A DETAILED STUDY OF CBR METHOD FOR SUB GRADE LAYER OF DIFFERENT SOILS IN FLEXIBLE PAVEMENTS

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ABSTRACT

As per IRC recommendation, California Bearing Ratio (CBR) value of sub grade is used for design of flexible pavements. California Bearing Ratio (CBR) value is an important soil parameter for design of flexible pavements and runway of air fields. It can also be used for determination of sub grade reaction of soil by using correlation. It is one of the most important engineering properties of soil for design of sub grade of roads. 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), 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 estimation of the CBR could be done on the basis of these tests which are quick to perform, less time consuming and cheap, then it will be easy to get the information about the strength of sub grade over the length of roads, By considering this aspect, a number of investigators in the past made their investigations in this field and designed different pavements by determining the CBR value on the basis of results of low cost, less time consuming and easy to perform tests. In this study, attempts have been made to seek the values of CBR of different soil samples and correlate their CBR values for the design purpose of flexible pavement as per guidelines of IRC: SP: 37-2001.

Keywords: California Bearing Ratio, correlation, soaked, unsoaked, flexible pavement.

1. INTRODUCTION

California bearing ratio (CBR) is an empirical test and widely applied in design of flexible pavement over the world. This method was developed during 1928-29 by the California Highway Department. Use of CBR test results for design of roads, introduced in USA during 2nd World War and subsequently adopted as a standard method of design in other parts of the world, is recently being discouraged in some advanced countries because of the imperialness of the method (Brown, 1996). The California bearing ratio (CBR) test is frequently used in the assessment of granular materials in base, sub base and sub grade layers of road and airfield pavements. The CBR test was originally developed by the California State Highway Department and was thereafter incorporated by the Army Corps of Engineers for the design of flexible pavements. It has become so globally popular that it is incorporated in many international standards ASTM 2000.

1.1 General

Expansive soils are found in arid and semi-arid regions of the world and, hot climate and poor drainage conditions are usually associated with the formation of these soils. In INDIA, these soils are generally called as black cotton soils and cover about 20% of the total land area. They are found in the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamilnadu.

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 increase in axle load and phenomenal growth of traffic warrant as much importance in design, construction and maintenance of roads. In this chapter a glimpse of different approaches of flexible pavement design is narrated. State of the art practice of pavement design with geosynthetic is also discussed. Finally a methodology for design of coir mat reinforced pavement developed in this study is presented.

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. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. This chapter gives an overview of pavement types, layers, and their functions, and pavement failures. Improper design of pavements leads to early failure of pavements affecting the riding quality.

1.2 Types of Pavement Structure

Based on the structural behavior, pavement are generally classified into two categories

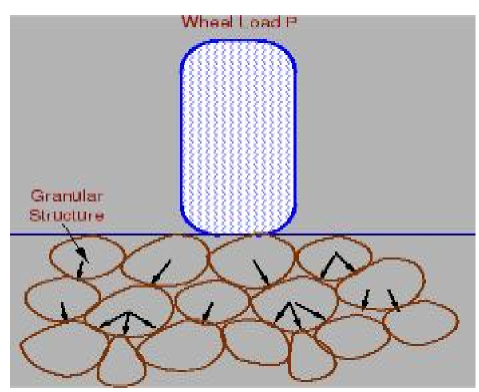
1. Flexible pavement
2. Rigid pavement

The cement concrete pavement slab can very well serve as a wearing surface as well an effective base course. Therefore usually the rigid pavement structure consists of a cement concrete slab, below which a granular base or sub-base course may be provided.

Providing a good base or sub base course layer under the cement concrete slab, increases the pavement life considerable and therefore works out more economical in the long run[3-4]. The rigid pavements are usually designed and the stresses are analysis using the elastic theory, assuming the pavements as an elastic plate resting over an elastic or a viscous foundation.

1.3 Flexible Pavements:

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure.



Load transfer in granular structure

1.4 Typical layers of a flexible pavement

Typical layers of a conventional flexible pavement includes seal coat, surface course, tack coat, binder course, prime coat, base course, sub-base course, compacted sub-grade, and natural sub-grade.

