iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: III Month of publication: March 2026

DOI: https://doi.org/10.22214/ijraset.2026.78860

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

Design and Construction of Flexible Pavement Using CBR Method: A Case Study

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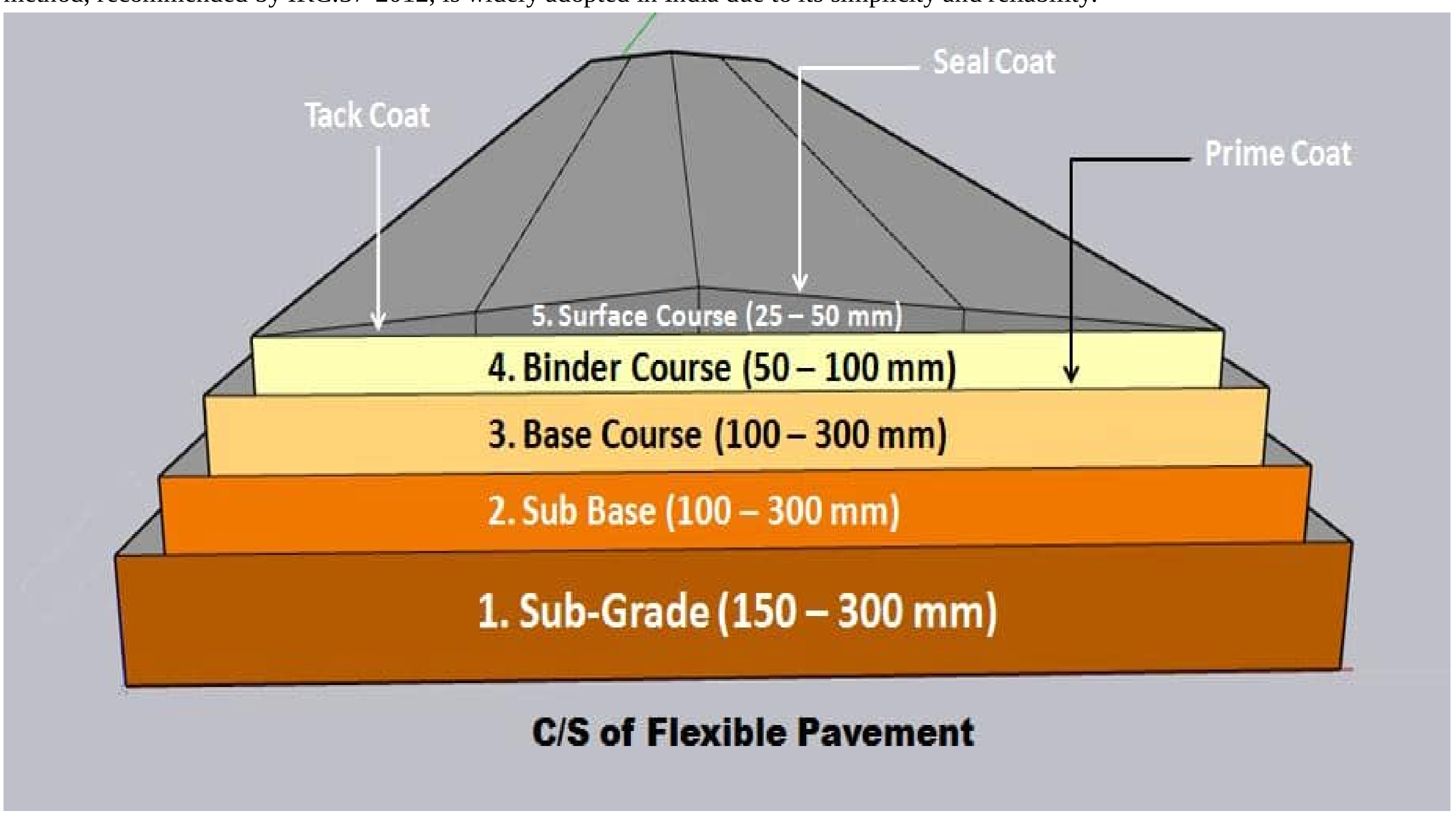
Abstract: Flexible pavements play a crucial role in modern transportation infrastructure due to their cost-effectiveness, ease of construction, and maintenance advantages. This study presents the design and construction methodology of a two-lane flexible pavement using the California Bearing Ratio (CBR) method in accordance with IRC:37-2012 guidelines. The work includes soil testing, traffic analysis, material selection, and layer thickness design. Laboratory tests such as Liquid Limit, Plastic Limit, Free Swell Index, and CBR were conducted to evaluate subgrade properties. Based on the obtained CBR value of 14.36%, suitable pavement layer thicknesses were determined. The study demonstrates the practical implementation of IRC guidelines and highlights the importance of proper material selection, compaction, and drainage for long-term pavement performance.

