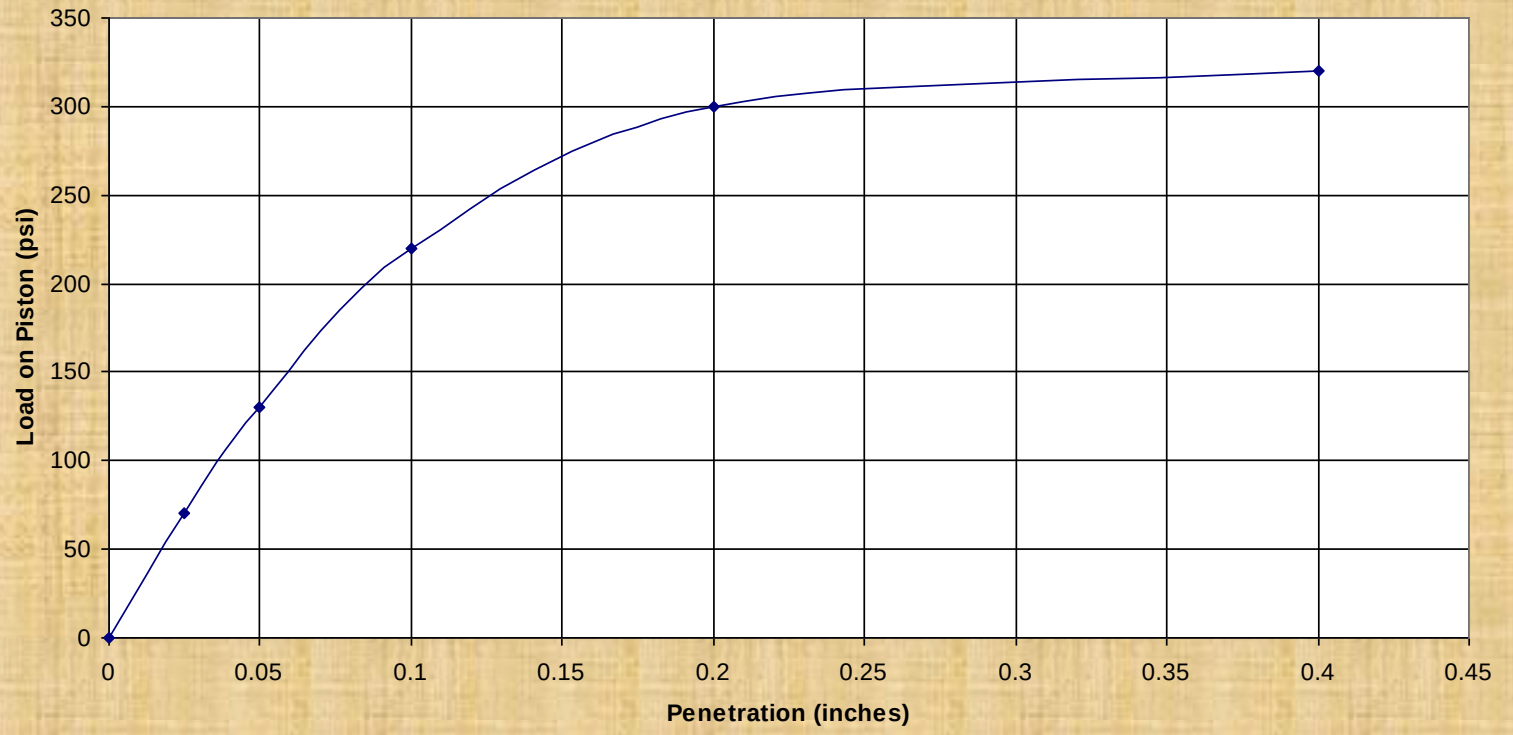
Take load readings at different penetrations

