Characterization of Soil Mixed with Reclaimed Asphalt Pavement (RAP) Materials

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Abstract: Black cotton soil (Silty loamy - CH) is one of the major soil deposit in India and characterized by high shrinkage and swelling properties. This BC soil occurs mostly in the central and western parts and covers approximately 20 % of the total area of India. Because of high swelling and shrinkage characteristics, the BC soil has been a challenge for the highway engineers. BC soil has very low bearing capacity. Soaked the laboratory CBR values of BC soils are generally found in the range of 2 to 4 %. Due to very low CBR values of black cotton soil excessive pavement thickness is required for flexible pavement. Reclaimed asphalt or recycled asphalt payment (RAP) is reprocessed pavement material containing asphalt and aggregate. There are many reasons to use RAP material including cost, the environment, and sustainability. Large length of asphalt roads in India the opportunity exists to really create environmentally friendly, sustainable projects using reclaimed materials. This research paper mainly focusses on investigate the use of reclaimed Asphalt pavement material in black cotton soil and to check the natural properties and behavior for the same. The present work is focus on MMGSY roads near Bharuch and soil sample was collected for various test to analyses the properties of BC soil and with additional RAP material. The tests results show improved CBR values. The optimum dosage of reclaimed Asphalt pavement materials decided which is represented in the paper.

***IndexTerms* - Black Cotton (BC) Soil, Reclaimed Asphalt Pavement (RAP) Materials, California Bearing Ration (CBR), Compaction Test,**

1. INTRODUCTION

Rapid Industrialization coupled with large scale infrastructural development results in huge scarcity of construction materials and has shown increase in environmental pollution. Due to heavy axle loads and other environmental factors the deterioration of pavement takes place which affects the riding quality and there by huge cost is incurred in maintenance, especially in black cotton soil the adverse impact is noted maximum as the soil is very poor for engineering uses. The preliminary investigation of black cotton soil is carried out to evaluate the physical and engineering properties as per Indian Standard Codal Practice and the problems associated to it was noted. For classification of soil, IS: 1498 – 1970 was applied and from that soil class is CH. To eliminate the problems of failures in flexible pavement due to highly plastic soil, soil stabilizer is used in proposed pavement design is suggested. For Study purpose, to increase the bearing capacity of CH soil various soil tests were performed using various proportions of stabilizer (RAP – 10%, 20%, 30%, 50%, 70%). From the test results it is observed that MDD is maximum for 70% RAP material by weight of soil. The soaked CBR value was 1.98% Which increases to 4.09 %. From this observation thickness of pavement get reduced to the certain extent which directly implies to cost reduction in pavement construction.

This research work involves the “Characterization of Soil mixed with Reclaimed Asphalt Pavement (RAP) Material”, which is the formal procedure of pavement recycling and also it is a logical and practical way to conserve our diminishing supply of construction materials and to help reduce the cost of preserving our existing pavement network.

In the study, laboratory investigation need to be carried out on black cotton soil with and without percentage of RAP material to evaluate the enhance engineering properties of mix material in various RAP content using various tests such as Grain size analysis, Atterberg’s limits, Compaction test, California Bearing Ratio (CBR) test, and further study is to evaluate the quantity estimation to calculate the economic benefits in utilization of RAP materials by using guide of pavement design as per IRC: 37 – 2012.

Moreover, the use of reclaimed pavement construction is gaining popularity for its advantage over convention materials including conservation of natural resources, conservation of energy, preservation of environment, reduced life-cycle costs, besides conservation of depleting oil-based hydrocarbons binders. Developed nations have already standardized the procedures to utilize recycled and secondary materials in the pavement construction. Thus, pavement recycling has become an alternative.

2. LITERATURE REVIEW

Reclaimed asphalt pavement (RAP) is defined as removed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement.

Asphalt pavement has been America's most recycled material for a long time. Using RAP material has well-recognized financial and environmental benefits. Although most of the produced RAP is recycled, a large portion of it is wasted or down-graded when used in landfills, embankment or base layers.

