



NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE
(FEDERAL MINISTRY OF INNOVATION, SCIENCE AND TECHNOLOGY)

California Bearing Ratio (CBR)

INTERNATIONAL WORKSHOP ON
GLOBAL TRENDS IN DESIGN & CONSTRUCTION OF DURABLE ROAD
PAVEMENTS
(24TH TO 28TH NOVEMBER, 2025)

OVERVIEW OF CBR

- The California Bearing Ratio (CBR) is an empirical index that expresses the strength of a soil or aggregate material by comparing its resistance to penetration with that of a standard crushed rock.

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The test was developed in the 1920s by the California Division of Highways as a simple method to evaluate the load-bearing capacity of soils used in road and airfield construction. Over time, it became widely adopted globally due to its simplicity and strong correlation with pavement performance.

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CBR provides a direct measure of subgrade strength, which is critical for determining pavement layer thicknesses. A higher CBR value indicates a stronger material capable of supporting heavier traffic loads, making it an essential parameter in the design of flexible pavements.

CBR APPARATUS

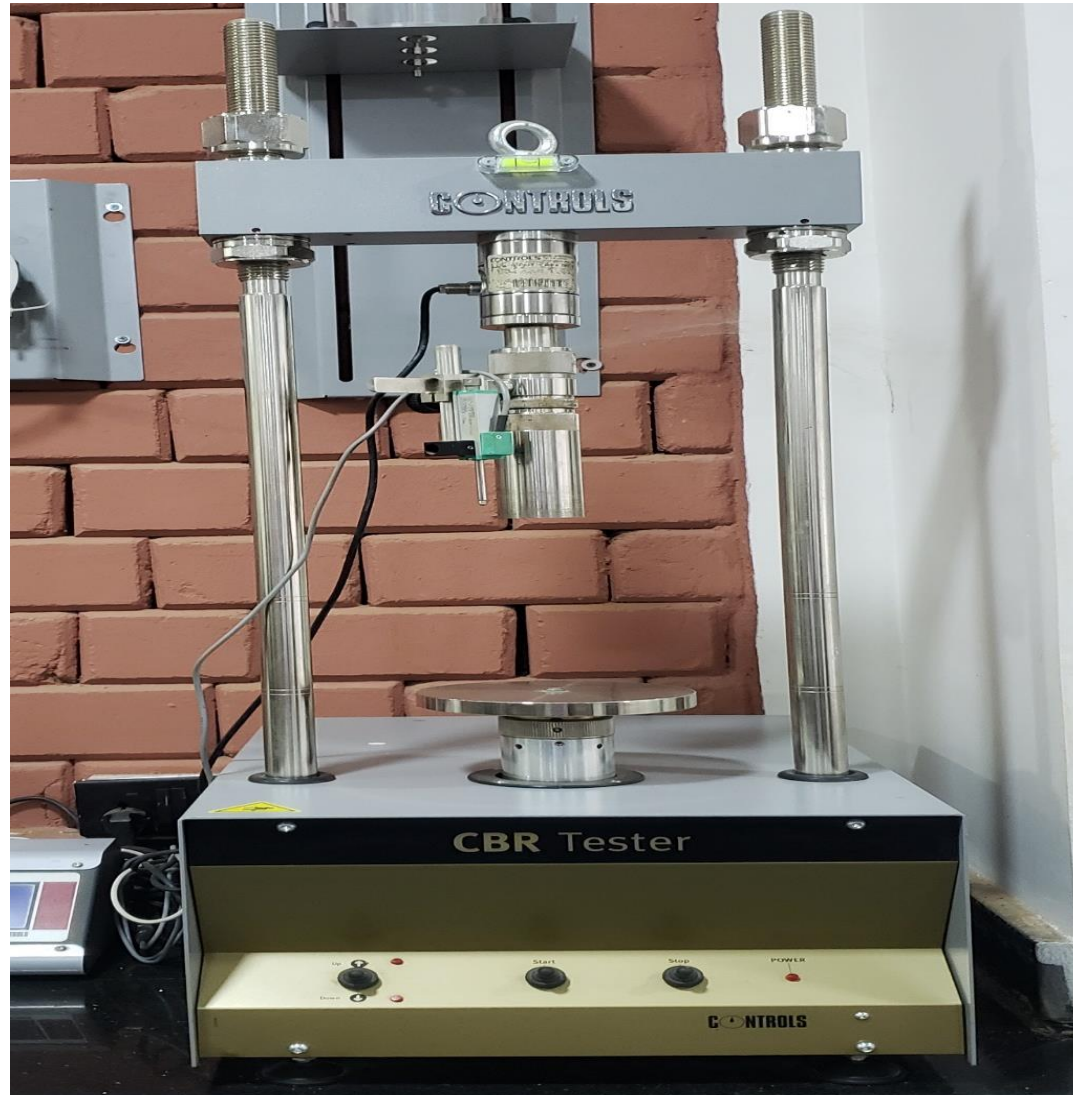


Plate I: Digital CBR Apparatus

PRINCIPLE OF THE CBR TEST

Penetration Resistance Compared to Standard Material