1.5 Factors to Be Considered For Flexible Pavement Sub grades

The information obtained from the explorations and test previously described should be adequate to enable full consideration of all factors affecting the suitability of the sub grade and subsoil. The primary factors are as follows:

- The general characteristics of the sub grade soils such as soil classification, limits, etc.
- Depth to bed rock.
- Depth to water table (including perched water table).
- The compaction that can be attained in the sub grade and the adequacy of the existing density in the layers below the zone of compaction requirements.
- The CBR that the compacted sub grade and uncompacted sub grade will have under local environmental conditions. In-place densities are satisfactory.
- The presence of weak of soft layers in the sub-soil.
- Susceptibility to detrimental frost action.

1.6 Methods of Flexible Pavement Design

There exist a number of methods for the design of flexible pavements as summarized by Rao, 2007. These are empirical method with or without a soil strength test, limiting shear failure method, limiting deflection method, regression method based on pavement performance, mechanistic-empirical method and design based on theoretical studies.

The use of empirical method without a strength test dates back to the development of Public Roads (PR) soil classification system, in which the sub grade was classified as uniform from A-l to A-8 and non-uniform from B-l to B-3. This System was later modified by the Highway Research Board (HRB, 1945), in which soil were grouped from A-l to A-7 and a group Index was added to differentiate the soil within each group.

In this limiting shear failure method the thickness of pavement is determined so that shear failure will not occur. The major properties of sub grade soil considered are cohesion and angle of internal friction. Me Leod (1953) advocated the use of logarithmic spirals to determine the bearing capacity of pavement.

1.7 Role of Transportation:

The evolution and advancements in transportation facilities have been closely linked with the development of human being throughout the history of the world. Transportation contributes to the economic, industrial, social and cultural development of any country. Transportation is vital for the economic development of any region since every commodity produced, whether it is agricultural or distribution. At the production stage, transportation is required for carrying raw materials like seeds, manure, coal, steel, machines, component parts, etc. At the distribution stage, transportation is required from the production centres like the farms and factories to the marketing centres and later to the retailers and to the consumers. Inadequate transportation facilities retard the process of socio-economic and cultural development of the country. Development of adequate transportation system in a country indicates its economic growth and progress in social development.

1.8 Role of Transportation for the Development of Rural Areas in India:

The impacts of rural road connectivity from the recent rural road development programmes in the country are as follows:

- Improvement in transportation services leads to improved access to market centres for the rural producers, better availability of farm inputs at reduced prices.
- Diversification of agricultural produce with improved market access promotes shift in favour of cash crops and commercialization of agricultural activities.
- Diversification of livelihood opportunities with better connectivity enhances employment opportunities in the non-agricultural sectors.
- Improved services with improved road connectivity, inter-alia, enhances access to education, health and financial services.
- Increase in the outreach due to improved rural roads facilities better availability of public services and functionaries in rural areas.

1.9 Importance of Roads in India

In general, developing countries have to upgrade the road transportation system to a higher level, both in terms of length and quality so as to meet the demand which is being generated by the development plans. Road development generates considerable employment potential, which is of additional significance to the developing country.

1.10 Scope and Objective of the Design

The road pavements are generally constructed on low embankments, above the general ground level or the adjoining land, wherever possible in order to avoid the difficult drainage and maintenance problems. The term road or roadway thus constructed is therefore termed 'highway' and the science and technology dealing with roads is generally called 'Highway Engineering' and 'Highway Technology'.

The guidelines are applied to design flexible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC/MOST standards. These guidelines apply to new pavements.

1.11 Basis of Design

The prime factor influencing the structural design of a pavement is the load-carrying capacity required. The thickness of pavement necessary to provide the desired load-carrying capacity is a function of the following five principal variables:

- Vehicle wheel load or axle load.
- Configuration of vehicle wheels or tracks.
- Volume of traffic during the design life of pavement.
- Soil strength.
- Modulus of rupture (flexural strength) for concrete pavements.

1.12 Design criteria

The flexible pavements has been modeled as a three layer structure and stresses and strains at critical locations have been computed using the linear elastic model. To give proper consideration to the aspects of performance, the following three types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered:

1. Vertical compressive strain at the top of the sub-grade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.
2. Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
3. Pavement deformation within the bituminous layer.