Now adays, RAP materials are used by many researchers for his studies such as RAP materials are used as unbound granular layers, as a stabilizer, in low-volume roads, as a subgrade material. When RAP material is mixed with subgrade soil then the RAP mixed soil is increase with the increase in deviatory stress and bulk stress and less sensitive with the confining pressure. Resilient modulus of RAP mixed soil is the maximum at the optimum moisture content. Resilient modulus of RAP mixed soil increases with RAP content.

Hence, RAP can be used in Subgrade soil to increase the resilient capacity of soil. In some papers, RAP materials are used for pavement unbound granular layer by using accelerated pavement testing and the conclusion was Reasonable improvement in subgrade stability could be achieved using up to 40% of RAP materials blended with large-sized recycled concrete aggregates. Despite achieving better relative compaction and higher composite stiffness, unpaved sections with 100% RAP capping displayed higher rutting compared to their virgin aggregate counterparts.

When RAP materials are used for utilization of Indian Low volume roads how much proportion of the RAP materials are used and how much strength we can achieve by substitution in virgin aggregate as a base material in low volume roads.

The main focus for low volume roads is to promote the high proportion of RAP in VA as a pavement material. The overall results show the proportion of 80% RAP and 20% VA are used as an Indian low volume road.

3. LABORATORY TESTING

The soil was collected from the Ghamnad village in Amod taluka of Bharuch district, Gujarat and RAP material is collected from Vallabh Vidyanagar, Anand. Gujarat. Black cotton soil which is characterized by high swelling and shrinkage properties and because of these properties, the black cotton soil is challenge for the highway engineers and RAP materials are the reclaimed or recycling material which is nothing but a waste material.

Therefore, laboratory testing is carried out for the improvement and stabilize the soil by using RAP material. Various laboratory testing was performed for evaluated the properties of Soil and RAP material.