0.025" ……70 psi
0.05"……..130 psi
0.1"…….220 psi
0.2"…….300 psi
0.4"…….320 psi

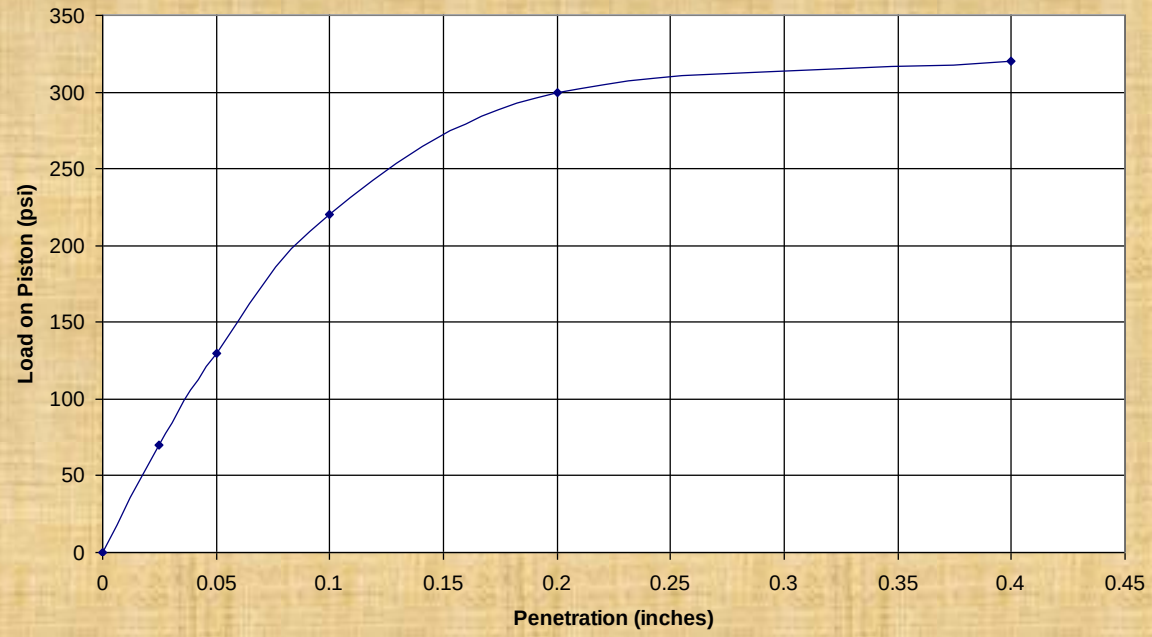
Penetrations of 0.05" per minute

Achieve OMC & Max. Dry Unit Wt.

Plot the Data:



Determine the CBR values for the 0.1” and 0.2”penetration.



“The Gold Standard” for CBR
for 0.1” of penetration, 1000 psi (3000 lb.)
for 0.2” of penetration, 1500 psi (4500 lb.)

Example above:
for 0.1” of penetration, 220 psi
for 0.2” of penetration, 300 psi

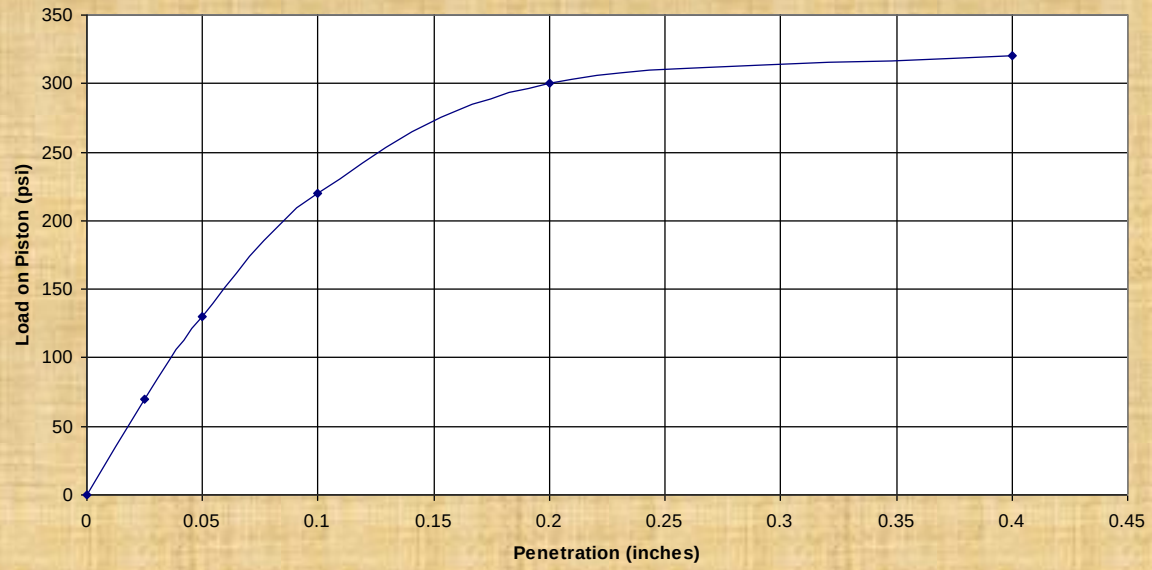
The standard material for this test is crushed California limestone