The CBR test measures the resistance of a soil sample to penetration by a standard plunger. This resistance is compared to the resistance of a well-graded crushed rock, which serves as the reference material.

Load–Penetration Relationship

During the test, load is applied to the plunger at a constant rate (1.27 mm/min), and the corresponding penetration is recorded. The resulting load–penetration curve is used to determine the load values at specific penetration depths.

Key Penetration Depths: 2.5 mm and 5.0 mm

CBR values are calculated at two standard penetrations, 2.5 mm and 5.0 mm. The higher of the two values is typically adopted as the CBR of the soil, unless the 5.0 mm value is atypically higher, indicating unusual soil behavior.

TYPES OF CBR TESTS

Laboratory CBR Test

Conducted under controlled conditions using compacted soil specimens. The test allows precise control of moisture content, compactive effort, curing, and soaking, providing reliable data for pavement design.

Field CBR Test

Performed directly on in-situ subgrade using a portable CBR apparatus. It provides quick estimations of subgrade strength without sampling or laboratory preparation, but results are more variable due to site conditions.

Soaked vs. Unsoaked Conditions

- *Soaked CBR*: The specimen is submerged for 4 days before testing. This simulates worst-case moisture conditions and is commonly used for pavement design.
- *Unsoaked CBR*: Tested at natural moisture content. Suitable for temporary works or when subgrade saturation is unlikely.