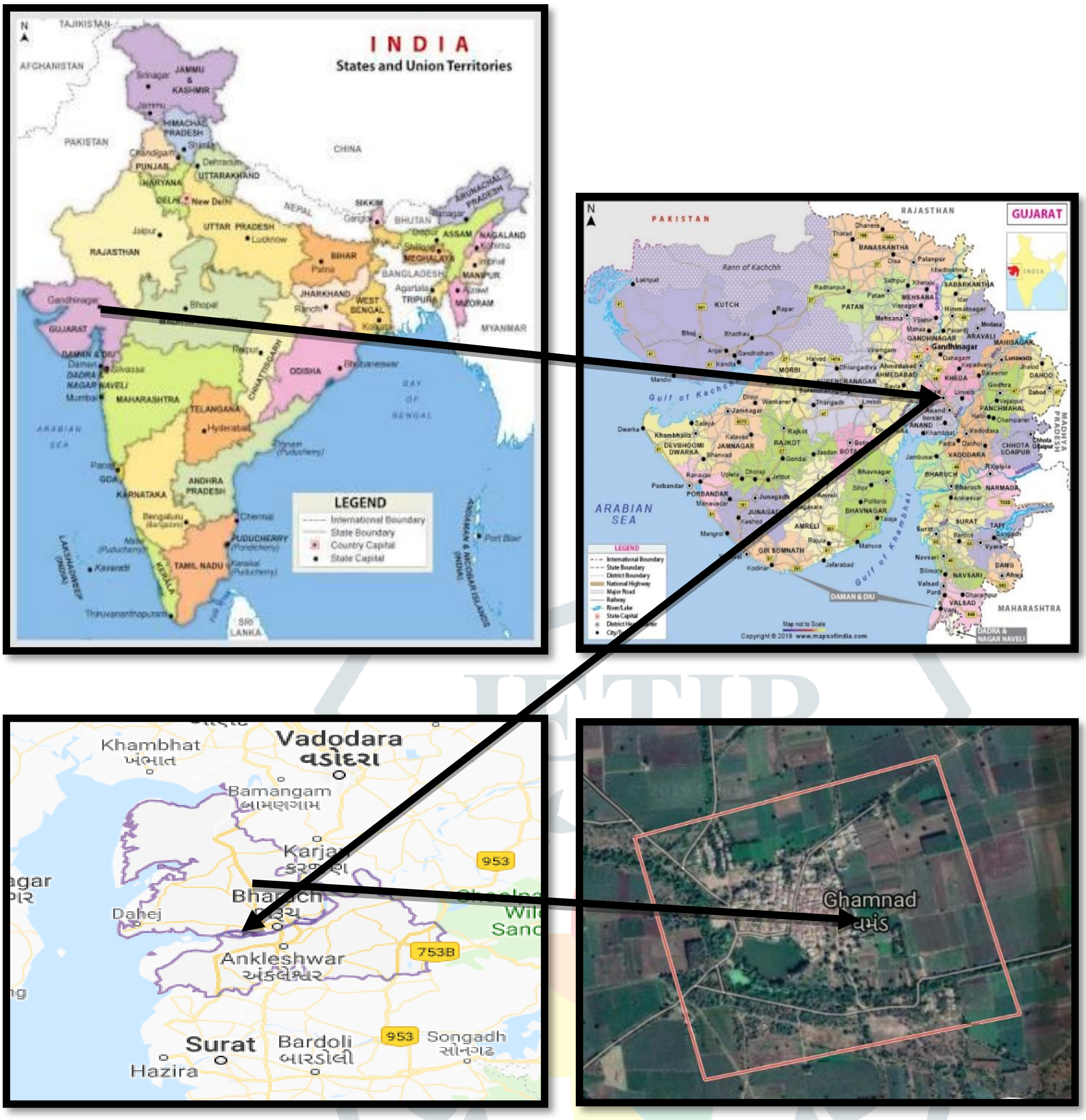


Figure 1: Map of Study Area

Various tests were performed which are enlisted as follows: Determination of Grain Size Analysis (IS: 2720 (Part IV) – 1985), Determination of Liquid and Plastic Limit (IS: 2720 (Part V) – 1986), Determination of Free Swell Index of Soils (IS: 2720 (Part XL) – 1977), Determination of Water Content – Dey Density Relation Using Heavy Compaction (IS: 2720 (Part VIII) – 1997), Laboratory Determination of California Bearing Ration (IS: 2720 (Part XVI) – 1987), Determination of Specific Gravity of Soil (IS: 2720 (Part 3/Sec 1) – 1980).

A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called *gradation*) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass. By performing grain size analysis and Atterberg's limit test the soil is highly plastic clayey soil (CH – Silty loamy).

The liquid limit (LL) It is defined as the percentage moisture content at which a soil changes with decreasing wetness from liquid to plastic consistency or with increasing wetness from plastic to liquid consistency. It is the water content at which a soil changes from plastic to liquid behavior. By testing, the LL is 70.13%.

The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling. In other words, it is the percentage moisture content at which a soil changes with decreasing wetness from the plastic to the semi-solid consistency or with increasing wetness from the semi-solid to the plastic consistency. By testing, the PL is 38.76%.