Actual load or pressure = CBR
Standard load or pressure

220 psi = 0.22, or 22%
1000 psi

300 psi = 0.20, or 20%
1500 psi

CBR of material = 22%



"The Gold Standard" for CBR
for 0.1" of penetration, 1000 psi
for 0.2' of penetration, 1500 psi

Example above:
for 0.1" of penetration, 220 psi
for 0.2" of penetration, 300 psi

Use 0.1" of penetration, unless 0.2" is the greater value.

- If so, then rerun the test, taking the higher of the two values from this second trial

Actual load or pressure = CBR
Standard load or pressure

220 psi = 0.22, or 22%
1000 psi

300 psi = 0.20, or 20%
1500 psi

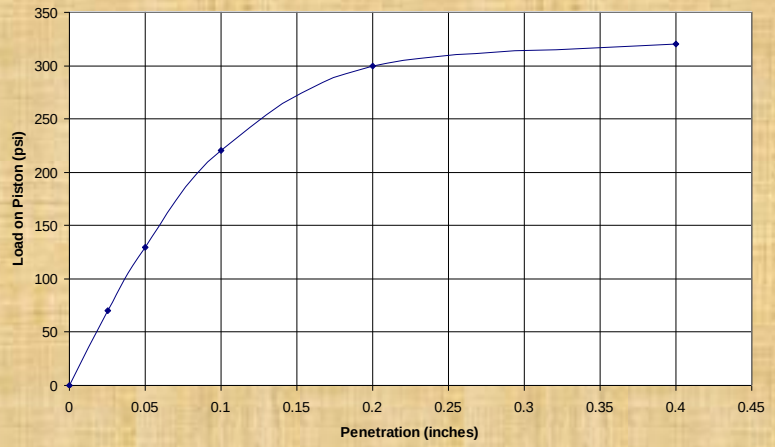
CBR of material = 22%,
or "22"

In General:
- The harder the surface, the higher the CBR rating.
- A CBR of 3 equates to tilled farmland,
- A CBR of 4.75 equates to turf or moist clay,
- Moist sand may have a CBR of 10.
- High quality crushed rock has a CBR over 80.
- The standard material for this test is crushed California limestone which has a value of 100.

"The Gold Standard" for CBR
for 0.1" of penetration, 1000 psi
for 0.2' of penetration, 1500 psi