1.13 Soil conditions for Flexible pavements (FP):

1. The minimum thickness of the sub-grade is 500mm for NH and 300mm for SH as per IRC recommendations. And also, it needs a proper distribution of load transfer i.e. grain to grain load transfer. Hence, a proper adhesion between the different layers becomes an important criteria for the strength of FP.
2. The quality of sub grade is measured by CBR test. A weaker soil sub grade with lower CBR value will need a FP with higher thickness. In converse we can say that a FP needs much thickness of sub grade. Hence the quality of sub grade can be low i.e. CBR value can be low for its long lasting property.
3. The sub grade should be compacted to permissible dry density i.e more than 1.75g/cc.

2. LITERATURE REVIEW

For the designing the flexible pavement by black cotton soil with slurry, many researchers did work on the black cotton soil with different materials. In the past many researchers have carried out their research work for designing the flexible pavement by black cotton soil using different types of admixture, stone dust and fiber. Some detailed literatures have been reviewed on this topic i.e. related to design of flexible pavement and material properties and some of the reviewed of the reviewed literatures are presented in proceeding paragraphs.

P. A. Sivasubramani et. al. (2017) studied to evaluate the potential of Bagasse Ash (BA) and egg shell powder (ESP) to stabilize soft and expansive soil. the physical properties of clay, BA and ESP have been studied by conducting laboratory tests. The CBR test were performed for black cotton soil with ESP. The percentage of BA varied from 5% to 25%, 3% ESP is added and tests were performed. After obtaining results, it is observed that the thickness of the pavement of stabilized soil is found lesser than the thickness of the pavement of virgin soil.

Er. Devendra Kumar Choudhary et. al. (2014) studied about the CBR method for designing the flexible pavement. They studied two different soil sample. The samples are clayey silt and Kopra and CBR test conducted on it. After obtaining results, the thickness of pavement is less while using Kopra compare to clayey silt and it is also determined that, thickness of crust varied with the change in value of CBR. With higher value of CBR the crust thickness is less.

Abhijitsinh Parmar et. al. (2013) also performed CBR test for designing the flexible pavement with using black cotton soil as base material. They designed pavement by using lime and fly ash as admixture in black cotton soil. After conducting experiments, it was observed that the optimum moisture content and maximum dry density were improved by 11.1% and 10.74% respectively. The free swell index was also improved by 13.74%.

3. MATERIALS

High-quality materials must be used in base courses of flexible pavements. These high-quality materials provide resistance to the high stresses that occur near the pavement surface.

The CBR test is carried out on material passing a 20mm test sieve. If soil contains particles larger than this the fraction retained on 20mm shall be removed and weighed before preparing the test sample. If this fraction is greater than 25% of the original sample the test is not applicable. The moisture content of the specimen or specimens can be adjusted as necessary following the procedure given in Chapter 4. The moisture content used is normally to the Optimum Moisture Content (OMC), but obviously this can be varied to suit particular requirements.

1. Soil
2. Aggregates
3. Bitumen

3.1 SOIL

Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory.

Showing the Soil

The supporting soil beneath pavement and its special under courses is called sub grade. Undisturbed soil beneath the pavement is called natural sub grade. Compacted sub grade is the soil compacted by controlled movement of heavy compactors.

3.2 Aggregates

Aggregates generally occupy 65- 80% of a concrete's volume. Aggregates are inert fillers floating in the cement paste matrix for concretes of low strength. The strength of aggregates do not contribute to the strength of concrete for low strength concrete. The characteristics of aggregates impact performance of fresh and hardened concrete.

Aggregates

3.3 Bitumen

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost.

Bitumen

3.4 Silty Soli:

Silty soil is slippery when wet, not grainy or rocky. The soil itself can be called silt if its silt content is greater than 80 percent. When deposits of silt are compressed and the grains are pressed together, rocks such as siltstone form. Silt is created when rock is eroded, or worn away, by water and ice.

Silty Soil

4. EXPERIMENTAL PROGRAM

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

4.1 Collection of Materials

The materials were obtained from the nearby borrow areas, 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.

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

Grain size analysis is carried out to determine the relative percentages of different sizes of particles in the sample. 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.

4.3 Design of flexible pavements as per guidelines of IRC: 37-2001

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the guideline. The pavement designs are given for sub grade CBR values ranging from *2%* to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35° C. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

- Design traffic in terms of cumulative number of standard axles; and
- CBR of sub grade.

