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# A Comparative Study B/W Black Cotton Soil and Alluvial Soil for Economical Pavement Design by Lime & Fly-Ash Stabilization

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**ABSTRACT**
As we know the road development is one of the major parts of growing infrastructure & Pune, which is expanding at a very fast rate, the construction of roads is of major concern. Fly Ash is one of the abundant forms of Solid Waste produced at thermal power plants. Its disposal is a big problem keeping both these concerns in mind it was tried to come out with a project which will integrate Road development and Fly ash disposal. Thus, in this project we intend to use Fly ash & Lime in roads which will help us in following manner:

- High volumes of Fly ash will be used which will save the dumping sites to be used for better purposes.
- The use of fly ash will reduce the consumption of high volumes of fertile soil that can be used for cultivation purposes.
- Due to binding properties of lime & Fly ash, the pavement designed will be of higher strength.
- Overall thickness of the pavement can be reduced.

Two types of soils were used in this project, namely Alluvial Soil and Black Soil taken from nearby Pune.
***Keywords* –** Fly Ash, Lime, Pavements, Alluvial Soil, Black Cotton Soil, Solid waste

## I. AIM AND OBJECTIVES

1. To analyze the characteristics soils of Pune.
2. To analyze the characteristics of fly ash collected from Nasik Thermal Power Station.
3. To study the effect of soil properties after mixing flyash and lime with soil in different percentage.
4. To find the percentage saving in material in case of stabilized soil as compare to that of the natural soil.

## II. INTRODUCTION

### 2.1 About Maharashtra (study Region):

Maharashtra is a state located in West India. Maharashtra encompasses an area of 308,000 km² (119,000 mi²), and is the third largest state in India. The Western Ghats better known as Sahyadri, are a hilly range running parallel to the coast, at an average elevation of 1,200 metres (4,000 ft). To the west of these hills lie the Konkan coastal plains, 50–80 kilometres in width. To the east of the Ghats lies the flat Deccan Plateau.

There are many multi-state irrigation projects in development, including Godavari River Basin Irrigation Basin. The plateau is composed of black basalt soil, rich in humus. This soil is well suited for cultivating cotton, and hence is often called black cotton soil.Western Maharashtra, which includes the districts of Nashik, Ahmadnagar, Pune, Satara, Solapur, Sangli and Kolhapur, is a prosperous belt famous for its sugar factories. Farmers in the region are economically well off due to fertile land and good irrigation.

### 2.2 Soil Types in Maharashtra:

1. Black soil
2. Red Sandy Soil
3. Yellow and red soil
4. Coastal Alluvial soil

1. Black Cotton Soils :-
   In this region soils have high shrinkage and swelling characteristics. The shearing strength of the soils is extremely low. The soils are highly compressible and have very low bearing capacity. It is extremely difficult to work with such soils.
2. Red Sandy Soil :-
   In this region of study red sandy soils are soft and can be cut with a chisel when wet. However these harden with time. The plasticity of the red sandy soils decreases with depth as they approach the parent rock. These soils especially those which contain iron oxide have relatively high specific gravity.
3. Yellow and Red Soils –
   They are less clayey and sandier and are poor in important minerals like lime, phosphorous and nitrogen. Red soil is acidic like that of the Lateritic soil. This soil is mainly cultivated during the monsoon rainy season.
4. Coastal Alluvial Deposits: -
   The extent of coastal alluvial plains is controlled in large part by sea level, and alluvium deposited during previous times of low sea level (for example, during glacial epochs) may now lay tens or hundreds of meters below sea level.

## III. DESIGN APPROACH

### 3.1 Existing Design Approach

In the first edition of IRC:SP:20-2002, Rural Roads Manual the traffic parameter for pavement design is evaluated in terms of commercial vehicles per day, grouping together the heavy commercial vehicles like trucks, full-sized buses etc. with the much lighter commercial vehicles like tractors/tractors-trailers, pick-up vans, mini buses, tempos etc. The percentage of loaded, unloaded and overloaded commercial vehicles have not been considered in the traffic parameter[1].

The sub-grade strength parameter is evaluated in terms of 4-day soaked CBR values except in areas with annual rainfall less than 500 mm and where the water table is 'too deep'.

A set of pavement design curves A,B,C and D for traffic categories 0-15, 15-45, 45-150 and 150-450 CVPD have been provided as also design catalogues with minimum base course thickness of 150 mm for curves A and B and minimum base course thickness of 225 mm for curves C and D . The sub-base course thickness has been arrived at by subtracting the minimum base course thickness from the total pavement thickness requirement, obtained from the pavement design curves.

### 3.2 Recommended Design Approach

For purpose of pavement' structural design in this Design Manual, the low volume rural roads are divided into the following categories.

a) Gravel/Aggregate-surfaced roads (Unpaved Roads,)
b) Flexible Pavements (Paved Roads) and
c) Rigid Pavements.

The international experiences, for the past several decades, with Gravel roads notably in the USA show that the maximum traffic level up to 100,000 Equivalent Standard Axle Load (ESAL) applications can be considered for Gravel Roads, while the practical minimum level(during a single performance period) is 10,000. Below ESAL applications of 10,000 even Earth roads are suitable.

Gravel is defined as a mix of stone, sand and fine sized particles used as a sub bases, base or surfacing on a road, the material specifications for use in these layers being available in clauses 401 and 402 of the MORD Specification for Rural Roads. When the required gradation of gravel is not available in a natural form, the blending of naturally occurring materials in the required proportions may be resorted to.

For low volume rural roads, still carrying a sizeable volume of truck and bus traffic, the maximum number of ESAL applications considered for flexible or rigid pavement is up to 1 million ESAL applications (2). The practical minimum traffic level for a flexible or rigid pavement is about 50,000 ESAL applications during a single performance period.