Example above:
for 0.1" of penetration, 220 psi
for 0.2" of penetration, 300 psi

Potential Corrections to the Stress-Penetration Curves



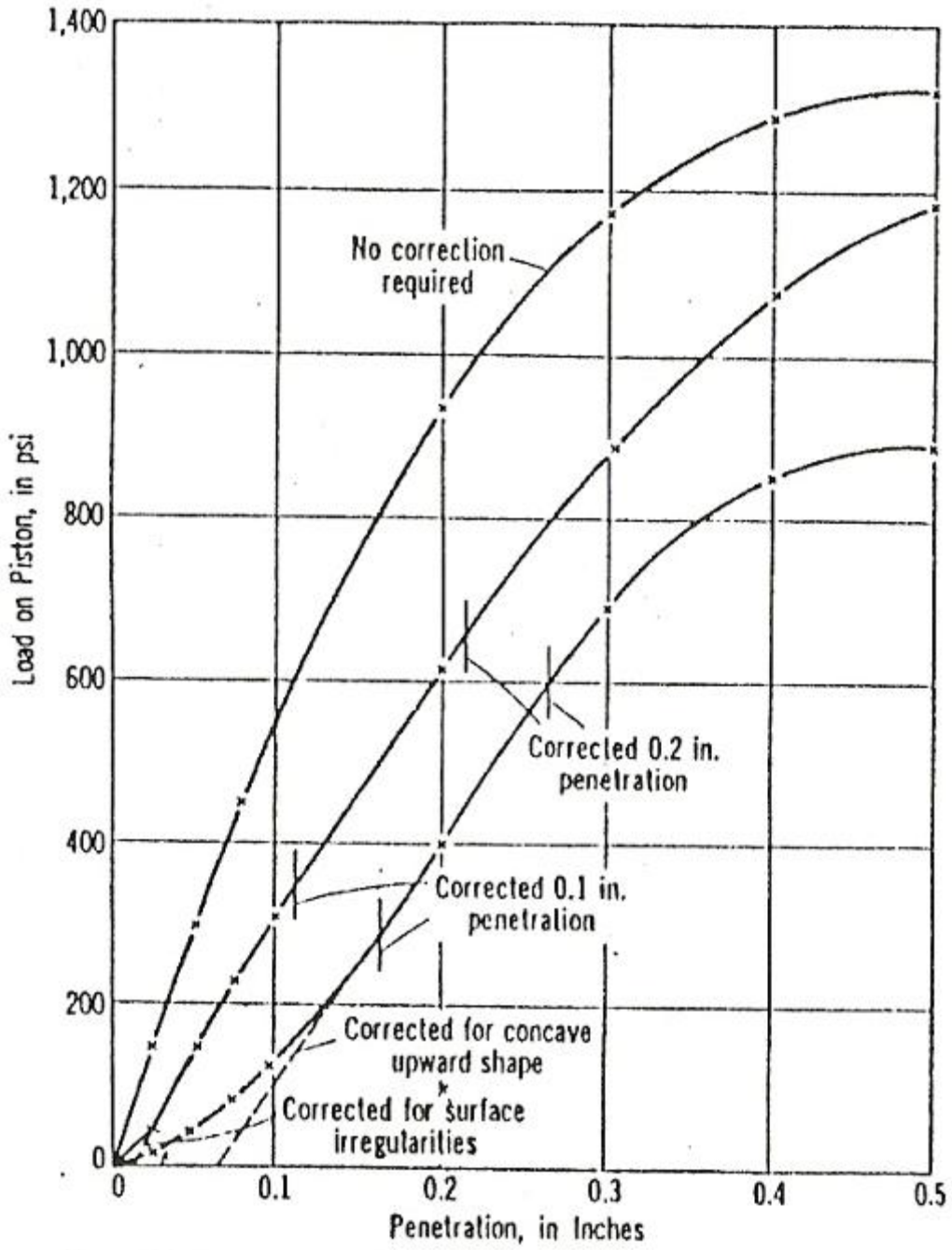
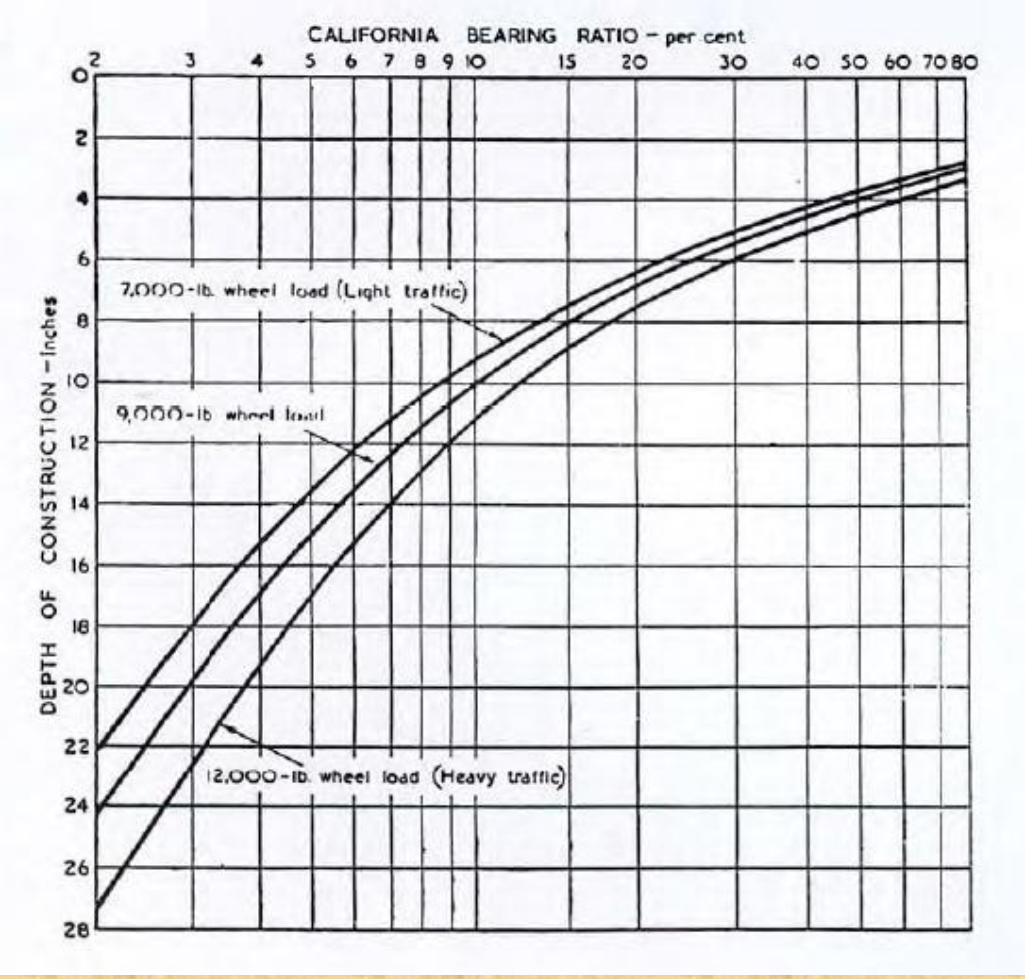