4.4 Vehicle Damage Factor:

The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads and axle configurations to the number of standard axle-load repetitions. The axle load equivalency factors are used to convert different axle load repetitions into equivalent standard axle load repetitions. For these equivalency factors refer IRC: 37-2001. The exact VDF values are arrived after extensive field surveys.

4.5 Pavement composition:

- **Sub-base:**

Sub-base materials comprise natural sand, gravel, laterite, brick metal, crushed stone or combinations thereof meeting the prescribed grading and physical requirements. Sub-base usually consist of granular material or WBM and the thickness should not be less than 150 mm for design traffic less than 10 msa and-200 mm for design traffic of 10-msa and above.

- **Base:**

The recommended designs are for unbounded granular bases which comprise conventional water bound macadam (WBM) or wet mix macadam (WMM) or equivalent confirming to MOST specifications. The materials should be of good quality with minimum thickness of 225 mm.for traffic up to 2 msaandiZSO mm for traffic-exceeding 2msa.

- **Bituminous surfacing:**

The surfacing consists of a wearing course or a binder course plus wearing course. For binder course, MOST specifies, it is desirable to use bituminous macadam (BM) for traffic up to 5 msa and dense bituminous macadam (DBM) for traffic more than 5 msa.

4.6 The following design procedure is recommended (Step by step procedure)

Step 1: Determine soil sub grade strength. Use of Standard Penetration Test (SPT) is not recommended for soft clays.

Step 2: The sub grade strength is determined at several locations at different times of the year. Make strength determinations at several locations where the sub grade appears to be weakest. Strength should be evaluated at a depth of 0 to 200 mm and from 200 to 500mm; six to ten strength measurements are recommended at each location to obtain a good average value. Tests should be also performed when the soils are in their weakest condition, when the water table is the highest etc.

Step 3: Determine the maximum single axle load maximum dual wheel load and the maximum dual tandem wheel load anticipated for the road way during the design period.

Step 4: Estimate the maximum amount of traffic anticipated for each design vehicle class.

Step 5: Establish the amount of tolerably rutting during design life of the roadway.

Step 6: Obtain appropriate sub grade stress level in terms of the bearing capacity factors.

Step 7: Determine the required aggregate thickness from the USFS design charts for each maximum loading. Enter the curve with appropriate bearing capacity factors (NC) multiplied by the design sub grade shear strength c to evaluate each required stress level (eNc)'

Step 8: Select the design thickness based on the design requirements; the design thickness should be given to the next higher 25 mm.

Step 9: Check the Geotextile drainage and filtration requirements. Use gradation and permeability of the sub grade, the water table conditions, and the retention and permeability criteria.

Step 10: Check the geo textile survivability strength requirements (construction stresses through grab strength, sewn seam strength, tear strength; puncture strength burst strength and UV stability). Survivability of geo grids and geo textiles for major projects should be verified by conducting field tests under site specific conditions.

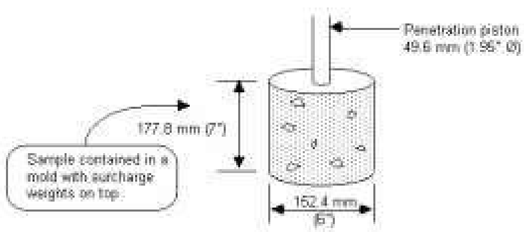
Step 11: Specify geo textiles that meet or exceed these survivability criteria.

4.7 California Bearing Ratio (CBR)

As per IRC recommendation, California bearing ratio value of sub grade is used for design of flexible pavements. California bearing ratio value is an important soil parameter for design of flexible pavements and runway of air fields. The test is performed according to IS 2720 (Part 16) – 1979. The California bearing ratio test is performed in laboratory of University Teaching Department, RTU, Kota for black cotton soil and mix specimen of soil.

The CBR test forms part of the site investigation and is used to determine the thickness of materials needed for the proposed road construction.

The basic CBR test involves applying load to a small penetration piston at a rate of 1.3 mm (0.05") per minute and recording the total load at penetrations ranging from 0.64 mm (0.025 in.) up to 7.62 mm (0.300 in.). Figure is a sketch of a typical CBR sample.



