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Design of Flexible Pavement by CBR method

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A B S T R A C T

In a developing nation like India, the construction and improvement of highquality roads plays a significant role.
Since the beginning of 20th century, the automobile & truck have offered higher level of mobility as a result the existing pavement due to heavy moving load are now becoming non- functional before its intended service life period.
The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics & low noise pollution.
The pavement is crucial part of any road project and needs to withstand traffic load without deteriorating or deforming to the extent that it becomes unstable during the design life period.
Two types of pavements are generally recognized as serving this purpose, **Flexible pavement** &**Rigid pavement.** Flexible pavements are those, which have low or immaterial flexural quality whereas rigid pavement on the other hand possess significant flexural strength & rigidity.

Here this paper discusses about design & evaluation of flexible pavement by **CBR Method.** An attempt is made to design a road at IET LUCKNOW based on postulates of pavement design. On the existing alignment of road, the soaked CBR value of soil subgrade is evaluated & based on this the thickness of pavement is designed taking design wheel load or by anticipated traffic into consideration.

Keywords: **Rigid pavement, Flexible Pavement, CBR method**

1. Introduction

In today`s scenario the economic growth of a community is dependent upon highway development to enhance mobility. But due to ineffectiveness of road engineers in designing of pavement, has lead to costly failures / wastages & expensive in some cases.

Improperly planned, designed, constructed & maintained roads can disrupt the social & economic characteristic of any size community.
Therefore, for conservative & proficient construction of roads, correct design of thickness of pavement is crucial.

A Flexible pavement is one that is made up of one or more layer of materials of highest quality material forming the top layer. The load carrying capacity of the flexible pavement is derived from the load distribution property & not from its flexural strength.

Components of flexible pavement:

Surface Course: This is the topmost layer; its function is to provide a smooth, strong, abrasion-resistant andreasonably impervious course. Since it is directly in contact with the vehicle tyre's, it has to resist the imposed wheel loads and transmit them safely to the layer below. This layer consisting of a mixture of aggregates and bitumen, heated and mixed properly

Base Course: This is immediately below the surface courseand its function is to distribute the stresses transmitted through the surface course evenly onto the layers below. Invariably, it consists of bituminous material and acts as a structural part of the pavement

Sub-Base Course: This comes just below the base course and provides additional help to the courses above it in distributing the loads. It also helps in preventing soil grains of the subgrade from intruding into the base course above, and counteracts frost action, if any. It may consist of stabilized soil or soil aggregate mixes, which facilitate drainage of free water from the pavement

Subgrade: It is the compacted natural soil immediately below the pavement layers; this acts as a foundation for the highway. The top surface of the subgrade is called the formation level.

Designing pavement by CBR method gives total thickness requirement of the pavement above a subgrade. On the basis of estimation of traffic load& bearing capacity of subgradewill lead to cost effective designing of roads.

2. Literature review

Since 2002, the world bank has constructed or rehabilitated more than 260000KM of roads. Roads are the arteries through which economy pulses. Road transport is most flexible and adaptable with an outreach into the most remote areas that are inaccessible by rail, air or water. Road transportation has gradually increased over the years with improvement in connectivity between cities, towns and villages in the country. The first evident of road development in the Indian subcontinent can be traced back to approximately around 2800BC in the ancient cities of Harappa and Mohenjo-Daro in the Indus valley civilization even in the roman empire they realized the importance of roads when they need to shift army troops from one place to another quickly as older methods require a lot of time to travel. Nowadays with introduction of modernization, heavy vehicles come into play which require proper designing and quality of pavement for smooth and efficient movement of vehicles over it therefore, it is of utmost importance to design pavement with a systematic approach. One of the main purposes of pavement design is to produce a soil structure system that will carry traffic smoothly and safely with minimum cost.