Fig. 16–5. Correction of Stress-Penetration Curves (Corps of Engineers)

Pavement Design

- CBR values of the subgrade
- Type of use expected
- Expected wheel load during service
- Types of materials available for the construction

Design Curves for Roads



Design Curves for Runways, Taxiways, Aprons etc.

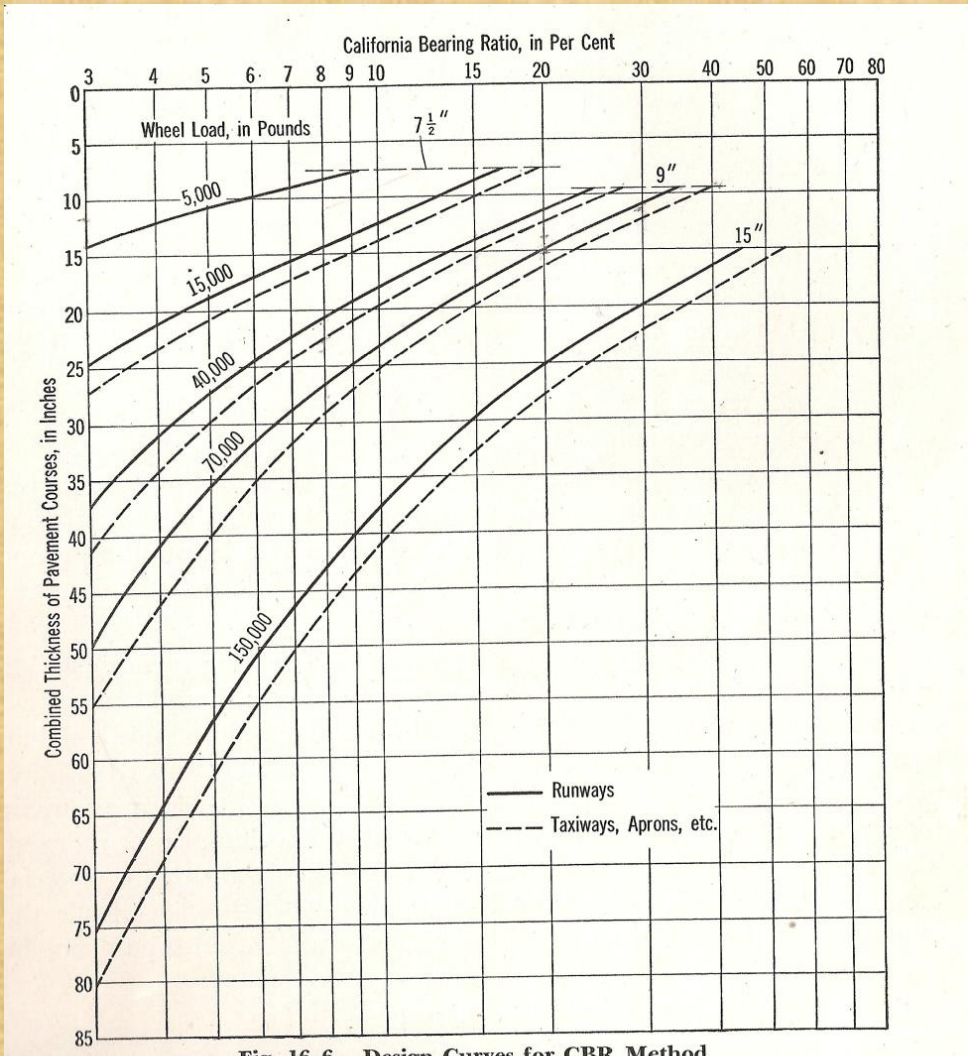


Fig. 16–6. Design Curves for CBR Method

wheel loads

Example

A compacted subgrade has a CBR value of 8. What is the minimum pavement thickness if it is to support a taxiway pavement designed to support a 80,000 lb. airplane (40,000 lb. wheel load)?

A point on the curve for a given CBR material represents the minimum thickness of pavement courses that will reside above it, in order to maintain stability