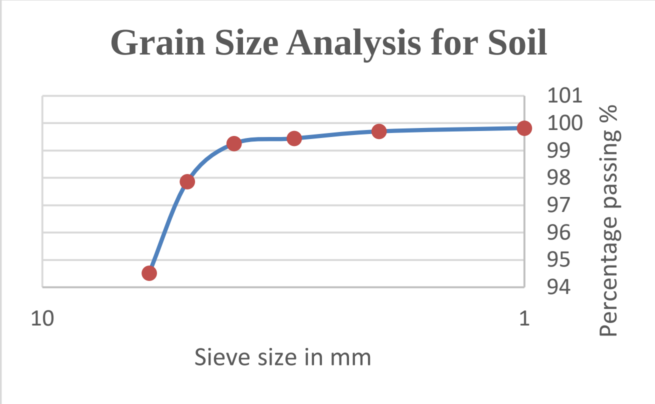


Figure 2: Sieve Analysis

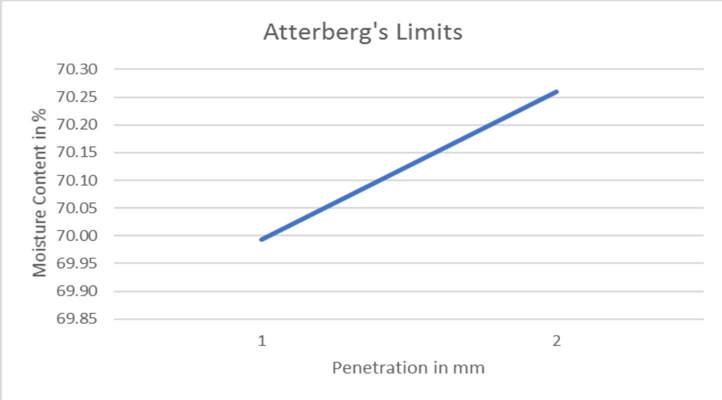


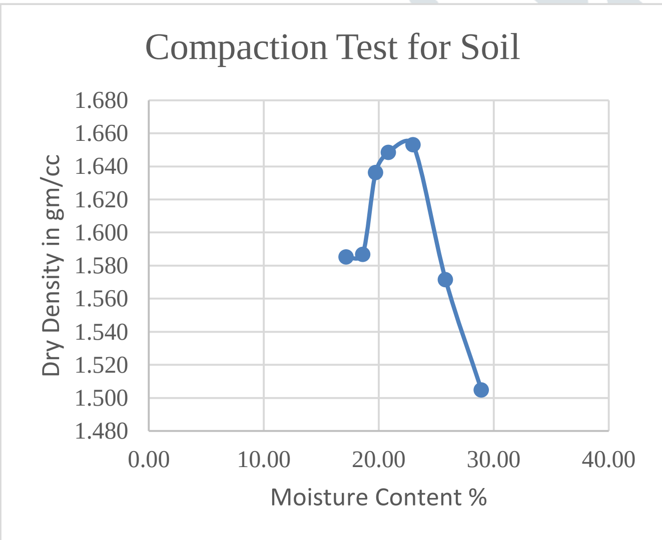
Figure 3: Atterberg's Limits

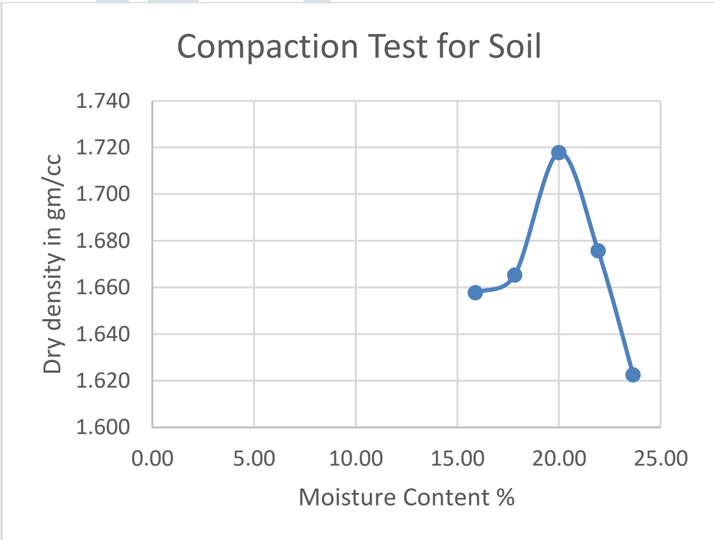
The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. The test is named in honor of Ralph R. Proctor [de], who in 1933 showed that the dry density of a soil for a given compactive effort depends on the amount of water the soil contains during soil compaction. His original test is most commonly referred to as the standard Proctor compaction test; his test was later updated to create the modified Proctor compaction test.

Compaction test was done for various proportion of RAP such 10%, 20%, 30%, 50% and 70% and the result as follows:

Table 1: Various Results of Compaction Test

Sr. No.	Type of Material	Maximum Dry Density	Optimum Moisture Content
1	100 % Soil	1.653	22.99
2	90 % Soil + 10% RAP	1.718	19.99
3	80 % Soil + 20% RAP	1.787	17.6
4	70 % Soil + 30% RAP	1.829	16.35
5	50 % Soil + 50 % RAP	2.013	12.75
6	30 % Soil + 70 % RAP	2.065	11.79