LABORATORY CBR SETUP

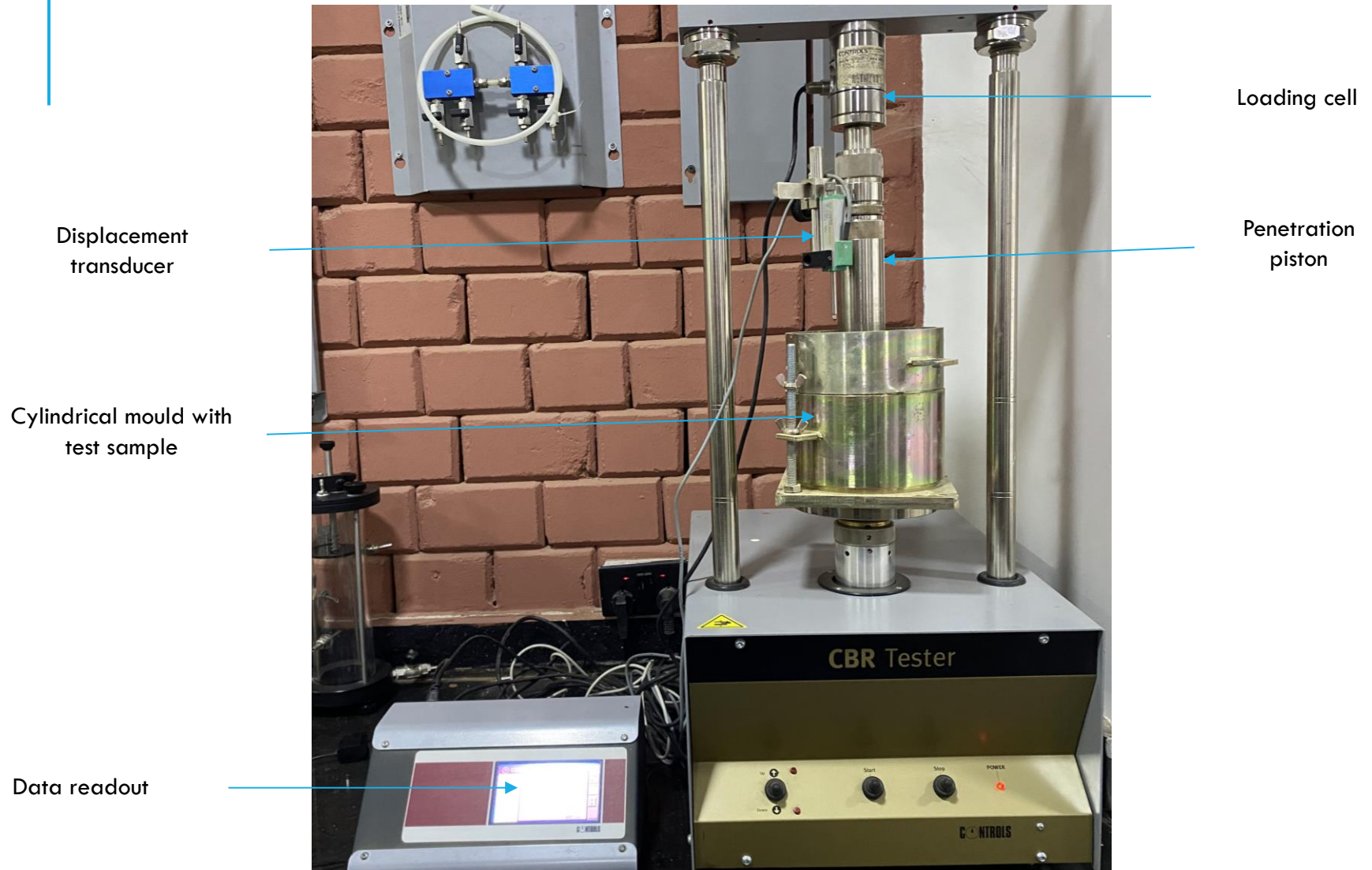


Plate II: Laboratory CBR setup

PREPARATION OF SOIL SAMPLE

Compaction: Proctor (Light/Heavy)

Soil is compacted using either the Standard Proctor (light compaction) or Modified Proctor (heavy compaction) method to achieve uniform density representative of field conditions.

Determination of OMC and MDD

The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are first established through compaction tests. These values guide moisture conditioning and compaction levels for preparing the CBR specimens.

Sample Curing and Soaking Procedures

After compaction, specimens may be cured for a specific period to allow moisture equilibrium. For soaked CBR tests, samples are submerged in water for 4 days with surcharge loads applied to simulate overburden pressure before penetration testing.



Plate III: Soil compaction for CBR test

TEST PROCEDURE

Placing Surcharge Weights

Appropriate surcharge weights are placed on the compacted specimen to simulate the overburden pressure that would exist in the field. This ensures the test conditions reflect actual pavement loading.

Penetration at 1.27 mm/min

A standard plunger is driven into the soil at a constant rate of **1.27 mm/min**, as specified by the test standard. This controlled penetration rate ensures uniform loading and reliable measurement of soil resistance.

Recording Load vs. Penetration Values

Throughout the test, the applied load corresponding to various penetration depths is recorded. These values are later used to generate the load–penetration curve and calculate CBR values at the standard 2.5 mm and 5.0 mm penetrations.