Keywords: CBR-(California Bearing Ratio), MORTH –(Ministry of Road Transport & Highways), WMM- (WET MIX MACADAM), AASHTO –(The American Association of State Highway and Transportation Officials), DBM- (Dense Bituminous Macadam), GSA- (Grain Size Analysis)

I. INTRODUCTION

Flexible pavement is widely used in highway construction due to its adaptability to varying subgrade conditions and cost efficiency. It consists of multiple layers including subgrade, granular sub-base (GSB), base course (WMM), and bituminous layers (DBM and BC). Each layer distributes vehicular load to lower layers, reducing stress intensity.

The design of flexible pavements is primarily based on traffic loading and subgrade strength. The California Bearing Ratio (CBR) method, recommended by IRC:37-2012, is widely adopted in India due to its simplicity and reliability.



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II. LITERATURE REVIEW

Jain et al. (2018) studied design methods for flexible and rigid pavements and emphasized cost-effective approaches. Prasad and Raju (2016) investigated flexible pavements on expansive soils and found that gravel sub-base performs better than fly ash. Kotak et al. (2017) highlighted the importance of traffic data and soil characteristics in pavement design. Ravinder (2019) discussed the use of cemented base and non-conventional materials in flexible pavement design.

These studies indicate that proper material selection and adherence to design guidelines significantly improve pavement performance.

adopted to know the required pavement thickness due to its easy and practical application. The traffic movement and subgrade soil characteristics need to be studied and required to design a pavement.

III. METHODOLOGY

The methodology adopted in this study includes:

1) Site selection and road alignment survey
2) Traffic volume study and design period (20 years)
3) Soil sampling and laboratory testing
4) Determination of CBR value
5) Pavement thickness design using IRC:37 guidelines

IV. MATERIALS USED

The following materials were used in pavement construction:

Soil (Subgrade)

Aggregates (GSB and WMM)

Bitumen (DBM and BC layers)

Cement and filler materials

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V. LABORATORY TESTS AND RESULTS

1) Liquid Limit Test

Liquid limit obtained = 24%

2) Plastic Limit Test

Plastic limit obtained = 11.85%

3) Plasticity Index

PI = 24 – 11.85 = 12.15%

4) Free Swell Index

FSI = 30%

5) California Bearing Ratio (CBR)

CBR at 2.5 mm = 14.36%

CBR at 5.0 mm = 11.13%

Design CBR value = 14.36%

Liquid Limit

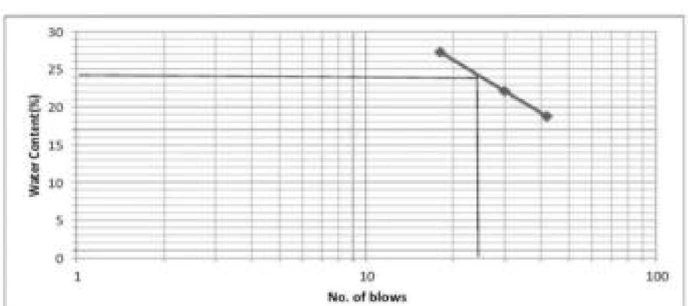
The water content at which measurable shearing strength is first apparent is called liquid limit and make the boundary between liquid state and plastic state. If the water content of the soil is steadily reduced further below the liquid limit soil volume and plasticity decreases.