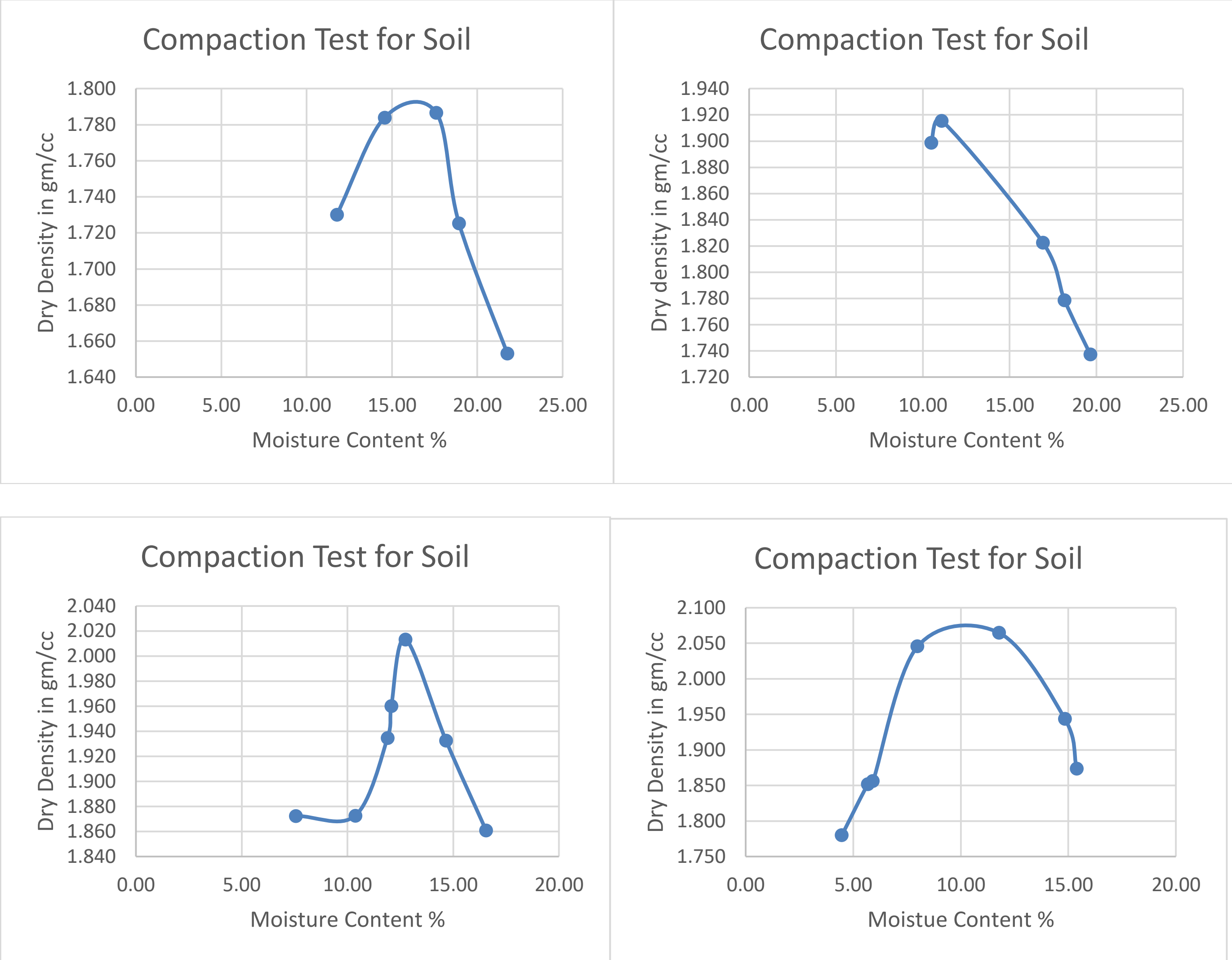


Figure 4: Graphs of Compaction Tests for Various proportion of Soil and RAP

From the above graphs, the maximum dry density is maximum for 30% soil and 70% RAP material.

