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DESIGN OF FLEXIBLE PAVEMENT BY CBR METHOD

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ABSTRACT
Highway and pavement design has a major part in the DPR projects. This paper discusses many practical considerations which are required before the construction of the pavement such as planning, geometrics, materials, and structural design of pavement, the design process to some extent as per the IRC's provision. In India, transportation system mainly is governed by Indian road congress (IRC). Currently, majority of the Indian roads are flexible pavements, the ones having bituminous layer/s.
As per IRC recommendation, California Bearing Ratio (CBR) value of sub grade is used for design of flexible pavements. CBR value of soil may depends on many factors like maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), free swell index of soil, type of soil, permeability of soil etc. Besides, soaked or unsoaked condition of soil also affects the value. These tests can easily be performed in the laboratory.
The California bearing ratio (CBR) is a penetration test for evaluation of mechanical strength of natural ground, sub grades and base courses beneath new carriageway construction. The CBR rating was developed for measuring the load-bearing capacity of soils used for building roads. In this study, attempts have been made to seek the values of CBR of soil sample and correlate the CBR value for the design purpose of flexible pavement as per guidelines of IRC: SP: 37-2001.
Keywords: Design of flexible pavement, California Bearing Ratio.

1. INTRODUCTION

Road transport is the only transport that provides door to door service to its customers. Road surface or pavement is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as a road or walkway. Road surfaces are frequently marked to guide traffic.
A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub- grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Basically, all hard surfaced pavement types can be categorized into two groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous (or asphalt) materials and a rigid pavement has concrete surface. This gives an overview of pavement types, layers and functions as well as the cost analysis. Most of the Indian highways system consists of flexible

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pavement; there are different methods of design of flexible pavement. The California Bearing Ratio (CBR) test is an empirical method of design of flexible pavement design. It was developed by the California Department of Transportation before World War II.

The basic site test is performed by measuring the pressure required to penetrate soil or aggregate 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. The CBR test is described in ASTM Standards D1883-05 (for laboratory-prepared samples) and D4429 (for soils in place in field), and AASHTO T193. The CBR test is fully described in BS 1377 : Soils for civil engineering purposes : Part 4, Compaction related tests, and in Part 9: In-situ tests.

The samples to be prepared at optimum moisture content (OMC) corresponding to the Proctor Compaction and soaked in water for a period of four days before testing. . It has been reported that, soaking for four days may be very severe and may be discarded in some cases. This test method is used to evaluate the potential strength of sub grade, sub base, and base course material for use in road and airfield pavements. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the sub grade strength which is most commonly expressed in terms of the California Bearing Ratio (CBR).With the CBR value of the soil known, the appropriate thickness of construction required above the soil for different traffic conditions is determined using the design charts, proposed by IRC. CBR value can be measured directly in the laboratory test in accordance with IS: 2720 (Part-XVI) on soil sample procured from the work site. Laboratory test takes at least 4 days to measure the CBR value for each soil sample under soaked condition. This test requires experience without which the results may be inaccurate.

CBR can also be used for measuring the load-bearing capacity of unimproved airstrips or for soils under paved airstrips. 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, while 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, meaning that it is not unusual to see CBR values of over 100 in well compacted areas.

2. EXPERIMENTAL DATA:

For checking the properties of the soil, reported different properties like Grain Size Analysis, free swell index, maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), etc.

COLLECTION OF MATERIALS

The material was obtained from an area where plenty amount of material is available for the construction purpose. The material which is collected for testing is different in quality and property, so that the material was separately tested in the laboratory so as to design the soil sub grade.

2.1 Grain Size Analysis (IS: 2720 - Part 4)

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This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles. The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.Dry method of sieving is used for coarser fractions (retained on 4.75 mm sieve) and wet method is used for finer fractions (retained on 75micron sieve) and pipette method is used for fractions passing 75 micron sieve.

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Figure1. Sieve Apparatus for Particle size analysis

2.1.1 Observation and Calculations:

Dry Sieving
Weight of sample = 2000gms.