The pavements designs presented in the Manual for both, gravel and flexible pavements (the rigid pavements designs are dealt with separately) are performance based drawing on the extensive experience in the U.S.A. on low volume road design, as brought out in the AASHTO Guide for Design of pavements structures (2).

The thickness of gravel aggregate - surface roads (unpaved roads) has been based on the following criteria:-

(i) The serviceability loss over the design life is limited to 2.0 taking the initial serviceability index to be 4.0 just before opening the road to traffic, and the terminal serviceability of 2.0 when rehabilitation will be due with or without provision of an overlay.
(ii) The allowable depth of rutting under 3 m straight edge does not generally exceed 50 mm.

The design traffic parameter has been expressed in terms of the cumulative 80 KN 18, 16 tones. ESAL applications during the design life. Seasonal variations by way of enhanced traffic during the harvesting season have also been considered[3].

For the evaluation of sub grade strength for new roads, selection of moisture content has been dealt with scientifically instead of always insisting on 4 -day soaked CBR values for the rehabilitation or up gradation of existing rural roads, the use of Dynamic Cone penetrometer (DCP) (mm/blow) has also been recommended for in situ subgrade strength evaluation.

### 3.3 Salient Features of Recommended Design

Some of the more important features of the recommended designs are as under.

- Pavement designs for new roads as well as for the up gradation / rehabilitation of existing roads have been included.
- The recommended designs aim is maximizing the use of locally available materials.
- A simple procedure has been detained for carrying out traffic counts. Computing the ADT and the number of ESAL applications during the design life, selected as 10 years.
- Categorizing the sub grade strength in 5 classes and classifying the traffic into 7 ranges has simplified the presentation of design catalogues for both gravel roads and flexible pavements.
- The importance of monitoring the long term performance of rural roads constructed with the recommended designs, by way of periodically carrying out condition surveys cannot be overemphasized.

## IV. MIX DESIGN AND PROPORTIONING

1. The mix with optimum proportion of (lime+flyash) to soil and also ratio by weight of lime to fly ash should first be decided in the laboratory by trial and error. The same should be adopted in the field.

2. The proportions of lime; fly ash and soil in the total mixture expressed in parts by dry weight.
3. Thus if the ratio : L : FA is 1 : 4 : the designation by parts may be
   i. **Lime : 3 parts**
   ii. **Fly ash : 12 parts**
   iii. **Soil : 85 parts**
   iv. **Total** (cm **dry wt. basis)=100**
4. Experience suggests that lime-fly ash ratios of 1:3 to 1:4 give optimum strength for various soil types suitable for lime-fly ash soil stabilization. Further increase in lime content does not indicate a proportionate increase in strength. Lime plus fly ash content ranging between 10 and 30 per cent by weight of the total dry mixture has been found to be suitable. Lime fly ash requirements, in fact, depend upon the percentage of fines in the total mix. Fine cohesive silts require a higher percentage of (lime-f fly ash) compared to well-graded soils. Strength development calls for sufficient matrix material (fines) to fill the voids in coarse materials.
4. The exact proportions of the ingredients viz. lime, fly ash and soil, to be adopted at a particular location should be based on the laboratory mix design depending upon the strength requirement. The minimum unconfined compressive strength and CBR values after 28 days curing and 4 days soaking should be 7.5 $kg/cm^2$ and 25 per cent respectively. In terms of seven days curing and four days soaking, the minimum unconfined compressive strength and CBR values should be 3 $kg/cm^2$ and 10 per cent respectively. The curing maybe done at a temperature ranging from 30°C to 38°C.
5. Trial mixes using (lime-fly ash) ratios of 1:2, 1:3, 1:4, are initially prepared. The following overall proportions may accordingly be used for preparing the mixtures for laboratory tests :
   a. ***Ratio Overall proportions by parts (L: FA: Soil)***
   b. 1:2 2.5 : 5 : 92.5
   c. 1:3 2.5 :7.5 : 90
      i. 4 : 12 : 84
      ii. 5 : 15 : 80
   d. 1:4 2 : 8 : 90
      i. 3 : 12 : 85
      ii. 4 : 16: 80
   e. Additional trials may be made if required. Amounts of lime quantity smaller than two per cent are generally not amenable to proper mixing and hence not recommended.
6. 7.5. Each of the mixes suggested above shall be subjected to laboratory compaction tests in accordance with the procedure laid down in IS: 2720 (Part VIII) using Heavy Compaction effort. The values of the maximum Dry Density and Optimum Moisture Content (OMC)[13] shall be scaled out from the plot in each case.
7. Either the unconfined compression or the CBR test may be employed for the determination of strength of the compacted soil lime fly ash mix depending on the design requirement[15]. In the case of the former test, specimens of the mix compacted at OMC anal with the same amount of compaction effort shall be prepared, cured for 28 days at a temperature ranging from 30°C to 38$^{C}$C and maintaining constant moulding moisture, and finally tested for unconfined compressive strength as per IS: 2720 (Part X). The specimen size may be 50 mm dia x 100 mm height in the case of fine grained and sandy materials or 100 mm diameter x 200 mm height for larger particle size mixtures (prepared after rejecting the par tides larger than 20 mm in size). Alternatively, the CBR test shall be carried out in the same way by curing samples for 7 days or 28 days, with 4 days soaking as the case may be in accordance with the provisions of IS:2720 (Part XVI-1965). The results of tests shall then be plotted using the compressive strength or CBR and the lime fly ash soil ratios as the two axes. The ratio corresponding to the Minimum Strength Requirement as specified will be adopted and the one which suggests minimum quantity of lime or the one which, according to detailed cost analysis, works out to be the most economical shall finally be selected. Specimen samples using the same proportions, prepared in the same manner will be tested for compressive strength or CBR for verification and confirmation. The maximum dry density (corresponding to heavy compaction effect) at which the soil- lime-fly ash mixture is finally prepared to be remoulded shall be called 'Control Density'.