The **California Bearing Ratio (CBR)** test is a penetration test meant for the evaluation of subgrade 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. CBR test was done for various proportion of RAP such 10%, 20%, 30%, 50% and 70% and the result as follows:

Table 2: Various results of CBR Test

Sr. No.	Type of Material	CBR Value
1	100 % Soil	1.98
2	90 % Soil + 10% RAP	3.61
3	80 % Soil + 20% RAP	3.85
4	70 % Soil + 30% RAP	4.09
5	50 % Soil + 50 % RAP	3.36
6	30 % Soil + 70 % RAP	2.64

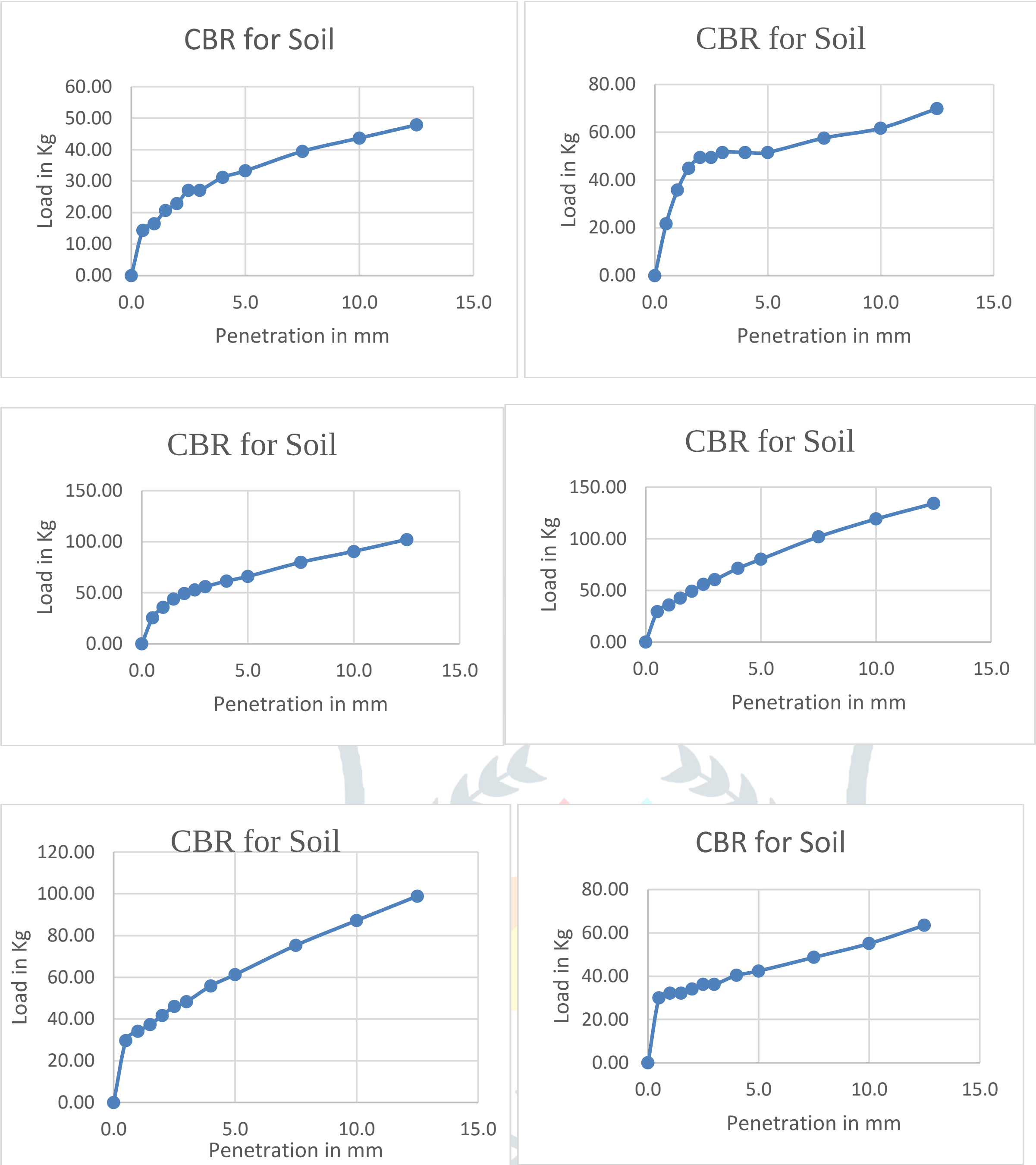


Figure 5: Graphs of CBR Tests for Various proportion of Soil and RAP

From the above graphs, the California Bearing Ration (CBR) value is maximum for 70% soil and 30% RAP material and its value is 4.09.

