# Stabilization Of Pavement Material Using Waste Brick Kiln Dust

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## ABSTRACT

This paper throws light on the suitability of waste Brick Kiln Dust (BKD) as soil stabilizer for use in pavement. The role of brick kiln dust in improving the characteristics of expansive subgrade material and other sub base material is analyzed. The amount of cost savings for a pavement when it is stabilized with brick kiln dust is also studied.

Initially, the physical properties of clay, brick kiln dust and red soil have been studied by conducting wet sieve analysis, Liquid Limit (LL) and Plastic Limit (PL) tests. Then, for the purpose of determining the strength of virgin and stabilized materials, California Bearing Ratio (CBR) test have been conducted.

The results of the experimental research show that brick kiln dust can effectively be used as a soil stabilizer for both subgrade and sub base layers as the CBR value of both is increased. A considerable amount of cost savings is also possible when the expansive clay soil is stabilized with BKD.

## 1. INTRODUCTION



Infrastructure projects such as highways, railways, water reservoirs, reclamation etc. require earth material in very large quantity [1]. Quite often, large areas are covered with highly plastic and expansive soil, which is not suitable for such purpose.

The problem of expansive soils is a worldwide one that poses several challenges for Civil Engineers. They can cause extensive damage to structures if not adequately treated [2]. Extensive laboratory / field trials carried out by various researchers have shown promising results for application of such expansive soil after stabilization with additives / stabilizers [3].

Ultimately, the main reason for using stabilization will usually be cost savings [4]. The Engineer is trying to build a problem-free pavement that will last for its intended design life for the most economic price [5]. The cost savings associated with stabilization can take many forms including reduced construction costs, reduced maintenance costs throughout the life of the pavement or an extension of the normal pavement life [6].

With growing environmental consciousness at all levels of society, the pollution caused by the brick industry is coming under close scrutiny from environmentalists and the government [7]. In order to minimize the rate of air pollution caused due to the emission of brick kiln dust [8], it can be effectively used as a stabilizing agent for expansive soils like clay. On the whole, the CBR value of subgrade and sub base layers will be increased when brick kiln dust is used as a stabilizing agent for pavement materials.

## 2. EXPERIMENTAL STUDY

Highly expansive clay has been collected from Ganapathy area in Coimbatore city. Brick kiln dust has been collected from brick kiln units in Kalapanaickanpalayam in Coimbatore city. The physical properties of clay, red soil and brick kiln dust have been studied by conducting wet sieve analysis, liquid limit and plastic limit tests.

Optimum proportion of brick kiln dust to be mixed with clay (subgrade) and red soil (sub base) has been arrived at so as to have a mix with a Plasticity Index (PI) of 6% or less. Optimum moisture content has been found out by carrying out Standard Proctor Compaction Test (SPCT). The change in strength of clay and red soil after being mixed with brick kiln dust has been determined by conducting CBR test. Based on the test results, flexible pavement has been designed with and without buffer layer and the percentage of cost savings of stabilized pavement with respect to unstabilized pavement is arrived.

## 3. TEST RESULTS

The results of classification tests conducted on the various materials used in the present study are given in table 1:

| Material | Grain size distribution | | | Liquid limit (%) | Plastic limit (%) | Plasticity index (%) | IS classification |
|---|---|---|---|---|---|---|---|
| | Gravel (%) | Sand (%) | Fines (%) | | | | |
| Clay | 0 | 16 | 84 | 51 | 42 | 9 | CH |
| Red soil | 18 | 56 | 26 | 45 | 30 | 15 | SM |
| BKD | 0 | 82 | 18 | Non - plastic | | 0 | SM |

Table 1. Classification test results



### 3.1. Optimum proportion of brick kiln dust to be mixed with clay and red soil

Liquid limit tests have been conducted for various trial proportions of clay and BKD and optimum quantity of BKD to be mixed with clay is found out such that liquid limit of the mix is not more than 30%. The results of liquid limit tests performed on various mixes are given in table 2:

| Proportion of clay with BKD | Liquid limit (%) |
|---|---|
| 80:20 | 48 |
| 50:50 | 40 |
| 40:60 | 30 |

Table 2. Liquid limit tests on mixes

The table 2 shows that a mix of clay and BKD in the proportion of 40:60 yields a liquid limit of 30%.