## V. CONSTRUCTION OPERATIONS

### 5.1 Preparation of Sub grade

All irregularities beyond the permitted tolerance should be rectified. The road bed shall be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water if necessary and rolled with 8-10 tone smooth wheeled rollers. Soft and yielding spots and ruts, if present, should be corrected and rolled until firm.

### 5.2 Weather Limitations

Lime-fly ash-soil stabilization should not be done when the air temperature in the shade is less than 10°C.

### 5.3 Batching and Mixing

Volume batching may be permitted only when it is unavoidable. The materials before being mixed together shall be thoroughly pulverized. Pulverization may be done either by making use of mechanical plants or manually by means of rotary tillers, disc harrows, crow bars, pick axes, bullock drawn ploughs, etc.

**5.4 Tolerance**

Limits of tolerance, for various materials in percentage by weight are as follows:

| | | |
|---|---|---|
| **Lime** | ± | **0.3** |
| **Fly Ash** | ± | **1.5** |
| **Soil/ Aggregate** | ± | **2.0** |

**5.5 Plant for Construction**

Before deploying the plant, the soil after it is made free of undesirable and deleterious matter shall be spread uniformly on the prepared road bed in a quantity sufficient to achieve the desired compacted thickness of the stabilized layer. When single pass equipment is to be employed, the soil shall be rolled lightly. The plant used shall either be of single-pass or multiple-pass type. With single-pass equipment the forward speed of the machine shall be so selected in relation to the rotor speed that the required degree of mixing, pulverization and depth of processing is obtained.

In multi-pass processing, the soil on the prepared road bed shall be pulverized to the required depth with successive passes of the plant and the moisture content adjusted to be within prescribed limits. The mixing plant shall be so set that it cuts slightly into the edge of the adjoining lane processed previously so as to ensure that all the material forming a layer has been properly processed for the full width.

**5.6 Construction with Manual Means**

Where manual mixing is permitted, the soil from borrow areas shall first be freed of all vegetation and other deleterious matter and placed on the prepared road bed. The soil shall then be pulverized by means of crow-bars, pick axes or other approved means. Water in requisite quantities may be sprinkled on the soil for aiding pulverization. On the pulverized soil, stabilizing materials) in requisite quantities shall be spread uniformly and mixed dry thoroughly by working with spades or other similar implements till the whole mass is mixed uniform and homogenous.

For all the three methods the maximum thickness of individual compacted layer shall not exceed 100 mm. The materials and their proportion shall be arranged, keeping this requirement in view. As the minimum thickness of lime fly ash soil layer has been prescribed as 150 mm, the same shall be laid in two layers. Before laying the second layer the compacted first layer shall be roughened to ensure proper bond between the layers.

**5.7 Moisture Content for Compaction**

The moisture content at compaction shall not be less than the optimum moisture content corresponding to IS: 2720 (Part VII) nor more than 2 per cent above it.

**5.8 Rolling**

Immediately after spreading, grading and leveling of the mixed material, compaction shall be carried out with 8 to 10 tonne smooth wheel rollers or other approved plant, preceded by a few passes of lighter rollers if necessary. Rolling shall commence at edges and progress towards the centre, except at super elevated portions where it shall commence at the inner edge and progress towards outer. During rolling the surface shall be frequently checked for grade and camber and any irregularities corrected by loosening the material and removing or adding fresh material. Compaction shall continue until the density achieved is at least 100 per cent of the maximum dry density for the material determined in accordance with IS: 2720 (Part VII).

Care shall be taken to see that the compaction of lime stabilized material is completed within four hours of its mixing or such shorter period as may be found necessary in dry weather.

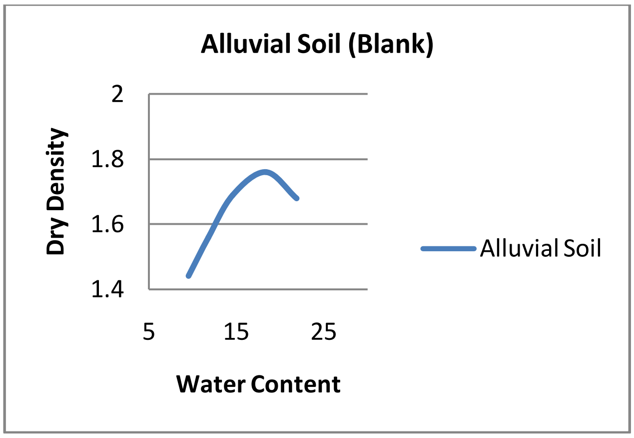
**5.9 Construction Joint**

No joints except construction joints shall be provided. At the end of the day's work, a straight tapering transverse construction joint for full width of the course shall be made by chamfering the edge of the already laid mix at an angle of about 30°. Before resuming work at any construction joint left at the end of previous work, the material at the joint shall be scarified and moistened, blended with new mixture and compacted to form a continuous section without a joint.