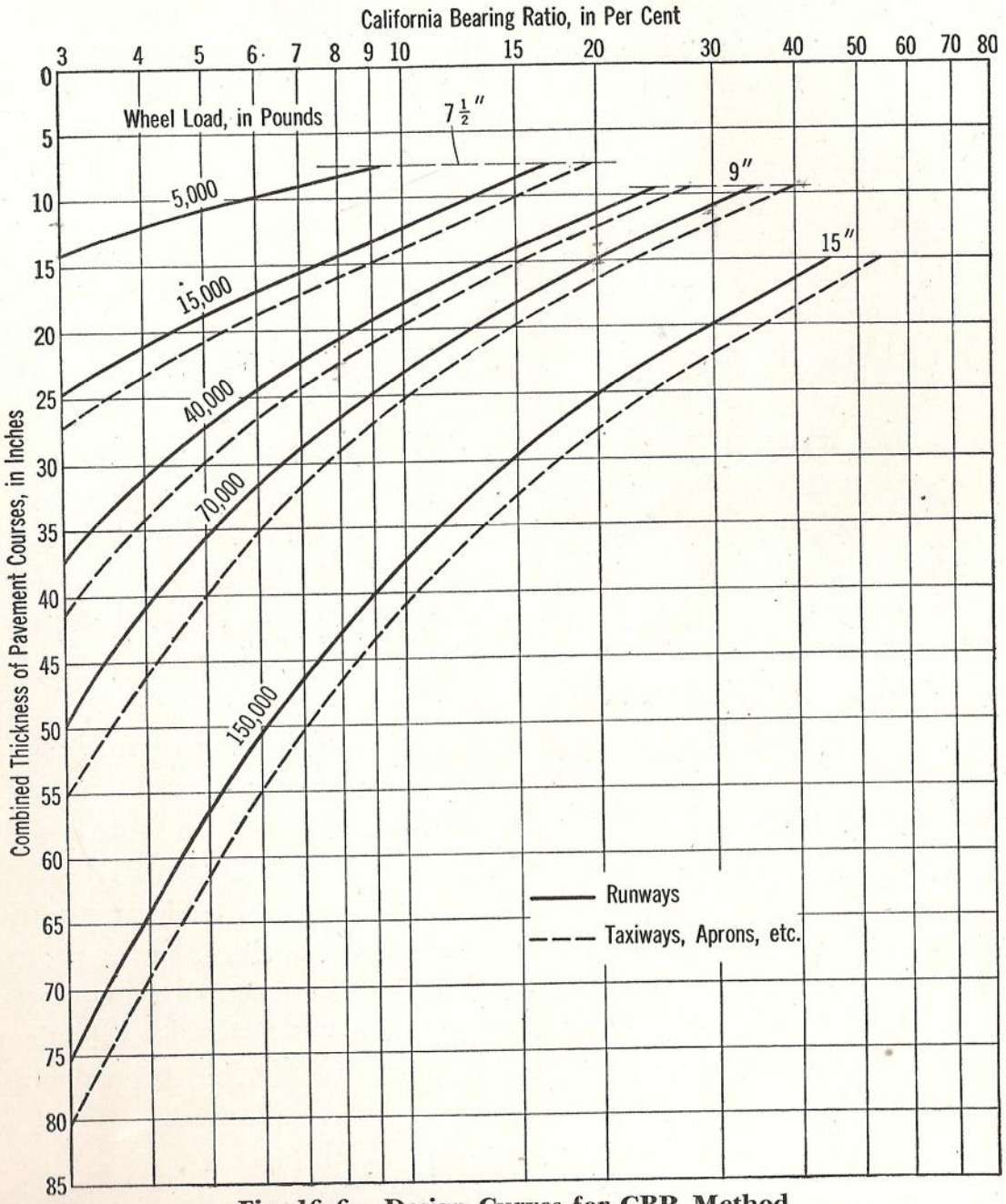


Fig. 16–6. Design Curves for CBR Method

wheel loads

CBR of subgrade = 8
(Taxiway)
Wheel load = 40,000 lb.

23 inches

Total thickness of construction = 23”