LOAD—PENETRATION CURVES

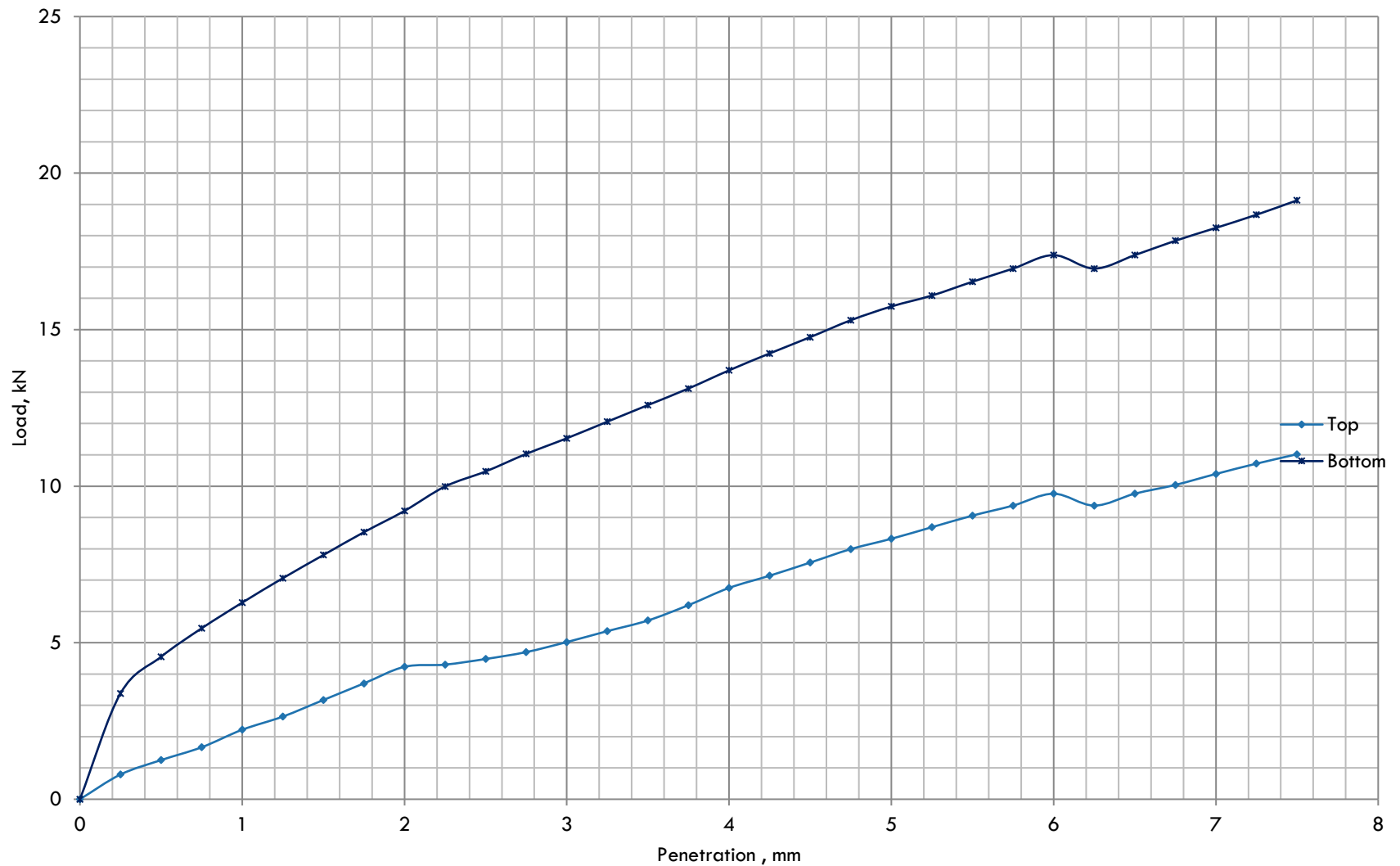


Figure 1: Typical load vs penetration graph

CALCULATION OF CBR VALUE

$$CBR (\%) = (Measured\ Load \div Standard\ Load) \times 100$$

- The CBR value is obtained by comparing the measured load on the soil sample at a given penetration with the standard load for high-quality crushed stone, then expressing it as a percentage.