Observations & calculations

Weight of soil sample taken = 150gm

S.No	Description	Sample 1	Sample 2	Sample 3	Sample 4
1	Weight of empty can, w1	10	10.5	11	11
2	Weight of the can + weight of dry soil, w2(g)	24	29.5	30	28
3	Weight of can + weight of dry soil, w3(g)	21	26	27	26
4	Water content, w(%)	27.27	22.1	18.75	13.33
5	No. of blows as observed, n	18	30	42	65

Graph



Graphical Representation of Liquid Limit Test From graph

Water content corresponding to 25 blows=24% Therefore,the liquid limit is 24%

Plastic Limit

It is water content below which the soil stops behaving as a plastic material. It begins to crumble when rolled into threads of 3 mm diameter.

At this water content, the soil loses its plasticity and passes a semi solid state.

Observation & Calculations

The Plastic Limit (average of 3 determinations) = 11.85%

Plasticity Index

Plasticity index is the main property that is to be determined for a soil before using the soil to any type of work. Generally for gravel it can be allowed upto 18 or 20.

But for highway construction it should be less than this is the difference of liquid limit and plastic limit. So there is no further experimentation for this.

Plasticity index of soil, IP = 24 – 11.85 = 12.15%

Free Swell Index

This parameter gives the swelling property of the soil. Free Swell Index (F.S.I) = ((Va-Vk)/Vk)*100

Observation & Calculation

Sl.N0	Determination No	1	2
1	Mass of dry soil passing 425µ (gm)	10	10
2	Volume of water in 24hrs swell (cc)	13	13
3	Volume of kerosine after 24hrs (cc)	10	10
4	Free swell index ((Va-Vk)/Vk)*100 (%)	30	30
5	Average (%)	30%	

California Bearing Ratio Test

This is a penetration test developed by the California Division of Highways, as a method for evaluating the stability the stability of soil sub grade and other flexible pavement materials. The test results have been correlated with flexible pavement thickness requirements for highways and air fields. The CBR test maybe conducted in the laboratory on a prepared specimen in a mould or in situ in the field.

Determination	1	2	3
weight of container (W0)	11	10	11
weight of container + wet soil (W1)	15	16	17.5
Weight of container + dry soil (W2)	14.5	15.4	16.9
Weight of water(w1-w2)	0.5	0.6	0.6

Weight of oven dry soil (W2-W0)	3.5	5.4	5.9
Water content W=(W1-W2\W2-WO) x 100	14.28	11.11	10.16

The Standard Load Values	Standard Load (kg)	Unit Standard Load
Penetration (mm)		(kg/sq.cm)
2.5	1370	70
5.0	2055	105
10.5	2630	134
10	3180	162
12.5	3600	183

CBR value is calculated by the formula,
CBR = [(Load sustained by specimen at defined penetration level)/(Load sustained by sustained crushed stone at same penetration level)]*100
Observations & Calculations

S.NO	Penetration (mm)	roving Ring Reading	Load on plunger(kg)
1	0.5	0.8	42.56
2	1.0	1.6	85.12
3	1.5	2.4	127.68
4	2.0	3.2	170.24
5	2.5	3.7	196.84
6	3.0	3.8	202.16
7	3.5	3.9	207.48
8	4.0	4.0	212.8
9	4.5	4.2	223.44
10	5.0	4.3	228.76
11	5.5	4.4	234.08
12	6.0	4.6	244.72
13	6.5	4.8	255.36
14	7.0	5.0	226.0
15	7.5	5.1	271.32
16	8.0	5.2	276.64
17	8.5	5.3	281.96
18	9.0	5.4	287.28
19	9.5	5.4	287.28
20	10.0	5.5	292.60