CBR Sample

4.8 Selection of Design CBR Values.

Flexible pavements may be designed using the laboratory soaked CBR, the field in-place CBR, or the CBR from undisturbed samples. Guides for determining when in-place tests can be used are given in details of the CBR test in MIL-STD-621A, Test Method 101.

Flexible pavement designs will provide the following:

- Sufficient compaction of the sub grade and of each layer during construction to prevent objectionable settlement under traffic.
- Adequate drainage of base course.
- Adequate thickness above the sub grade and above each layer together with adequate quality of the select material, sub base, and base courses to prevent detrimental shear deformation under traffic and, when frost conditions are a factor, to control or reduce to acceptable limits effects of frost heave or permafrost degradation.
- A stable, weather-resistant, wear-resistant waterproof, non-slippery pavement.

4.9 CBR test is performed on flexible pavement:

The CBR 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.

The CBR test is carried out on soils with a maximum particle size of 20mm. (Note: For material greater than 20mm please see Plate Bearing Tests). The technique involves driving a small cylindrical plunger (approx 50mm) into the ground at a uniform rate, using a four wheel drive vehicle as the reaction load to provide the force.

Showing the California bearing apparatus

4.10 California Bearing Ratio Test

AIM

The aim of this test is the determination of California Bearing Ratio value of the sub grade soil.

OBJECTIVE

To determine the California bearing ratio by conducting a load penetration test in the laboratory.

NEED AND SCOPE

The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. 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.

This instruction sheet covers the laboratory method for the determination of C.B.R. of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

Preparation of mould

a) Weigh the mould with base plate attached to the nearest 5 g (m2).

b) Measure the internal dimensions to 0.5 mm

c) Attach the extension collar to the mould and cover the base-plate with a filter paper.

d) Measure the depth of the collar as fitted, and the thickness of the spacer plug or plugs, to 0.1 mm.

Preparation of Specimen

4.13 Uses and Significance of California Bearing Ratio Test:

- The CBR test is one of the most commonly used methods to evaluate the strength of a sub grade soil, sub base, and base course material for design of thickness for highways and airfield pavement.
- The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. 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.
- This instruction sheet covers the laboratory method for the determination of C.B.R. of undisturbed and remolded /compacted soil specimens, both in soaked as well as un-soaked state.

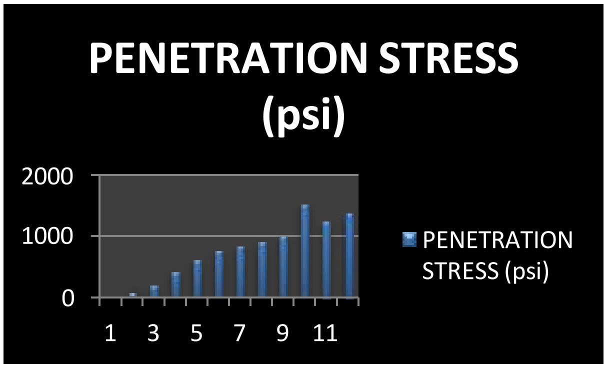
5. RESULTS

The Kota stone slurry is low plasticity material and black cotton soil is inorganic clay of medium plasticity but when amount of Kota stone slurry increases, the black cotton soil changes behavior from CI to CL.

CBR TEST DATA

PENETRATION (in)	PROVIDING RING DIAL READING	PISTON LOAD(lb)	AREA OF PISTON $(IN)^2$	PENETRATION STRESS (psi)
0	0	0	3	0
0.025	14.25	290.83	3	98.0
0.05	39.6	808.2	3	212.78
0.075	68.2	1391.9	3	432.55
0.1	98.06	2001.31	3	630.87
0.125	117.8	2404.18	3	779.20
0.15	129.4	2640.32	3	850.16
0.175	139.6	2849.1	3	923.33
0.2	148.7	3034.82	3	1012.13
0.3	170.7	3483.82	3	1534.55
0.4	183.8	3751.1	3	1246.27
0.5	202.2	4126.71	3	1366.56