Liquid limit and plastic limit tests have been conducted for various trial proportions of red soil and BKD and optimum quantity of BKD to be mixed with red soil is found out such that plasticity index of the mix is not more than 6%. The results of plasticity index tests performed on various mixes are given in table 3:

| Proportion of red soil : BKD | Liquid limit (%) | Plastic limit (%) | Plasticity index (%) |
|---|---|---|---|
| 100:0 | 45 | 35 | 10 |
| 60:40 | 26 | 18 | 8 |
| 50:50 | 16 | 11 | 5 |

Table 3. Plasticity index tests

From the above results, the optimum proportion of Red soil:BKD is found to be 50:50

### 3.2. Standard Proctor Compaction Test

The objective of Standard Proctor Compaction Test is to determine the optimum moisture content so that it could be used for compacting the pavement material in the CBR mould. The results of the tests are given in Fig. 1 to 4.

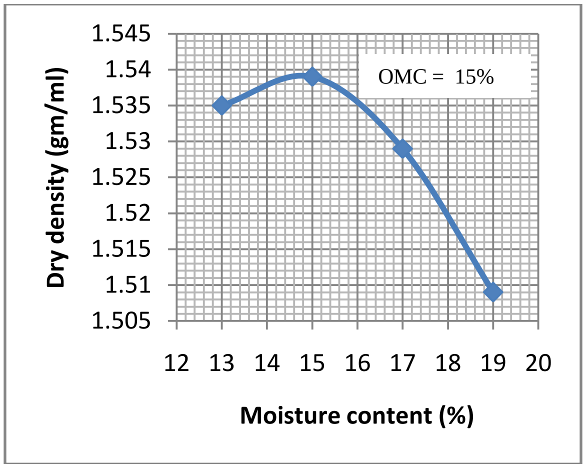


Fig.1. SPCT on clay

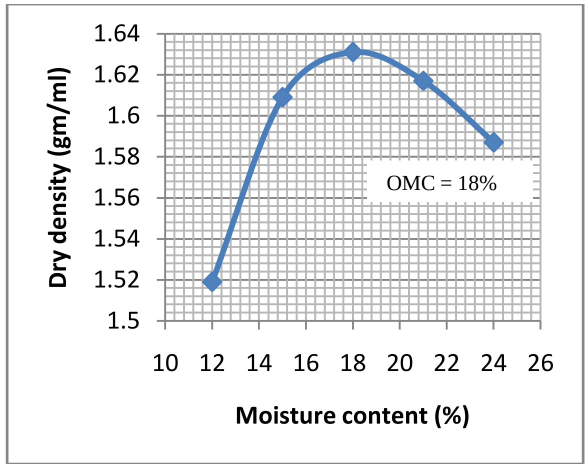


Fig.2. SPCT on clay + BKD



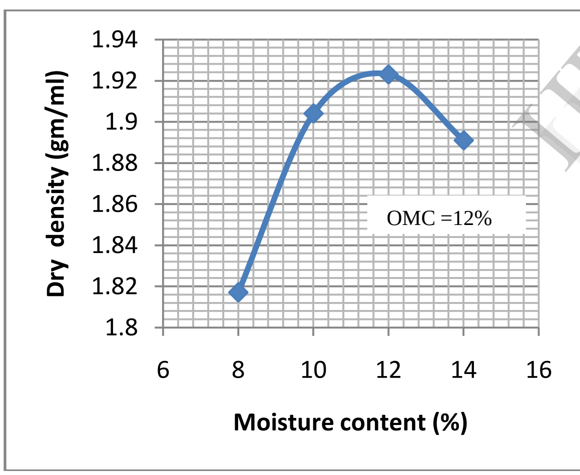


Fig.3. SPCT on red soil

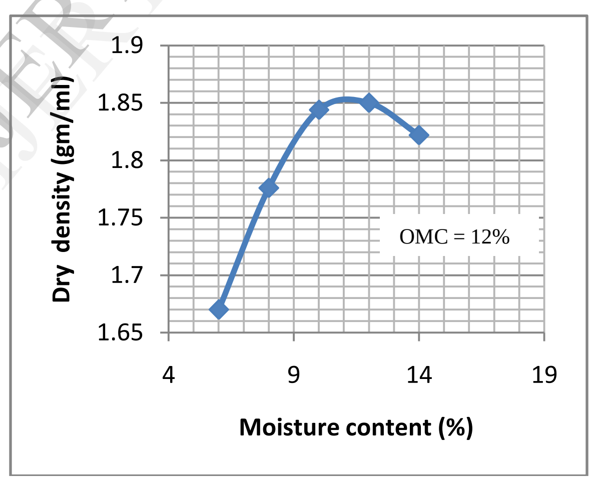


Fig.4. SPCT on red soil + BKD

### 3.3. California Bearing Ratio test

The California Bearing Ratio (CBR) test is a penetration test meant for the evaluation of strength of pavement material. For the design of flexible pavement as per IRC:37-2001 [10], the CBR values of various components of the pavement are used. The results of the CBR tests are presented from fig. 5 to 8