CBR2.5 = (196.84/1370)*100 = 14.36% CBR5.0 = (228.76/2055)*100 = 11.13% Graph

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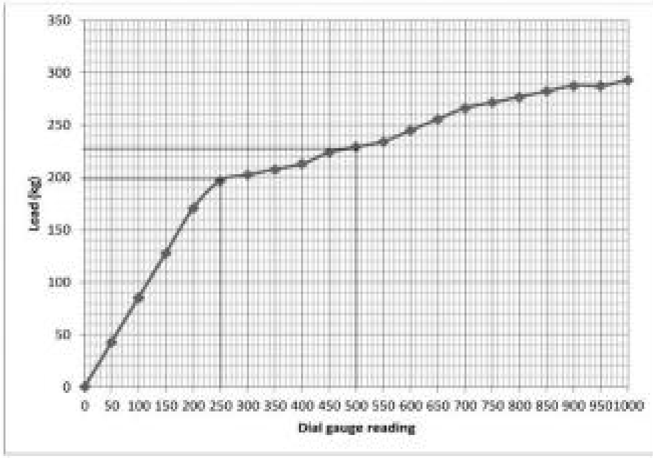

The CBR value of soil sample = 14.36%.

Penetration Test On Bitumen

The penetration test measures the consistency and stability of pure bitumen, oxidized bitumen(blown bitumen), and the residue of emulsion bitumen.

Relevant Indian Standard for Penetration Test on Bitumen:

IS 1203-1978 Edition 2.2 (1989-03): Methods for Testing Tar and Bituminous Materials

VI. PAVEMENT DESIGN

Based on IRC:37-2012 guidelines and CBR value, the pavement structure is designed as follows:

Subgrade = 500 mm

Granular Sub-Base (GSB) = 250 mm

Wet Mix Macadam (WMM) = 250 mm

Dense Bituminous Macadam (DBM) = 75 mm

Bituminous Concrete (BC) = 45 mm

VII. CONSTRUCTION PROCEDURE

The construction process includes:

Clearing and grubbing

Earthwork excavation

Embankment construction

Subgrade preparation

GSB layer laying and compaction

WMM layer construction

Prime coat application

DBM layer laying

Tack coat application

BC layer laying

Seal coat application

Proper compaction and moisture control were ensured at each stage.

VIII. EQUIPMENTS USED IN THE CONSTRUCTION

Excavators

Excavators are heavy equipment consisting of boom, stick, bucket and cab on a rotating platform house. Three types of excavators are used. Excavator

Dumpers

Dumpers are used for transportation of bulk materials such as sand, gravel and dirt. A dump truck consists of hydraulically operated open-box bed hinged at the rear, the front of which can be lifted to allow the contents to be deposited on the ground behind the truck at the site of delivery.

Road Roller

Road Roller is used for compaction of soil, gravel, concrete in the construction of roads. The rollers are used to thoroughly compact the materials and they do

not come too loose. Rollers have diesel engine, and a canop y to protect the driver, and a drum, the drum may be vibratory smooth or static smooth drum, to measure the level of compaction and water a compaction meter is provided.

Mechanical Paver

Mechanical paver is used to laying the bitumen on the roads. The bitumen mix is loaded into the mechanical paver through tipper Then it spreads on other side and lays The bitumen. This machine also helps in fixing the gradient of road on either side. Laying of bitumen through paver should ensure that no small lumps of aggregate or stone to be left over the surface. The standard width of paving is 8-12 ft (2.4-3.7). Mechanical paver also helps in partial compaction of bitumen on the surface of road.

Sprayer

Sprayer is usually known as bitumen distributor. A bitumen sprayer works as a controlling agent of the flow of bitumen and to spray the bitumen evenly on the road surface. This is mainly used for laying of prime coat, tack coat and seal coat. Spraying is generally made before the laying of hot mix bitumen on the road surface. The most basic quality of this sprayer is to store the bitumen in a tank, heat when requires and spray on the road easily

IX. RESULTS AND DISCUSSION

The CBR value of 14.36% indicates good subgrade strength suitable for flexible pavement construction. The designed pavement layers satisfy IRC requirements and ensure adequate load distribution.

The use of proper gradation in GSB and WMM layers improves stability, while bituminous layers provide durability and smooth riding surface. Adequate compaction and drainage significantly enhance pavement life.