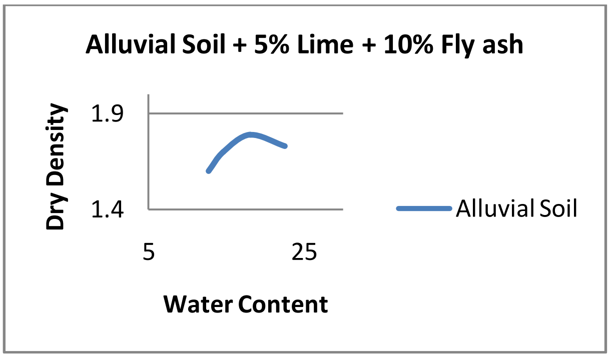
## VI. TEST RESULTS

Various tests have been performed on two different types of soil samples with different proportions of Fly-Ash and Lime. Test results are as follows:

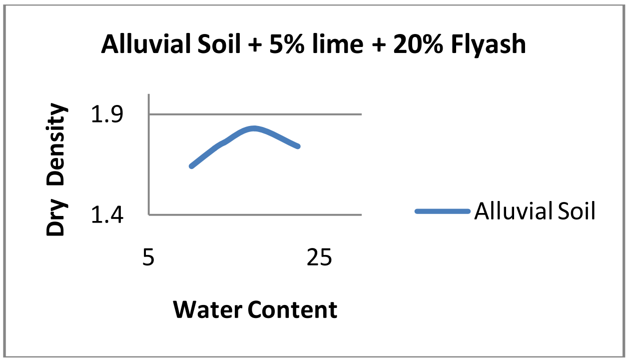
| **Alluvial Soil** | |
|---|---|
| **Water Content**[11] | **Dry Density** |
| 9.54 | 1.44 |
| 11.81 | 1.56 |
| 14.58 | 1.69 |
| 18.34 | 1.76 |
| 21.875 | 1.68 |



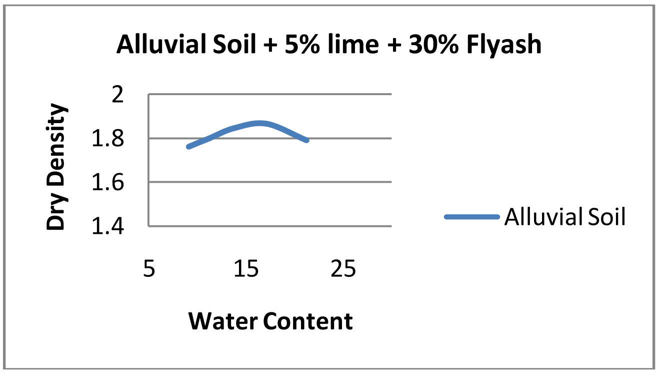

| Alluvial Soil + 5% lime + 10% Fly ash | |
|---|---|
| **Water Content** | **Dry Density** |
| 12.69 | 1.6 |
| 14.58 | 1.7 |
| 18.04 | 1.79 |
| 22.5 | 1.73 |



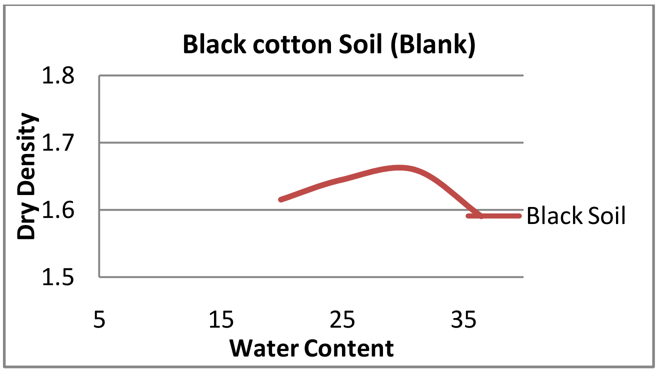

| Alluvial Soil + 5% lime + 20% Flyash | |
|---|---|
| **Water Content** | **Dry Density** |
| 10 | 1.64 |
| 12.69 | 1.73 |
| 13.83 | 1.76 |
| 17.42 | 1.83 |
| 22.5 | 1.74 |



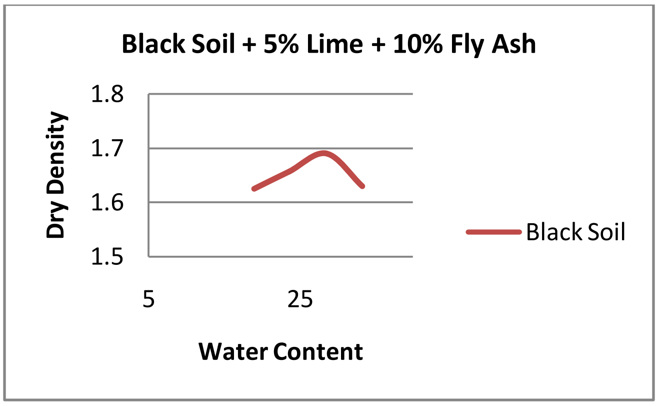

| Alluvial Soil + 5% lime + 30% Fly ash | |
|---|---|
| **Water Content** | **Dry Density** |
| 9.165 | 1.76 |
| 11.25 | 1.8 |
| 13.8 | 1.845 |
| 17.125 | 1.865 |
| 21.25 | 1.79 |



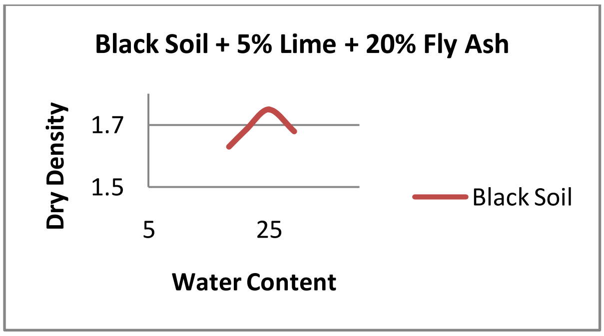

| Black Cotton Soil | |
|---|---|
| **Water Content** | **Dry Density** |
| 20 | 1.615 |
| 25 | 1.645 |
| 30.95 | 1.66 |
| 36.5 | 1.59 |