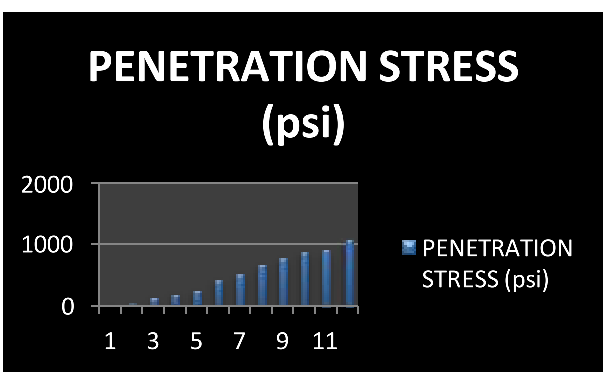
California Bearing Ratio Test using Black Cotton Soil material Data



Graph for CBR test using Black Cotton Soil material values

PENETRATION (in)	PROVIDING RING DIAL READING	PISTON LOAD(lb)	AREA OF PISTON $(IN)^2$	PENETRATION STRESS (psi)
0	0	0	3	0
0.025	14.25	290.83	3	65.67
0.05	39.6	808.2	3	147.54
0.075	68.2	1391.9	3	199.90
0.1	98.06	2001.31	3	264.34
0.125	117.8	2404.18	3	432.67
0.15	129.4	2640.32	3	532.76
0.175	139.6	2849.1	3	679.56
0.2	148.7	3034.82	3	797.17
0.3	170.7	3483.82	3	890.66
0.4	183.8	3751.1	3	916.78
0.5	202.2	4126.71	3	1069.98

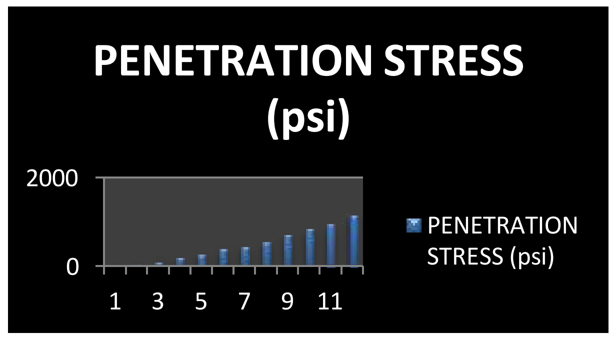
California Bearing Ratio Test using Red Soil material Data



Graph for CBR test using Red Soil material values

PENETRATION (in)	PROVIDING RING DIAL READING	PISTON LOAD(lb)	AREA OF PISTON $(IN)^2$	PENETRATION STRESS (psi)
0	0	0	3	0
0.025	14.25	290.83	3	68.12
0.05	39.6	808.2	3	112.45
0.075	68.2	1391.9	3	212.35
0.1	98.06	2001.31	3	285.24
0.125	117.8	2404.18	3	399.13
0.15	129.4	2640.32	3	450.15
0.175	139.6	2849.1	3	559.30
0.2	148.7	3034.82	3	717.47
0.3	170.7	3483.82	3	850.45
0.4	183.8	3751.1	3	930.30
0.5	202.2	4126.71	3	1126.30

California Bearing Ratio Test using Silty Soil material Data



Graph for CBR test using Silty sand material values

6. CONCLUSIONS

By the use of the consoled system any soil found anywhere, to be upgraded to achieve better characteristics necessary in improving road life and quality. As we know pavement based design and thickness of sub- base depends upon CBR value so increment in CBR value results in reduction of thickness of sub-base, which means materials require for pavements are having less quantity and it also save the construction time

1. In Black clay sub grades, in addition to large design thickness, sand blanket/CNS cushion requirement further makes pavement section thicker.

2. Construction of flexible pavement in Red clay based on improved sub grade concept is expansive by (18%) over the conventional design. Considering the long term performance of pavement, the pavement design by improved sub grade shall be preferred.
3. Construction of flexible pavement with improved sub grade in red clay is sub grade reduces constructed cost by about 5%.
4. Construction of flexible pavement with improved sub grade in Black clay is expensive by about 10% is comparison to pavement with sand blanket.
5. For construction of flexible pavements in expensive soil such as black clay improved sub grade concept shall be considered as pavement constructed with CNS cushion deteriorate over a period of time due to softening of top surface of CNS material.
6. Construction of flexible pavement with improved sub grade concept in red clay sub grades result in improved performance with reduced maintenance cost. Also sub grade strengthening in shoulder portion helps in preventing shear failures during overtaking of vehicles.

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