X. CONCLUSION

This study demonstrates the design and construction of flexible pavement using the CBR method. The results show that:

CBR method is effective and practical for pavement design

Proper material selection and testing are essential

IRC guidelines ensure safe and durable pavement design

Quality construction practices improve pavement performance

Flexible pavement remains a sustainable and economical solution for road infrastructure, especially in developing regions.

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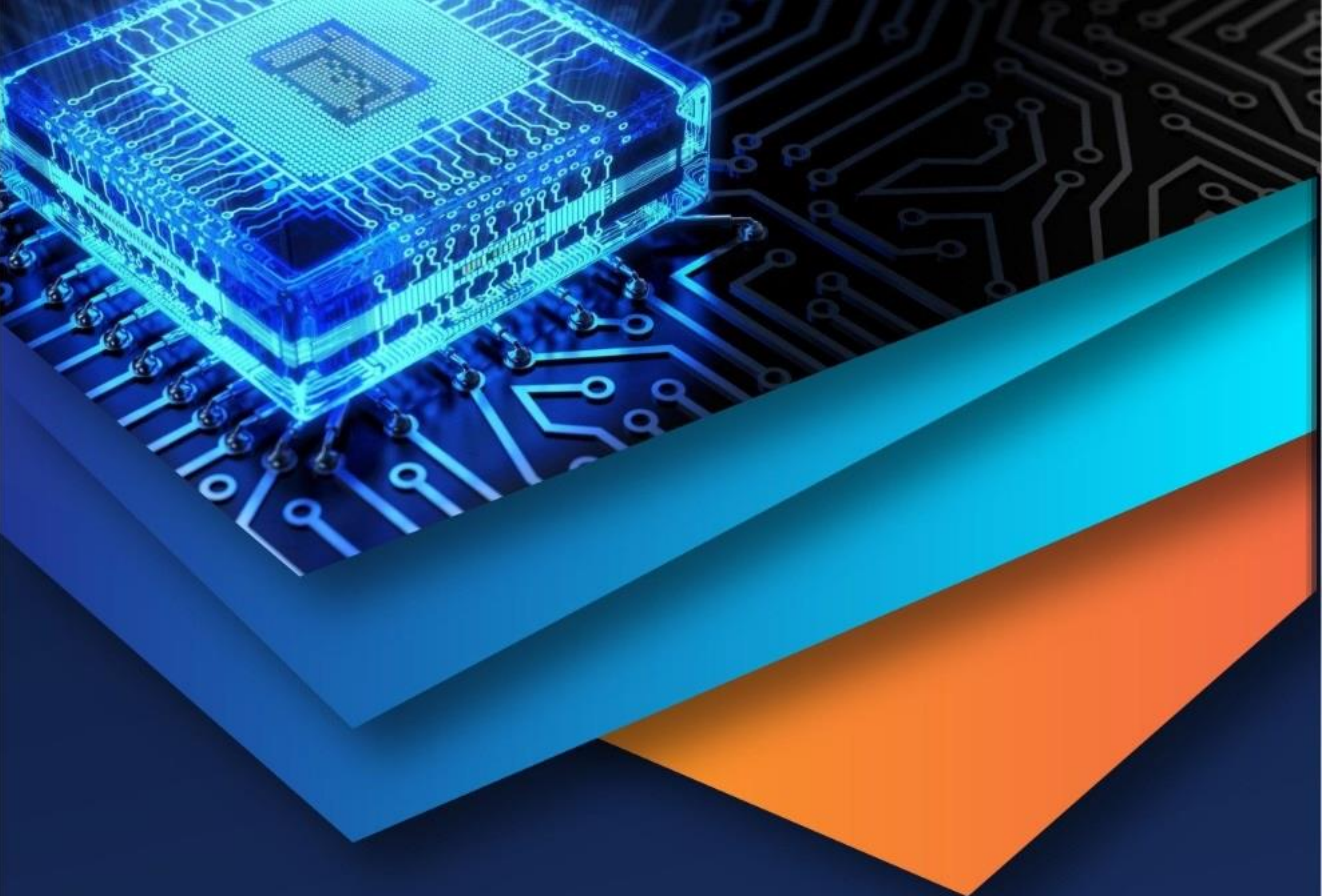

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