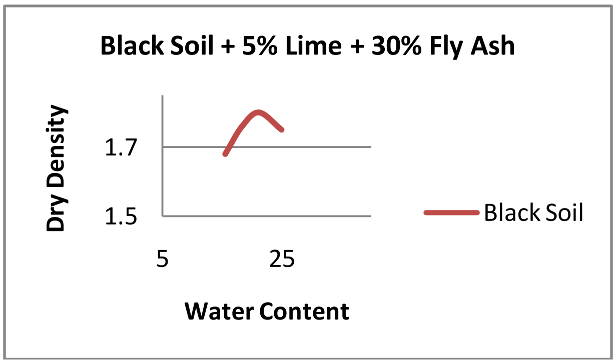

| Black cotton Soil + 5% Lime + 10% Fly Ash | |
|---|---|
| **Water Content** | **Dry Density** |
| 19 | 1.625 |
| 23.61 | 1.657 |
| 28.57 | 1.69 |
| 33.33 | 1.63 |



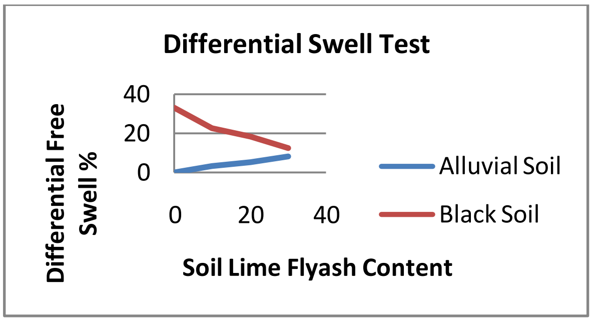

| Black Soil + 5% Lime + 20% Fly Ash | |
|---|---|
| **Water Content** | **Dry Density** |
| 18.34 | 1.63 |
| 21.25 | 1.685 |
| 25 | 1.75 |
| 29.165 | 1.68 |



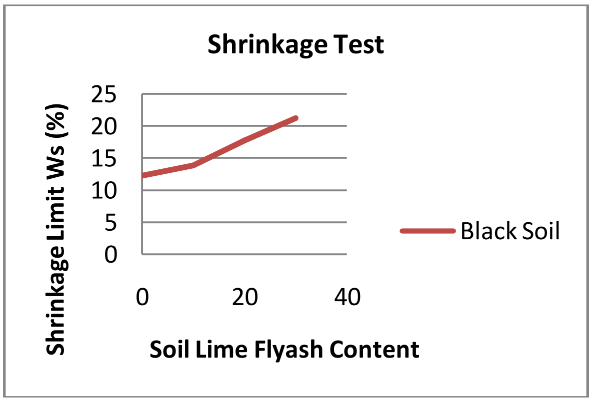

| Black Soil + 5% Lime + 30% Fly Ash | |
|---|---|
| **Water Content** | **Dry Density** |
| 15.475 | 1.68 |
| 18.335 | 1.76 |
| 21.25 | 1.8 |
| 25 | 1.75 |



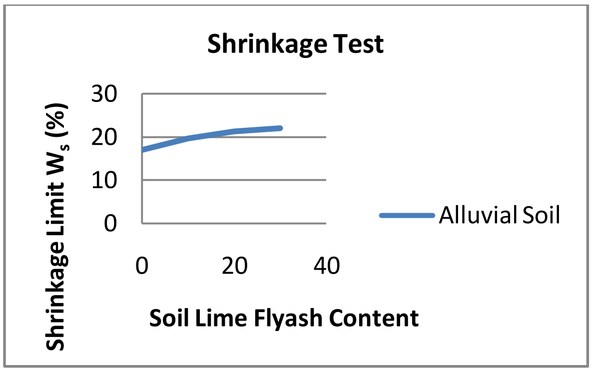

| Differential Swell Test | | |
|---|---|---|
| Percentage | **Alluvial Soil** | **Black Cotton Soil** |
| 0 | 0 | 33.33 |
| 10 | 3.48 | 22.8 |
| 20 | 5.18 | 18.3 |
| 30 | 8.33 | 12.5 |



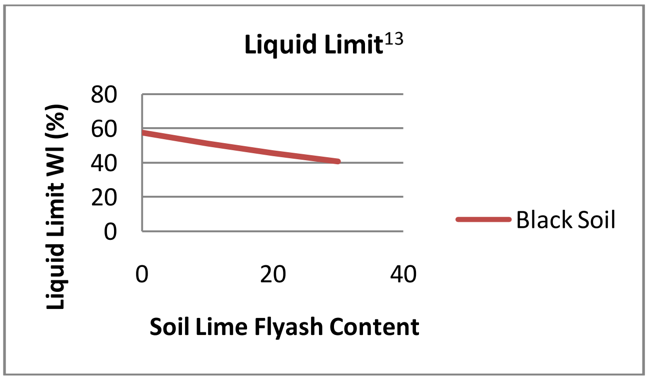

| Black Cotton Soil | |
|---|---|
| **Percentage** | **Shrinkage Limit** |
| 0 | 12.3 |
| 10 | 13.9 |
| 20 | 17.7 |
| 30 | 21.28 |