IS Sieve Designation	Weight of sample	% Weight retained	Cumulative weight	% of weight passing
100m	-	-	0	100
75m	-	-	0	100
20m	-	-	0	100
4.75mm	48	4.6	4.6	95.
Pan	190			

Table No. 1: Sieve Analysis of Soil

2.1.2 Result:

% of gravel in soil sample = 4.6% (<10%)

2.2 Free Swell Index (IS: 2720- Part 40)

Free Swell Index is the increase in volume of a soil, without any external constraints, on submergence in water. Expansive soils are those soils, which tend to swell when they absorb moisture and shrink when they lose moisture in summers. In summer or dry seasons, polygonal desiccation, or "Shrinkage cracks", results. The swelling properties were determined based on the swelling pressure and free swell index tests. These test results are conforming the collected soil sample fall under swelling soil.

2.2.1 Observation and Calculations:

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S.No	Observati	
1.	Volume of sample in kerosene	11ml
2.	Volume of sample in water	16ml
3.	Free Swelling Index	=(vol. in water - vol. in kerosene) / (vol. in kerosene) *100

Table No. 2: Free Swell Index

2.2.2 Result:

Free Swelling Index from the test is found to be = 45.45%.

2.3 Liquid Limit, Plastic Limit and Plasticity Index (IS 2720- Part 5):

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit.

The Liquid and Plastic Limits of soil indicate the water contents at which certain changes in the physical behavior of soil can be observed. From Atterberg limits, it is possible to estimate the engineering properties of fine-grained soils. Plasticity is the property that enables a material to undergo deformation without noticeable elastic recovery and without cracking or crumbling. Plasticity is a major characteristic of soils containing an appreciable proportion of clay particles. Thus these tests are used widely in the preliminary stages of designing any structure to ensure that the soil will have the correct amount of shear strength and not too much change in volume as it expands and shrinks with different moisture contents.

OBSERVATION AND CALCULATIONS:

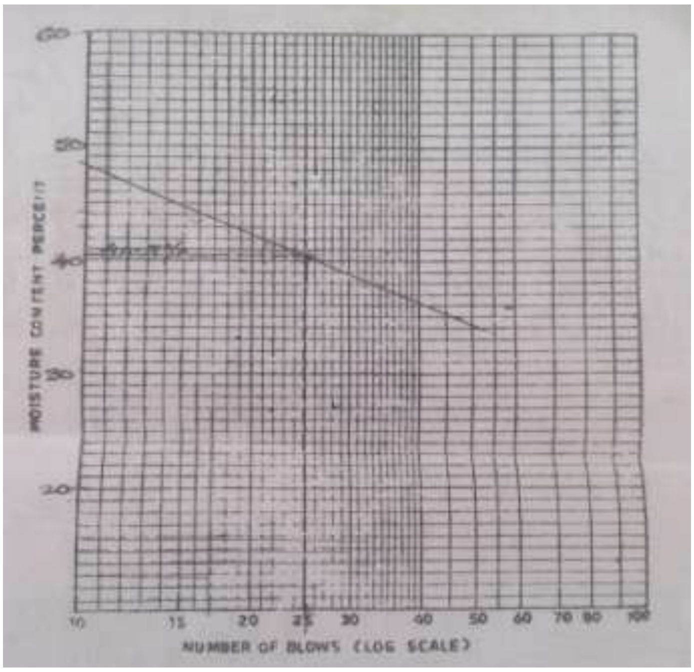
Determination of Liquid Limit (LL):

S.No.	Determination No.	1	2	3	4
1.	Wt. of container (gm)	13.843	15.033	14.370	14.625
2.	Weight of container + wet soil (gm)	46.770	47.53	47.920	47.760
3.	Weight of container + dry soil (gm)	37.180	37.270	37.740	37.23
4.	Wt. of dry soil (gm)	23.337	22.237	23.37	22.605
5.	Loss of Moisture (gm)	9.53	10.26	10.18	10.53
6.	Moisture content %	40.83	46.13	43.56	46.58
7.	Number of blows	39	27	33	23

Table No. 3: Determination of Liquid Limit

Result:

Moisture content at 25 blows from the graph



Liquid limit = 46.5 %

Determination of Plastic Limit (PL)

S.No.	Determination No.	1	2	3
1.	Wt. of container (gm)	15.321	15.285	14.825
2.	Weight of container + wet soil (gm)	36.920	39.895	38.350
3.	Weight of container + dry soil (gm)	32.580	34.835	33.685
4.	Wt. of dry soil (gm)	17.05	19.55	18.860
5.	Loss of Moisture (gm)	4.340	5.06	4.665
6.	Moisture content %	25.45% (M1)	25.88 % (M2)	24.73% (M3)

Table No. 4: Determination of Plastic Limit

Plastic Limit = [(M1) + (M2) + (M3)]/3
i.e. PL = [25.45+25.88+24.73]/3 = 25.35%

Plasticity Index (PI) = LL-PL = 45.6-25.35 = 20.25%

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2.4 Proctor Density (IS: 2720 – Part 7):

Compaction is the process of densification of soil mass by reducing air voids. The purpose of laboratory compaction test is so determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum, the amount of water is thus called the Optimum Moisture Content (OMC). In the laboratory different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.