- CBR values are calculated at the standard penetration depths of **2.5 mm** and **5.0 mm**. Both values are determined from the load–penetration curve.

- Typically, the **2.5 mm penetration value** is used as the CBR of the soil. However, if the **5.0 mm value is significantly higher**, it may be adopted instead indicating that the soil offers greater resistance at deeper penetration.

SAMPLE CBR RESULTS

CALIFORNIA BEARING RATIO TEST						
Test Method			BS 1377: Part 4: 1990: 7.2.3		Date	
Force measuring device		Load cell (50 kN cap)		Soaked/Unsoaked		soaked
Duration of Soaking: 96 hours				Mean calibration		
Penetration of plunger mm	Force on plunger		Penetration of plunger mm	Force on plunger		
	Top	Bottom		Top	Bottom	
0.00	0	0	5.25	7.56	13.98	
0.25	0.70	1.22	5.50	7.88	14.18	
0.50	1.11	1.73	5.75	8.16	14.37	
0.75	1.48	2.41	6.00	8.49	14.55	
1.00	1.98	3.04	6.25	8.16	14.8	
1.25	2.35	3.84	6.50	8.49	14.99	
1.50	2.82	4.76	6.75	8.73	15.19	
1.75	3.29	5.67	7.00	9.04	15.43	
2.00	3.76	6.6	7.25	9.33	15.55	
2.25	3.83	8.24	7.50	9.59	16.02	
2.50	3.99	8.95				
2.75	4.18	9.65				
3.00	4.47	10.71				
3.25	4.78	11.32				
3.50	5.08	11.75				
3.75	5.52	12.19				
4.00	6.01	12.5				
4.25	6.35	12.81				
4.50	6.73	13.12				
4.75	7.11	13.4				
5.00	7.40	13.69				
			CBR value at penetration of:			
			2.5mm	5.0mm		
	Top	%	30.21	37.02		
	Bottom	%	67.80	68.45		
	Accepted CBR	%	52.74			

FACTORS AFFECTING CBR

- **Moisture Content**

An increase in moisture generally reduces soil stiffness and strength, leading to lower CBR values—especially in fine-grained soils.

- **Dry Density**

Higher dry density improves particle interlocking and load-bearing capacity, resulting in higher CBR values.

- **Soil Type and Plasticity**

Clayey soils with high plasticity typically exhibit lower CBR values, while granular soils provide higher penetration resistance.

- **Compactive Effort**

Greater compactive effort increases dry density and reduces voids, thereby enhancing the CBR value. Heavy compaction (Modified Proctor) usually yields significantly higher CBR than light compaction.

APPLICATION IN PAVEMENT DESIGN

- **Subgrade Strength Classification**

CBR values are used to categorize subgrade soils into strength classes (e.g., very poor, poor, fair, good), which helps determine their suitability for pavement support.

- **CBR-Based Pavement Thickness Design**

Many pavement design methods (e.g., TRRL, IRC) directly relate required pavement layer thickness to the subgrade CBR value, ensuring adequate performance under traffic loads.

- **CBR Requirements for Different Traffic Categories**

Higher traffic volumes and heavier axle loads require subgrades with higher CBR values or improved subgrade layers. Typical requirements may range from 5% for low-volume roads to 10–15% for major highways.

LIMITATIONS OF THE CBR TEST

Not Fully Representative for Coarse-Grained Soils

The test is less reliable for gravelly or highly coarse materials where penetration is influenced by particle size rather than true strength.

May Not Capture Long-Term Loading Effects

CBR is a short-term static penetration test and does not simulate long-term cyclic or environmental loading.

Empirical Nature of the Method

CBR-based designs rely on empirical correlations that may not fully reflect modern pavement conditions, traffic patterns, or soil variability.

BEST PRACTICES

Ensure proper compaction and correct moisture conditioning of samples.

Accurately record load—penetration values at standard intervals.

Prefer soaked CBR tests for worst-case design scenarios to ensure conservative pavement design.



THANK YOU