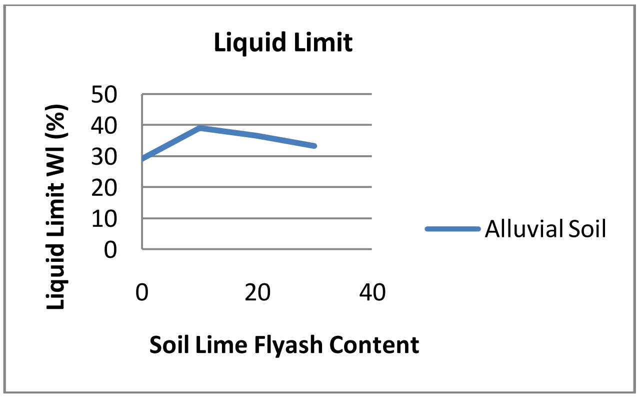

| Alluvial Soil | |
|---|---|
| **Percentage** | **Shrinkage Limit** |
| 0 | 17 |
| 10 | 19.7 |
| 20 | 21.4 |
| 30 | 22.1 |



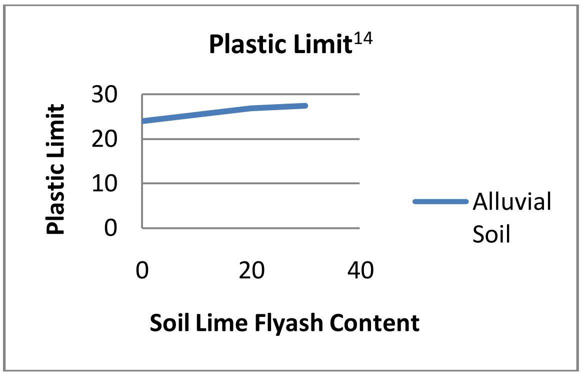

| Black Cotton Soil | |
|---|---|
| **Percentage** | **Liquid Limit** |
| 0 | 57.7 |
| 10 | 51.2 |
| 20 | 45.5 |
| 30 | 40.8 |



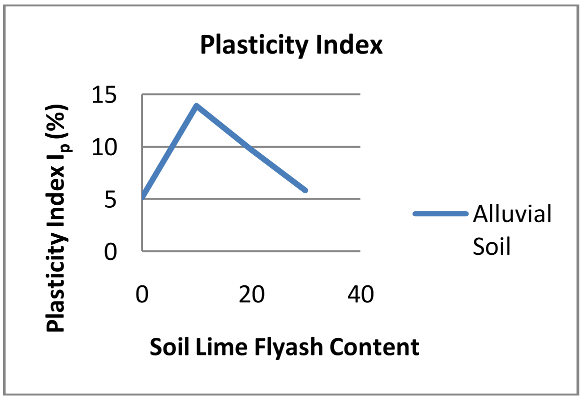

| Alluvial Soil | |
|---|---|
| **Percentage** | **Liquid Limit** |
| 0 | 29.2 |
| 10 | 39.04 |
| 20 | 36.6 |
| 30 | 33.3 |



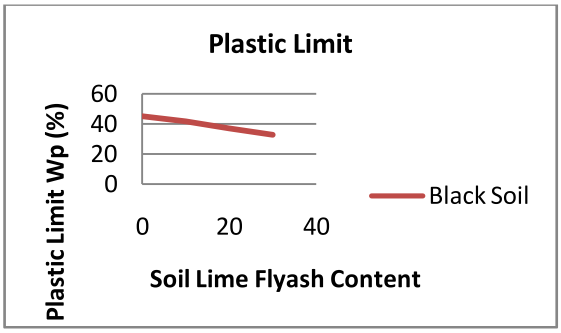

| Alluvial Soil | |
|---|---|
| **Percentage** | **Plastic Limit** |
| 0 | 24.01 |
| 10 | 25.5 |
| 20 | 26.83 |
| 30 | 27.47 |



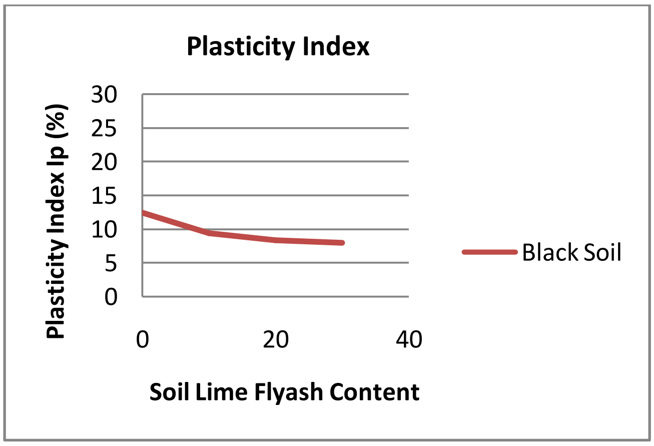

| Alluvial Soil | |
|---|---|
| **Percentage** | **Plasticity Index** |
| 0 | 5.19 |
| 10 | 13.9 |
| 20 | 9.77 |
| 30 | 5.83 |




| Black Cotton Soil | |
|---|---|
| **Percentage** | **Plastic Limit** |
| 0 | 45.21 |
| 10 | 41.83 |
| 20 | 37.14 |
| 30 | 32.81 |

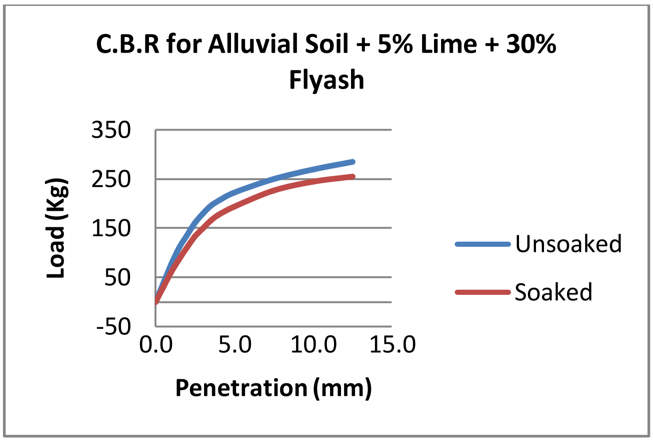



| Black Soil | |
|---|---|
| **Percentage** | **Plasticity Index** |
| 0 | 12.49 |
| 10 | 9.37 |
| 20 | 8.36 |
| 30 | 7.99 |