The perfect pavement is an ideal which will never be attained, since some of the qualities required in a perfect pavement are antagonistic to each other. An ideal pavement should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the subgrade soil
- Produce least noise from moving vehicles.
- Long design life with low maintenance cost.
- Structurally strong to withstand all types of stresses imposed upon it.

To fulfil these kinds of attributes, pavements are broadly classified into two types i.e flexible pavement and rigid pavement.

A flexible pavement can be defined as a pavement layer comprising of a mixture of aggregates and bitumen, heated and mixed properly and then laid and compacted on a bed of granular layer. Rigid pavements on the other hand, are made from cement concrete or reinforced concrete slabs, laid over a low strength concrete layer (Dry lean concrete, DLC) or on a well compacted layer of aggregates or both.

In a diverse nation like India,where population rate is increasing exponentially hence there is rapid increment in traffic flow on roads which require frequent modification and maintenance hence, efficient designing of pavements is of utmost importance.

To fulfil these requirements, flexible pavement is preferred over rigid pavements:

- Repairs & modifications are easy and it can be open and patched
- Materials are in expensive
- Frost heavy and settlement can be easily repaired
- Resist ice glaze formation
- Due to less time of curing, there is less traffic and business distractions

There are various methods to design flexible pavements but **CBR** method is most widely used.As per IRCrecommendation:

1.IRC 37:1970

- Based on CBR (California bearing ratio) of subgrade
- Traffic in terms of commercial vehicle (more than 3 tonnes laden weight)

2. IRC 37 :1984

- Based on CBR of subgrade
- Design traffic was considered in terms of cumulative number of equivalent standard axle load of 80KN in MSA (millions of standard axle
- Design charts were provided for traffic up to 30MSA using an empirical approach

3.IRC 37:2001

- Based on mechanistic empirical method
- Pavements were required to be designed for traffic as high as 150 MSA

- The limiting rutting is recommended as 20mm in 20% of the length for designed traffic

4. IRC 37:2012

- based on mechanistic empirical method
- the limiting rutting is recommended as 20 mm in 20% for design traffic up to 30MSA & 10% of the length for the design traffic beyond.

5. IRC 37:2018

- In the recent revision of IRC 37 2018,IITPAVE software is used to determine the thickness of compositions of pavement based on the CBR values.

3. WHY CBR?

We still use CBR for pavement design though its an empirical technique as it is a relatively simple test with a long record of use and hence, understanding of likely performance also it is easy to perform, inexpensive and has spread almost everywhere in the world.

CBR(California bearing ratio) method (IRC 37 1984)

The CBR method was developed originally by the California state highway department.
The California bearing ratio is a measure of the strength of the subgrade of the road or other paved area and of the materials used in its construction.
CBR is the ratio expressed in % of force per unit area required to penetrate a soil mass with standard circular plunger of 50mm diameter at the rate of 1.25mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 mm and 5.0 mm.

Advantages & Disadvantages:

- One of the key benefits of this method is the flexibility of the CBR test in the laboratory and flexible pavement construction approach using simple design maps.
- As technicality is relatively less in CBR methods, hence a nontechnical person can also perform it.
- This method is more adaptable and relatively expeditious for immediate use to design runway for airports.
- We can test soil with simple portable equipment.
- The test is primarily for subgrades but also applicable to various other kinds of materials.
- We can also perform this test at site as well
- The advantage of the CBR method is that it can be used to find the total thickness of the pavement &that of individual courses in addition to thickness of the subgrade soil (provided the CBR values of the materials of the courses are also known)

Along with the advantages there are some limitations of this method:
It is also important to consider the drawbacks of the CBR test itself on subgrade soil.

- Laboratory and Site compaction results are not identical.
- The values of the CBR does not reflect any of the fundamental properties of soil strength.
- As this method does not consider the strength of asphalt concrete, hence it sometimes results in too conservative design.

4. TEST PROCEDURE.

The CBR test is a penetration test in which a standard piston, with a diameter of 50 mm is used to penetrate the soil at a standard rate of 1.25 mm/minute.