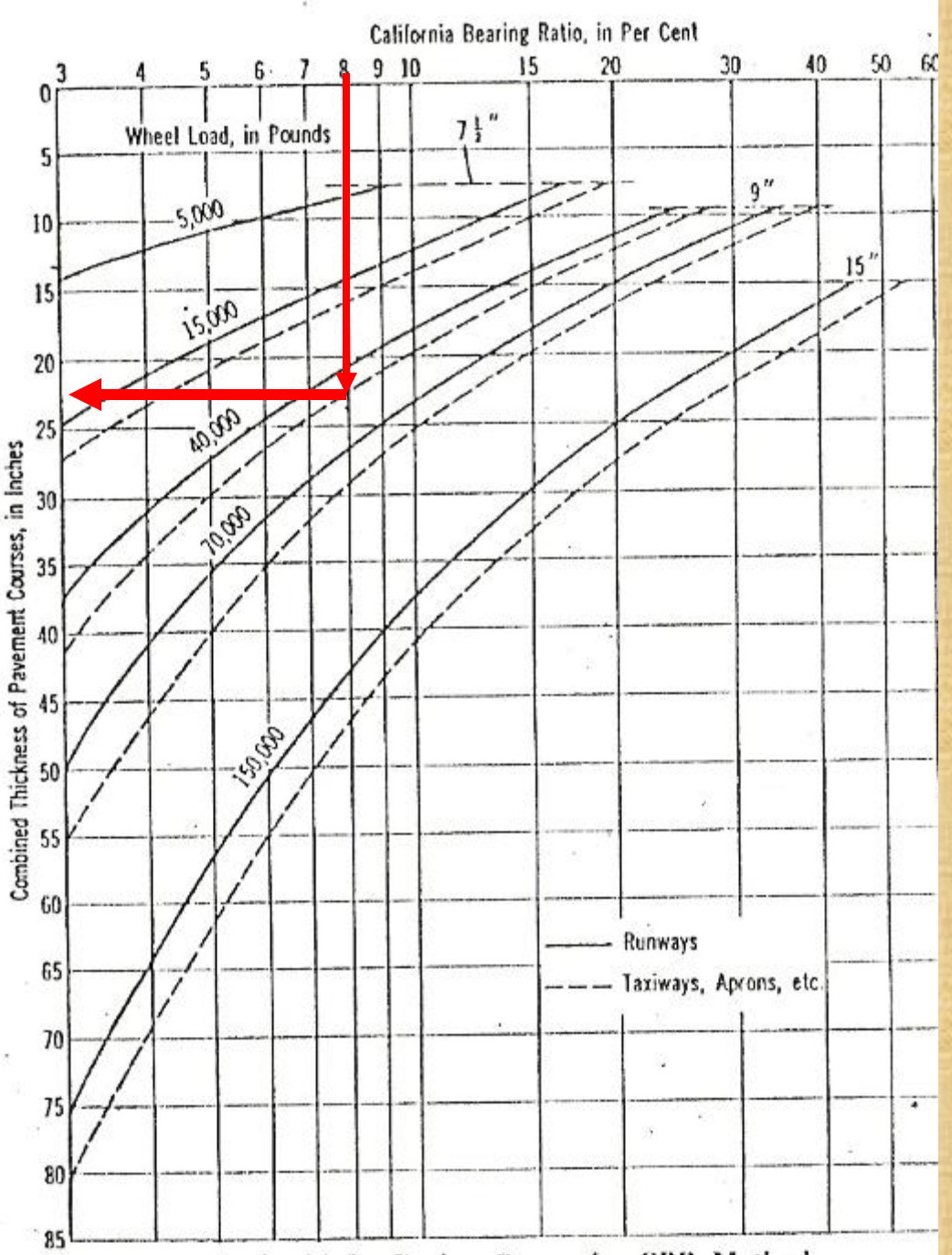


Fig. 16-6. Design Curves for CBR Method

wheel loads

Pavement Design

The Mechanics of the Design

A compacted subgrade has a CBR value of 8. What is the minimum pavement thickness if it is to support a taxiway pavement designed to support a 80,000 lb. airplane (40,000 lb. wheel load)? 23 inches

What is the optimal wearing surface thickness? 3 inches

What is the optimal CBR value of upper 6 inches of base? 6 inches of CBR 65/80

Wheel Loads	CBR Value
15k or less	50
>15k - 40k	65
>40k - 70k	80
>70k -150k	80+

Wearing Surface
0 -15k……..2”
>15k - 40k…..3”
>40k - 55k…..4”
>55k - 70k…..5”
>70k……..…6”

Typical Values of CBR

Material	CBR	Elastic Modulus (psi)
Crushed Stone (GW, GP, GM)	20 - 100	20,000 - 40,000
Sandy Soils (SW, SP, SM, SC)	5 - 40	7,000 - 30,000
Silty Soils (ML, MH)	3 - 15	5,000 - 20,000
Clayey Soils (CL, CH)	3 - 10	5,000 - 15,000
Organic Soils (OH, OL, PT)	1 - 5	< 5,000

Source: WSDOT Pavement Guide Interactive CD-ROM

Typical Values of CBR

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
	CL	≤ 15
	OL	≤ 5
	MH	≤ 10
	CH	≤ 15
	OH	≤ 5

Source: WSDOT Pavement Guide Interactive CD-ROM

Rating of Materials using CBR

California Bearing Ratio (%)	Rating
2 - 5	Very Poor Subgrade
5 - 8	Poor Subgrade
8 - 20	Poor to Fair Subgrade
20 - 30	Excellent Subgrade
30 - 60	Good Sub-base
60 - 80	Good Base
80 - 100	Best Base

Rating of Materials using CBR in Pakistan

California Bearing Ratio (%)	General Rating	Uses	Classification System	
			USCS	AASHTO
0 – 3	Very Poor	Subgrade	OH, CH, MH,OL	A5, A6, A7
3 – 7	Poor to Fair	Subgrade	OH, CH,MH, OL	A4, A5, A6, A7
7 – 20	Fair	Sub-base	OL, CL, ML, SC, SM, SP	A2, A4,A6, A7
20 – 50	Good	Base, Sub-base	GM, GC, SW, SM, SP, GP	A1-b, A2-5, A3, A2-6
> 50	Excellent	Base	GW, GM	A1-a, A2-4, A3