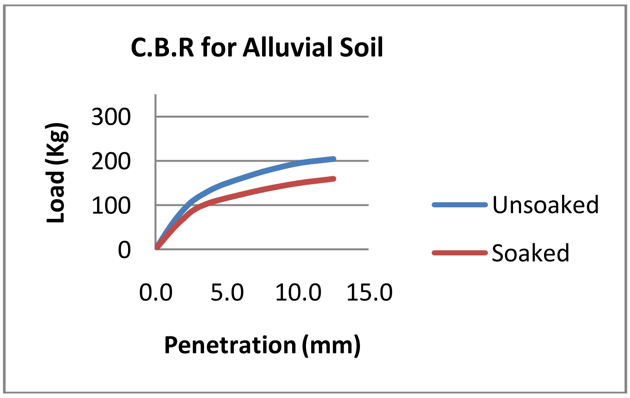

**C.B.R for Alluvial Soil + 5% Lime + 30% Fly ash**

| Penetration | Load (Unsoaked) | Load (Soaked) |
|---|---|---|
| 0.0 | 0 | 0 |
| 0.5 | 37 | 30 |
| 1.0 | 75 | 60 |
| 1.5 | 110 | 87 |
| 2.0 | 135 | 110 |
| 2.5 | 160 | 132 |
| 3.0 | 180 | 150 |
| 3.5 | 195 | 165 |
| 4.0 | 205 | 177 |
| 5.0 | 222 | 194 |
| 7.5 | 250 | 227 |
| 10.0 | 270 | 245 |
| 12.5 | 285 | 255 |

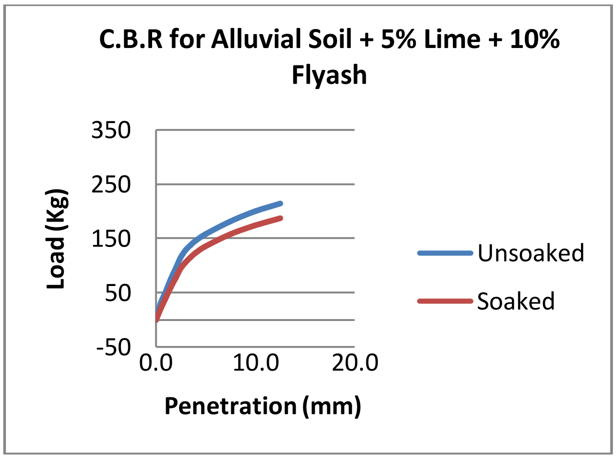



**C.B.R for Alluvial Soil**

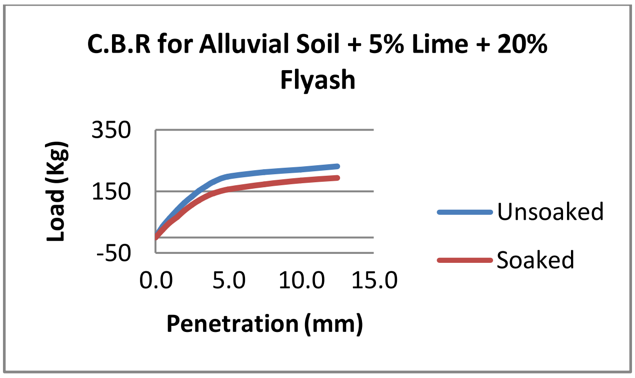
| Penetration | Load (Unsoaked) | Load (Soaked) |
|---|---|---|
| 0.0 | 0 | 0 |
| 0.5 | 25 | 20 |
| 1.0 | 50 | 38 |
| 1.5 | 72 | 55 |
| 2.0 | 90 | 70 |
| 2.5 | 106 | 84 |
| 3.0 | 118 | 94 |
| 3.5 | 128 | 102 |
| 4.0 | 136 | 108 |
| 5.0 | 150 | 116 |
| 7.5 | 175 | 135 |
| 10.0 | 195 | 150 |
| 12.5 | 205 | 160 |



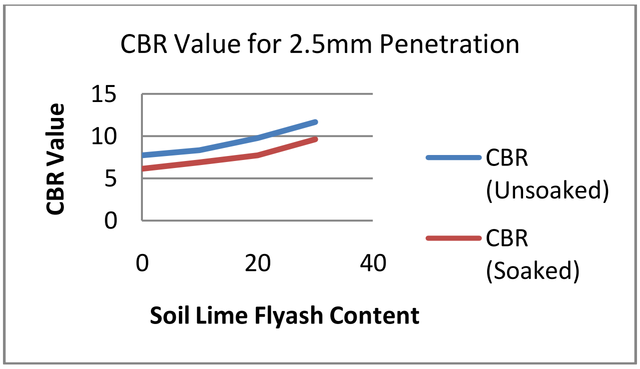
| C.B.R for Alluvial Soil + 5% Lime + 10% Fly ash | | |
|---|---|---|
| **Penetration** | **Load (Unsoaked)** | **Load (Soaked)** |
| 0.0 | 0 | 0 |
| 0.5 | 30 | 20 |
| 1.0 | 52 | 40 |
| 1.5 | 75 | 60 |
| 2.0 | 96 | 78 |
| 2.5 | 114 | 94 |
| 3.0 | 128 | 106 |
| 3.5 | 138 | 116 |
| 4.0 | 146 | 124 |
| 5.0 | 158 | 136 |
| 7.5 | 182 | 158 |
| 10.0 | 200 | 174 |
| 12.5 | 214 | 188 |