Although the force rises with the depth of penetration, in many cases, it does not increase as quickly as it does for the standard crushed rock, so the ratio falls. The CBR is a measure of resistance of a material to penetration of a standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered to if a high degree of reproducibility is desired. The CBR test may be conducted on a remoulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

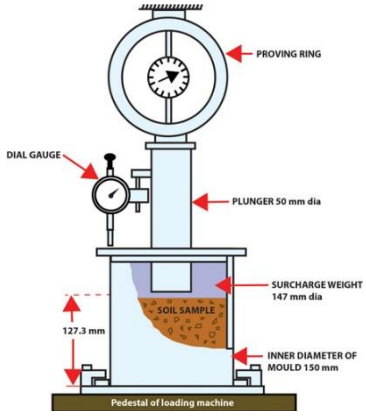

Figure 1: Apparatus for CBR test

The laboratory CBR apparatus consists of a mould of 150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking. If a soaked (wet) measurement is desired, the specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.

- Samples are collected at the required site we are going to design the pavement.
- Sieve the sample through 20 mm IS sieve, take 5 kg of the sample of soil specimen add water to soil in the quantity such that optimum moisture content is reached.
- Then soil and water are mixed thoroughly, spacer disc is placed over the base plate at the bottom of mould and a coarse filter paper is placed over the spacer disc.
- Mould is cleaned and oil is applied all over it, now $1/5^{th}$ of the mould is filled with the prepared soil and the layer is compacted by giving 56 distributed blows.
- The top layer of the compacted soil is stroked off then the next layer is filled and the process is repeated again and again.
- The collar is attached to the mould after the third layer and the process is pursued.
- Collar is removed after the fifth layer and the extra soil is scraped. Base plate is removed and the mould is inverted and then it is clamped to base plate.
- On the top surface of soil 2.5 kg of surcharge is placed. Mould is then taken to the testing machine.
- The plunger is penetrated into the soil and a seating load of 4kg is applied so that the contact between soil is plunger is established.
- Now the dial reading are standardized to 0.
- Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
- Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10 and 12.5 mm

Standard Load Values for CBR Test

Penetration(mm)	**Standard Load(kg)**	**Unit Standard Load(kg/cm2)**
2.5	1370	70
5	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

CALIFORNIA BEARING RATIO CALCULATION FROM THE TEST VALUES

Stress strain curve of CBR method:

The curve between stress v/s strain is drawn If the curve is concave upward in the near of the origin, the values will be adjusted according to the guideline.

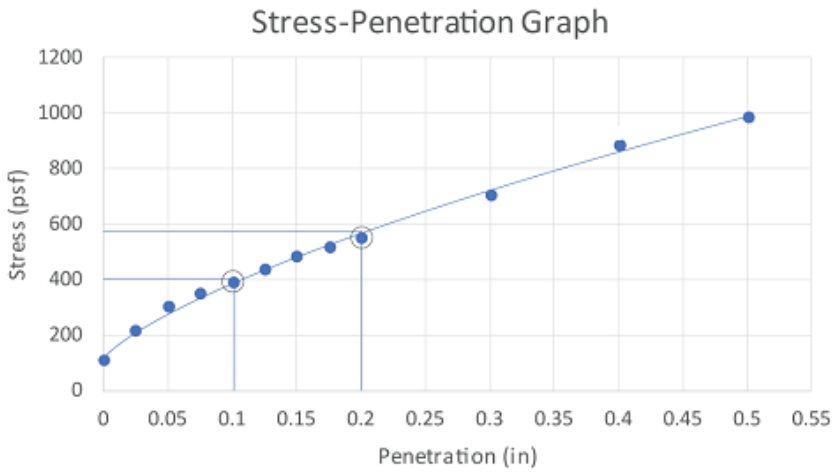

Figure 2: Graph showing penetration corresponding to stress

CBR calculation:

The CBR values are usually calculated for penetration of 2.5 mm and 5mm . generally, CBR value at 2.5mm will be greater than at 5mm and this value is taken as CBR for design purpose.

$$\text{CBR, \%} = \frac{\left[\begin{array}{l}\text{Load (or pressure) sustained by the}\\ \text{specimen at 2.5 or 5.0 mm penetration}\end{array}\right]}{\left[\begin{array}{l}\text{Load (or pressure) sustained by standard aggregates}\\ \text{at the corresponding penetration level}\end{array}\right]} \times 100$$

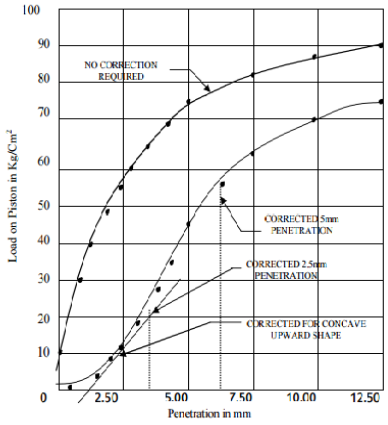

Figure 3: Graph showing piston load corresponding to penetration

5. CASE STUDY AND AREA OF CONCERN

Here in this paper, an effort is made with a purpose to design a flexible pavement in our prestigious institute IET LUCKNOW. Samples are collected from different patches of existing road and different suggestions were made to enhance the quality of existing pavement.

1. **Collection of samples:** 3 samples of soil had been collected in the location of the site.
2. **Types of test:** different types of test are conducted on the samples and these are

- **Plastic limit**
- **Liquid limit**
- **Specific gravity**
- **Sieve analysis**

Here are some glimpses of existing pavement are shown:

Figure 4 & Figure 5

It is seen that our existing pavement lags in surface finish and also develops pot holes at many places. When rain water comes and fills in pot holes for a longer duration, then this water may get percolated into soil due to permeability and can cause harm to subgrade layer.

6. SAMPLE PROBLEM ON CBR METHOD:

Design a flexible pavement based on CBR method for which input loads are as follows:

2.5 mm: 74.4 Kg

5.0 mm: 98 kg

Assume ADT = 500, r = 7%,

CBR corresponding to 2.5mm penetration = (74.4/ 1470)*100 =5.06%

CBR corresponding to 5.0 mm = (98/2055)*100 = 4.76%

Average Daily Traffic (ADT) = 300

Annual rate of growth of traffic (r) = 7%

Time taken for pavement construction (n) = 1.5 year No. of vehicles for design (A) = $P (1 + r)^{(n)}$

= 500(1+0.07)^1.5

=553.40=554 vehicle/day

Therefore, Design Curve E is to be used for design as the design traffic volume is in the range 450 to 1500 vehicles/day.

Using the design chart, the total pavement thickness over subgrade having CBR of 5.4% is obtained as 40cm for curve E.

Thus, 40cm of pavement materials is required to cover the natural soil subgrade having 5.4% CBRvalue.

Therefore, the thickness of base and sub base courses are 12.5cm and 22cm having CBR value 55% and 25% using the design chart.

The CBR values for the gravel and road metal are assumed as follows:

Type of material	Suggested CBR values(%)
Gravel	25
Road metal	55

7.CONCLUSION

From the above case study, we can conclude that:

- In this case study, we have adopted several techniques to design flexible pavement as per IRC recommendation. Though there are several methods of designing pavements such as GI method, triaxial method, Burmeister method and so on but we have adopted CBR method for our analysis as it is worldwide accepted also recommended by IRC
- It has been observed that value corresponding to 2.5 mm penetration is greater then 5.0 mm but if 5.0 mm comes to be greater than 2.5 mm then the test is repeated., and if same result comes out than value corresponding to 5.0 mm is taken.
- CBR method is preferred over other methods as it is cost effective & simple.
- CBR method is comparatively quick and we can get more accurate outputs

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