2.4.1 Calculations:

1. Description of Sample = Yellow soil
2. Weight of Mould = 2310 gm
3. Volume of Mould = 1000 cc
4. % retained on 20mm I.S Sieve = Nil

Water Content											
Soil Sample No.	1		2		3		4		5		
Water Sample No.	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	
Wt. of Container(gm)=W_c	7.78	7.83	7.71	7.9	7.5	7.9	8.1	7.6	7.7	7.65	
Wt. of Container + wet soil(gm) = W_1	11.78	11.05	10.71	11.1	10.7	12	11.1	10.2	10.3	10.33	
Wt. of Container + dry soil(gm) = W_2	11.48	10.91	10.41	10.75	10.3	11.52	10.70	9.84	10.02	9.92	
Water content= $(W_2-W_1)/(W_1-W_c)$*	7.9	8.1	11.1	10.9	12.5	13.1	15.3	16.0	17.1	17.6	

Density

Determination No.	1	2	3	4	5	6
Assumed water content, w%	10	12	14	16	18	
Actual average water content, w%	8	11	12.8	15.65	17	
Weight of Mould + Compacted soil (gm)	3457.2	3721.2	3909.0	3782.5	3715.2	
Weight of Compacted soil (gm)	1524.2	1788.2	2176	2149	2082	
Bulk density (gm/cc) = W/(Mould Volume)	1.615	1.894	2.093	1.959	1.888	
Dry density (gm/cc) = Bulk density/(1+w)	1.50	1.71	1.86	1.69	1.61	

Results: (As per Graph Below)
1. Optimum moisture content = 12.8%
2. Maximum dry density = 1.86 gm/cc

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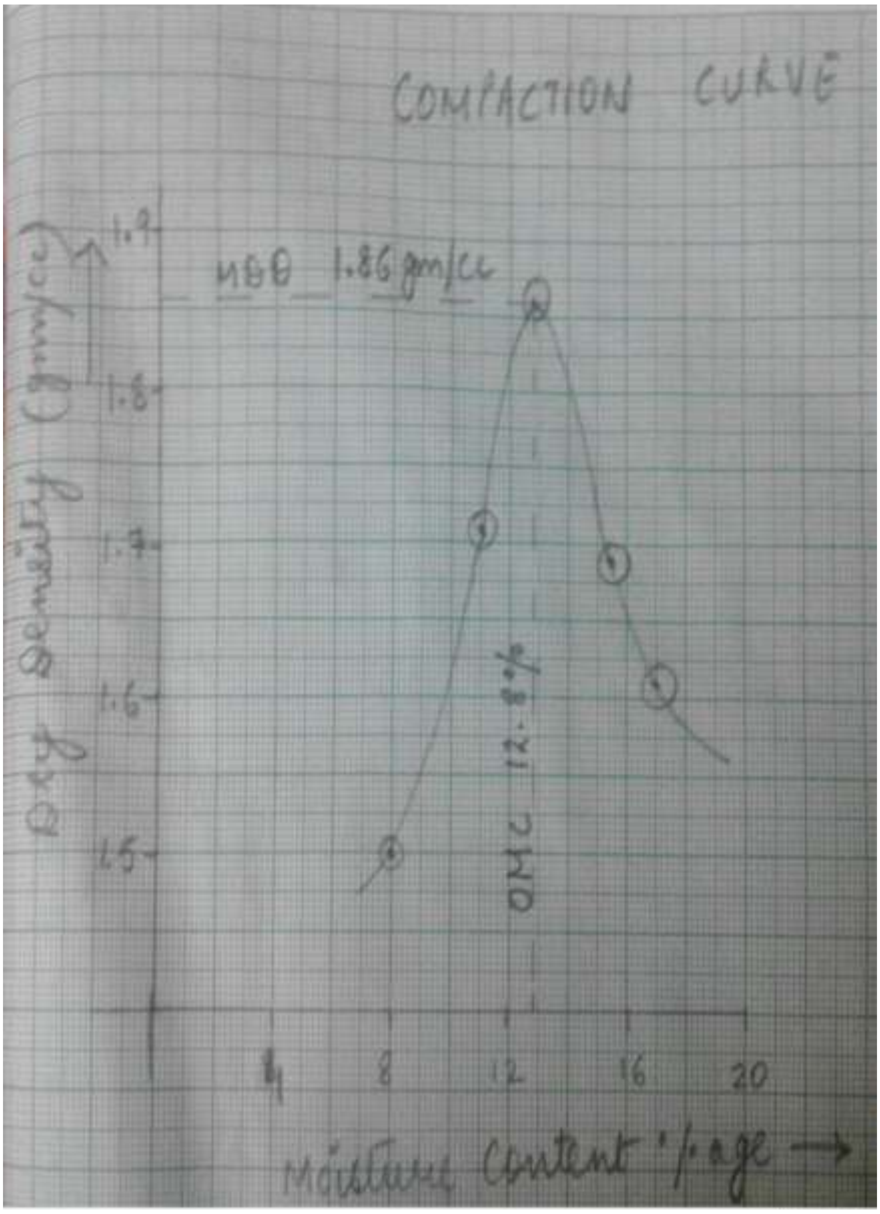