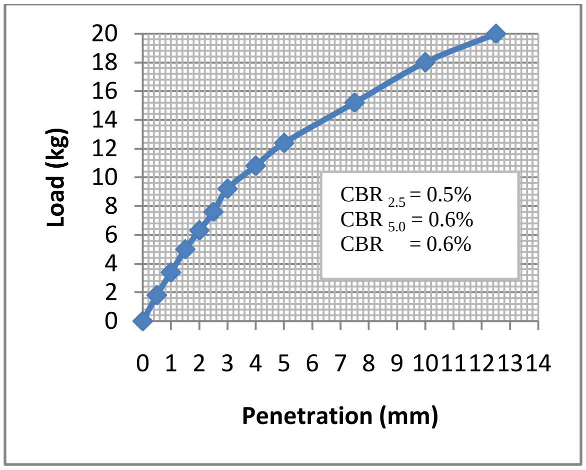


Fig.5. CBR test on clay

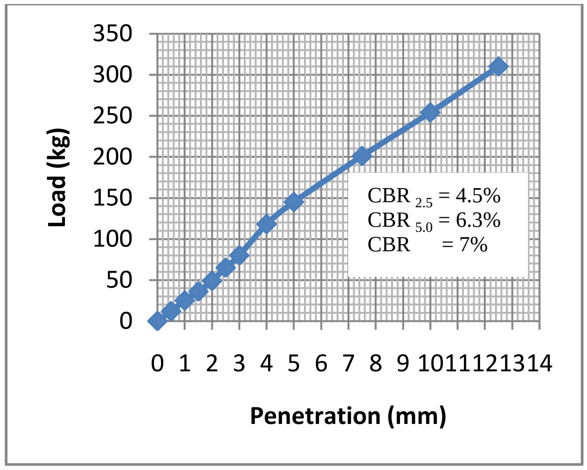


Fig.6. CBR test on clay + BKD

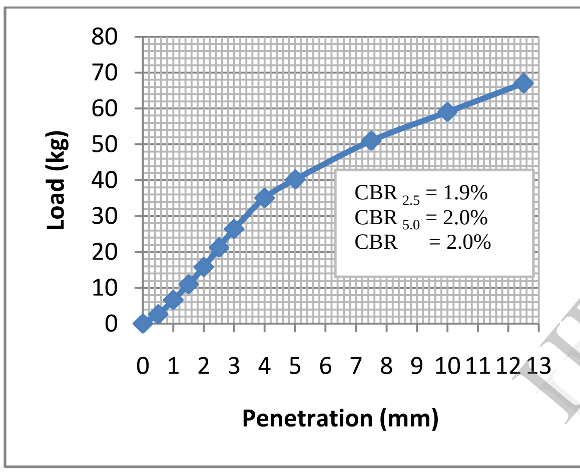


Fig.7. CBR test on red soil

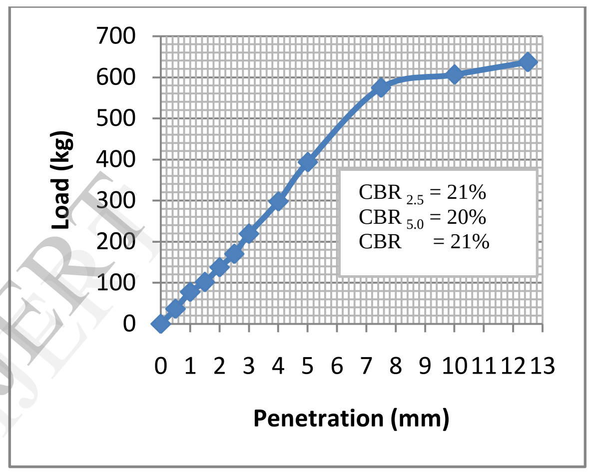


Fig.8. CBR test on red soil + BKD

## 4. DESIGN OF FLEXIBLE PAVEMENT

### 4.1 Pavement design with buffer layer

As per clause 4.2.1.5 of IRC: 37-2001, the subgrade must have a minimum CBR value of 2%. When highly expansive soil is present as a subgrade material, buffer layer having thickness ranging from 0.6m to 1.0m needs to be provided. The first step in pavement design is to estimate the cumulative number of standard axles to be catered for the design, which is calculated as follows:

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

Where,

N = Cumulative number of standard axles to be catered for the design in terms of msa

A = Initial traffic in the year of completion of construction in terms of number of commercial vehicles per day (cv/day)

D = Lane distribution factor (As per clause 3.3.5.1 of IRC37:2001, assumed as 1)

F = Vehicle damage factor (As per clause 3.3.4.4 of IRC37:2001, assumed as 1.5)

n = Design life in years (As per clause 3.3.3.2 of IRC37:2001, assumed as 15 years)
r = Annual growth rate of commercial vehicles (As per clause 3.3.2.2 of IRC37:2001, assumed as 7.5%)
The initial traffic in the year of completion of construction can be calculated as,

$$A = P\,(1+r)^x$$

Where,
P = number of commercial vehicles as per last count (assumed as 120)
x = number of years between last count and year of completion of construction (assumed as 2 years). Substituting the respective values, A = 139 and N = 2 msa

From plate 1 of IRC37:2001, for the minimum CBR value of 2%, the total pavement thickness is 715mm. The recommended pavement structure is given in fig. 9:

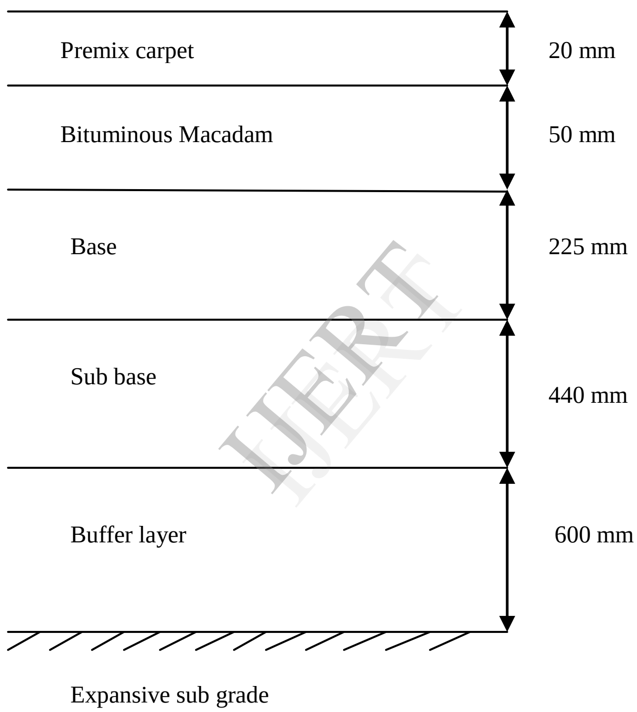


Fig.9. Pavement structure with buffer layer

### 4.2 Pavement design without buffer layer

Since the treated subgrade is not only less expansive (LL < 35%) but also has an enhanced CBR of 6%. From plate 1 of IRC37:2001, for the CBR value of 6%, total thickness of the pavement is 450mm. The recommended structure of the pavement is given in Fig. 10

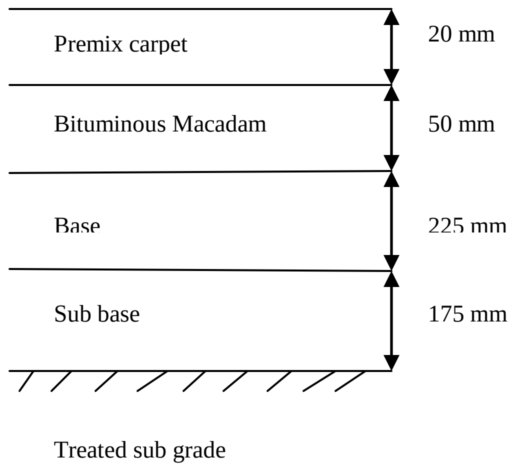


Fig.10. Pavement structure without buffer layer

## 5. COST ESTIMATION

The quantity of various materials and cost of pavement per unit area for pavement structure with buffer layer are given in tables 5.1 and 5.2 respectively.