4. PAVEMENT DESIGN

In this research, the data was considered for various combination of traffic, layer configuration, and assumed materials properties based on design thickness obtained as per IRC: 37 – 2012 "Guidelines for the design of flexible pavement".

According to selected road stretch the various data was collected and assumed and used as input data in IITPAVE software and the rutting and fatigue model is developed and then quantity estimation was done for pavement design of construction of new flexible pavement.

1. Two lane single carriage way
2. Initial traffic in the year of completion of construction = 650 CVPD (sum of both direction)
3. Traffic growth rate = 5 %
4. Design life = 15 years
5. Vehicle damage factor = 3.5 (Plain Terrain)
6. Design CBR of subgrade soil = 4 %

Design Parameters

a) Design traffic in cumulative number of standard axles (8160 Kg), can be computed using the following equation:

$$N = \frac{365 * [(1+r)^{n} - 1]}{r} * A * D * F$$

Where,

N = cumulative number of standard axles to be created for the design in terms of million standard axle (msa),

A = initial traffic in the year of completion of construction in term of the number of commercial vehicles per day = 650 cvpd

D = lane distribution factors = 0.50 (two lanes single carriage way)

F = vehicle damage factor = 3.5

n = design life in years = 15 years

r = annual growth rate of commercial = 5 %

Fatigue Model

$N_f = 0.711*10^{-04}*[1/\varepsilon_t]^{3.89}*[1/M_R]^{0.854}$

Where,

N_f = fatigue life in number of standard axles,

ε_t = Maximum tensile strain at the bottom of the bituminous layer, and

M_R = resilient modulus of the bituminous layer.

Rutting Model

$N = 1.41*10^{-08}*[1/\varepsilon v]^{4.5337}$

Where,

N = number of cumulative standard axles, and

εv = Vertical strain in the subgrade

Fatigue and rutting model are used to define the allowable horizontal strain at the bottom of the bituminous layer and vertical strain in the subgrade respectively. Using IITPAVE software, we define the computed strain which is less than the allowable strain. In most cases the tensile strain at the bottom of the bituminous layer is higher in the longitudinal direction (epT) rather than in radial direction (epR). If tensile strain in the bituminous layer is high, increase the thickness of the bituminous layer. If the vertical subgrade strain is higher, increase the thickness of subbase layer.

Figure 6: Pavement Composition of GB & GSB and RAP

5. CONCLUSIONS

The detailed analysis was carried out on the RAP material and Black Cotton Soil to understand their properties and effect on the pavement design. Based on the study, following conclusions can be drawn:

- Liquid Limit and Plastic limit tests carried on black cotton soil determined that black cotton soil belongs to the CH (Highly Plastic Clayey Soil) category. Compaction test depicted that the Optimum Moisture Content (OMC) increases with the increase in Maximum Dry Density (MDD) but up to certain limit. The dry density sharply decreases when the value of moisture content increases beyond 24.2%. The CBR value of the soil is 1.98% which is very low and needs improvement for the design of pavement.
- It is necessary to evaluate the characteristics of RAP material for using it as component in the pavement design. The Centrifuge Extraction test resulted in 3.31% of bituminous content; conducted on the RAP material. The Grain size analysis resulted in 20mm average size of aggregate in the RAP.
- Altering the characteristics of soil, by the addition of stabilizer (RAP material) in suitable dosage as per IS: 2720 (Part 7), the MDD value obtained at 30% soil and 70% RAP is 2.065 at OMC equal to 11.79%.
- To improve the value of CBR, test on various proportions of soil and RAP are carried out. The maximum CBR value is obtained at 70% soil and 30% RAP which is equal to 4.09%. This shows that the combination of 70% soil and 30% RAP gives the maximum value of CBR and can be used for pavement design as per IRC:37 -2012.
- The general pavement design having DBM and Base layers have a thickness of 599 mm. But with the use of treated RAP layer, the thickness reduces to 465 mm. The DBM and Base layers are replaced by Treated RAP layer as the design traffic volume is low on the road.

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