2.5 The California Bearing Ratio Test (IS: 2720 - Part 16)

Need and Scope

The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, subgrades and base courses beneath new carriageway construction.

It is the ratio of force per unit area required to penetrate into a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm / min. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

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2.5.1 CALCULATION (Case I – (Yellow soil (Clayey silt))

1. Sample = Yellow soil
2. Source of material =Quarry
3. Value of one Division of proving Ring = 2.5 Kg

Time of Penetration c/0.25 mm/min	**Penetration in mm**	**Proving ring Reading No. Divisions**			**Test load/Corrected load 3 × Value of One division in (kg)**			**Standard load in (kg) on Plunger area 19.64 cm2**	**Unsoaked /Soaked CBR % 4/5 × 100**			**Average CBR**
1	2	3			4			5	6			7
		I	II	III	I	II	III		I	II	III	
0.0	0.0											
0.24	0.5	9	10	10								
0.48	1.0	16	15	15								
1.12	1.5	21	20	18								
1.36	2.0	25	24	23								
2.0	2.5	28	28	27	70	70	67.5	1370	5.10	5.10	4.92	5.04%
2.24	3.0	31	31	30								
3.12	4.0	34	34	34								
4.0	5.0	38	37	37	95	97.5	92.5	2055	4.62	4.50	4.50	4.54%
6.0	7.5	43	42	44								
8.0	10.0	46	45	47								
10	12.5	48	47	49								

Table No. 5: Data sheet for CBR Test

Results

Average CBR – 2.5 mm Penetration = 05.04 %
Average CBR – 5.00 mm Penetration = 4.54 % **I**
2.5 mm Penetration CBR = Test load/ Standard load × 100% = (28×2.5/1370) × 100 = 5.10%
5 mm Penetration CBR = Test load/ Standard load × 100% = (38×2.5/2055) × 100 = 4.62%
II
2.5 mm Penetration CBR = Test load/ Standard load × 100% = (28×2.5/1370) × 100 = 5.10%
5 mm Penetration CBR = Test load/ Standard load × 100% = (37×2.5/2055) × 100 = 4.50%
III
2.5 mm Penetration CBR = Test load/ Standard load × 100% = (27×2.5/1370) × 100 = 4.92%
5 mm Penetration CBR = Test load/ Standard load × 100% = (38×2.5/2055) × 100 = 4.50%

Average CBR at 2.5 mm Penetration = (I+II+III)/3 = 5.04%

3. Design of Flexible Pavement as per IRC: 37-2001

A Flexible Pavement is being designed in accordance with the charts in IRC 37-2001.
The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design life for different sub-grade CBR values ranging from 2 % to 10%. The design charts will give the total thickness of the pavement for the above inputs. The total thickness consists of granular sub-base, granular base and bituminous surfacing.

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3.1 Design Wheel Load:
Urban traffic is heterogeneous. There is a wide spectrum of axle loads plying on these roads. For design purpose it is si1mplified in terms of cumulative number of standard axle (8160 kg) to be carried by the pavement during the design life. This is expressed in terms of million standard axles or msa.