Table 5.1. With buffer layer – calculation of quantities



| S.No | Particulars of items of works | No | Length (m) | Width (m) | Depth (m) | quantity |
|---|---|---|---|---|---|---|
| 1 | Compaction of subgrade | 1 | 1 | 1 | 0.5 | 0.5$m^3$ |
| 2 | Buffer layer | 1 | 1 | 1 | 0.6 | 0.6$m^3$ |
| 3 | Sub base layer | 1 | 1 | 1 | 0.440 | 0.440$m^3$ |
| 4 | Base | 1 | 1 | 1 | 0.225 | 0.225$m^3$ |
| 5 | BM | 1 | 1 | 1 | 0.050 | 0.050$m^3$ |
| 6 | Premix carpet | 1 | 1 | 1 | - | 1$m^2$ |

Table 5.2. With buffer layer – abstract of cost

| S.No | Particulars of items of works | Qty | Unit | Rate | | Per | Amount | |
|---|---|---|---|---|---|---|---|---|
| | | | | Rs | Ps | | Rs | Ps |
| 1 | Compaction of subgrade | 0.5 | $m^3$ | 120 | 00 | $m^3$ | 60 | 00 |
| 2 | Buffer layer | 0.6 | $m^3$ | 300 | 00 | $m^3$ | 180 | 00 |
| 3 | Sub base layer | 0.440 | $m^3$ | 600 | 00 | $m^3$ | 264 | 00 |
| 4 | Base | 0.225 | $m^3$ | 1100 | 00 | $m^3$ | 247 | 50 |
| 5 | BM | 0.050 | $m^3$ | 6000 | 00 | $m^3$ | 300 | 00 |
| 6 | Premix carpet | 1 | $m^2$ | 30 | 00 | $m^2$ | 30 | 00 |
| Total cost = Rs.1081.50 | | | | | | | | |

Similarly, the quantity of various materials and cost of pavement per unit area for pavement structure without buffer layer are given in tables 5.3 and 5.4 respectively.

5.3. Without buffer layer – calculation of quantities

| S.No | Particulars of items of works | No | Length (m) | Width (m) | Depth (m) | quantity |
|---|---|---|---|---|---|---|
| 1 | Compaction of subgrade | 1 | 1 | 1 | 0.5 | $0.5m^3$ |
| 2 | Sub base layer | 1 | 1 | 1 | 0.175 | $0.175m^3$ |
| 3 | Base | 1 | 1 | 1 | 0.225 | $0.225m^3$ |
| 4 | BM | 1 | 1 | 1 | 0.050 | $0.050m^3$ |
| 5 | Premix carpet | 1 | 1 | 1 | - | $1m^2$ |

5.4. Without buffer layer – abstract of cost

| S.No | Particulars of items of works | Qty | Unit | Rate | | Per | Amount | |
|---|---|---|---|---|---|---|---|---|
| | | | | Rs | Ps | | Rs | Ps |
| 1 | Compaction of subgrade | 0.5 | $m^3$ | 150 | 00 | $m^3$ | 75 | 00 |
| 2 | Sub base layer | 0.175 | $m^3$ | 600 | 00 | $m^3$ | 105 | 00 |
| 3 | Base | 0.225 | $m^3$ | 1100 | 00 | $m^3$ | 247 | 50 |
| 4 | BM | 0.050 | $m^3$ | 6000 | 00 | $m^3$ | 300 | 00 |
| 5 | Premix carpet | 1 | $m^2$ | 30 | 00 | $m^2$ | 30 | 00 |
| Total cost = Rs.757.50 | | | | | | | | |

Comparison of table 5.2 and 5.4 shows a cost reduction of 30% when the expansive subgrade is treated with BKD.



## 6. CONCLUSION

From the test results and cost estimation, the following conclusions have been made:

1. The stabilization process of clay and red soil with Brick Kiln Dust is very effective.
2. The CBR value of clay is increased from 0.6% to 6% and that of red soil is increased from 2% to 21%.
3. Addition of BKD to expansive subgrade not only reduces expansive nature of subgrade but also increases its CBR value.
4. Reduction of expansive nature of subgrade eliminates buffer layer and increase of CBR value reduces the overall thickness of pavement.
5. Elimination of buffer layer and reduction of overall thickness of pavement offsets the cost and mixing cost of Brick Kiln Dust with clay so much that a reduction in overall cost of 30% is effected.

## REFERENCES

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