3.2 Soil Sub Grade Data: C.B.R of soil sub grade = 5% Liquid limit = 46.5%

Plastic limit = 25.35% Plasticity index
(PI) = 20.25% O.M.C = 12.8%
Standard proctor density (gm/cc) = 1.86 gm/cc
Modulus of sub grade Reaction K – value =2.94 Kg/cm^2

DATA
1. According to the test results, the C.B.R. value of the sub-grade soil is found to be 5%.
2. Traffic Vehicle per day, as per survey done is found to be 300 CVPD.
3. Traffic growth rate, to be taken as 7.5% (assumed)
4. Vehicle Damage Factor, for plain terrain = 3.5 Standard Axle per CV

(As per Clause 3.3.4.4 Table 1 of IRC -37 -2001)

5. Design Life = 10 Years.

6. Design Calculations:
Now, the design traffic is considered by the following formula:

$N = 365 \times [(1+r)^{n} – 1] \times A \times D \times F/r$

Where,
N = Cumulative number of Standard axles to be catered in the design in terms of use.
A = Initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day. D = Lane distribution factor
F = Vehicle damage factor n = Design life in years
r = Annual growth rate of commercial vehicles (this can be taken as 7.5% if no data is available)

Calculations:
So, $N = 365 \times [(1+ 0.075)^{10} – 1] \times 550 \times 1 \times 3.5 / (0.075)$ N = 9.94 msa
(Million Standard Axle)

7. Total Pavement Thickness for design C.B.R. = 660 mm
(As per Plate – 1 of IRC-37-2001)
The thickness of individual component layers of flexible pavement by CBR method is given below: So pavement thickness =660mm
Thickness of surface course =40mm
Thickness of DBM =70mm Thickness of base course=250mm Thickness of sub base=300mm

4. Conclusions:

CBR is a widely used method to design the flexible pavements, beside all the limitations it is easy to perform and still does not need any big instruments etc. The value of CBR test is then compared with the following table to get the quantity of material from which the required thickness and other parameters are decided.

CBR VALUE	SUBGRADE STRENGTH	COMMENTS
3% and less	Poor	Capping required
3% - 5%	Normal	Capping considered according to road category.
5% - 15%	Good	Capping normally unnecessary except on very heavily

Pavement Thickness.

S.No	Description	Layers	Layers Thickness(mm)
1.	Soil with 5% CBR value	Granular Sub Base	300
2.		Base Coarse (WMM)	250
3.		DBM	70
4.		BC	40
Total			660

References:

1. IS 2720 Part-5 **"***Method of test for Soil-Determination of Liquid limit and Plastic limit".*
2. IS 2720 Part –8 **"***Method of test for Soil-Determination of Water Content, Dry density relation using a heavy Compaction & light compaction***"**.
3. Partha Chakroborty & Animesh Das **"***Principles of Transportation Engineering***"**Ministry of Road Transport and Highways Report of the Specifications for Road and Bridge Work in India
4. **"**Khanna .S.K & Justo C.E (March 2001)**"**, Highway Engineering, Nem Chand & Bros Publications, Roorkee (U.A), Eighth Edition.
5. IS 2720 Part-16 **"***Method of test for Soil-Laboratory determination of CBR***"**.
6. IRC-SP 37-2001, **"***Guidelines for the Design of Flexible Pavements***"** IRC, New Delhi
7. Brown, S.F. (1996) **"***Soil Mechanics in Pavement Engineering***"**. Geo technique, 46 (3), 383-426.
8. **"**Highway Material Testing**"**, lab manual by S.K. Khanna and C.E.G. Justo.
9. Bindra, S.P. 1991(IV–Edition). **"***A Course in Highway Engineering***"** 1991, Dhanpat Rai & Sons.
10. Roy T.K., Chattopadhyay B.C. and Roy S.K., (2006). **"***Prediction of CBR for Subgrade of Different Materials from Simple Test***"**. Proc. International Conference on 'Civil Engineering in the New Millennium – Opportunities and Challenges, BESUS, West Bengal,Vol.-III :2091-2098.
11. IS: 1498-1970, **"***Classification and Identification of soils for general engineering purposes***"**, Bureau of Indian Standard, New Delhi.
12. ASTM Designation D1883, 2007. **"***Standard Test Method for CBR (California Bearing Ratio) of Laboratory***"**. Compacted Soils, PP 2-3.