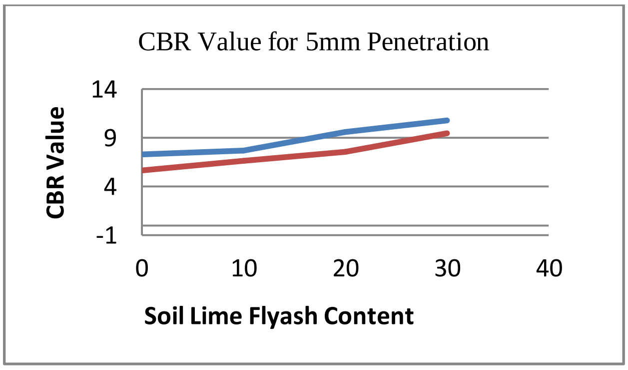

| C.B.R for Alluvial Soil + 5% Lime + 20% Flyash | | |
|---|---|---|
| **Penetration** | **Load (Unsoaked)** | **Load (Soaked)** |
| 0.0 | 0 | 0 |
| 0.5 | 36 | 25 |
| 1.0 | 64 | 48 |
| 1.5 | 90 | 68 |
| 2.0 | 114 | 88 |
| 2.5 | 134 | 106 |
| 3.0 | 152 | 122 |
| 3.5 | 168 | 134 |
| 4.0 | 182 | 144 |
| 5.0 | 198 | 156 |
| 7.5 | 212 | 174 |
| 10.0 | 222 | 186 |
| 12.5 | 232 | 194 |



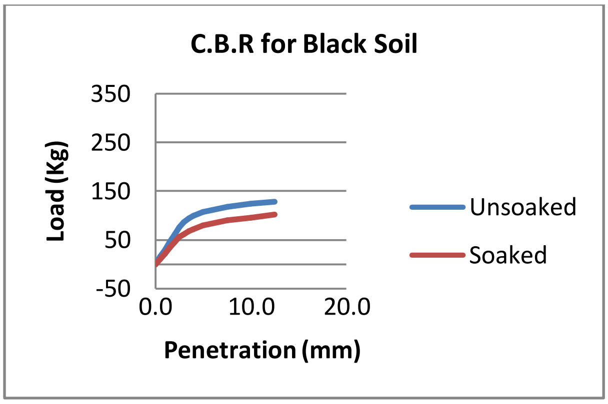

| CBR Value for 2.5mm Penetration | | |
|---|---|---|
| **Percentage** | **CBR (Unsoaked)** | **CBR (Soaked)** |
| 0 | 7.73 | 6.13 |
| 10 | 8.32 | 6.86 |
| 20 | 9.78 | 7.73 |
| 30 | 11.67 | 9.63 |



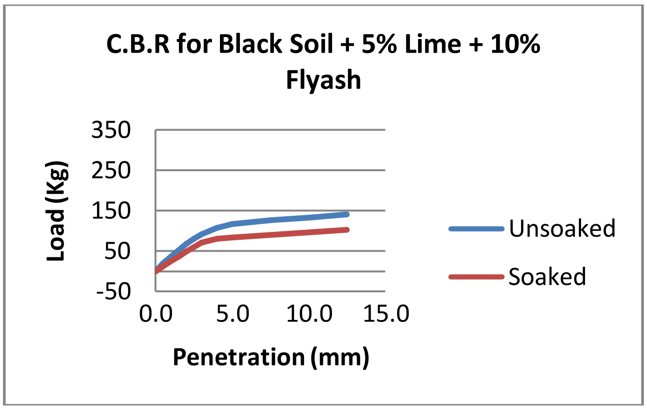

| CBR Value for 5mm Penetration | | |
|---|---|---|
| **Percentage** | **CBR (Unsoaked)** | **CBR (Soaked)** |
| 0 | 7.29 | 5.64 |
| 10 | 7.68 | 6.61 |
| 20 | 9.6 | 7.59 |
| 30 | 10.8 | 9.44 |



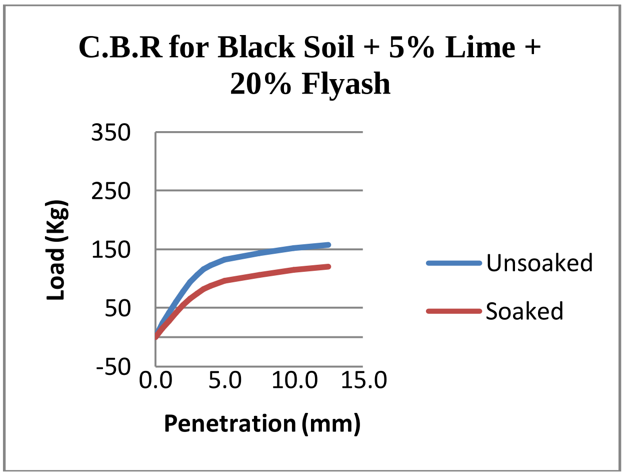
| C.B.R for Black Soil | | |
|---|---|---|
| Penetration | Load (Unsoaked) | Load (Soaked) |
| 0.0 | 0 | 0 |
| 0.5 | 15 | 10 |
| 1.0 | 30 | 22 |
| 1.5 | 45 | 34 |
| 2.0 | 62 | 46 |
| 2.5 | 76 | 56 |
| 3.0 | 86 | 62 |
| 3.5 | 94 | 68 |
| 4.0 | 100 | 72 |
| 5.0 | 108 | 80 |
| 7.5 | 118 | 90 |
| 10.0 | 124 | 96 |
| 12.5 | 128 | 102 |



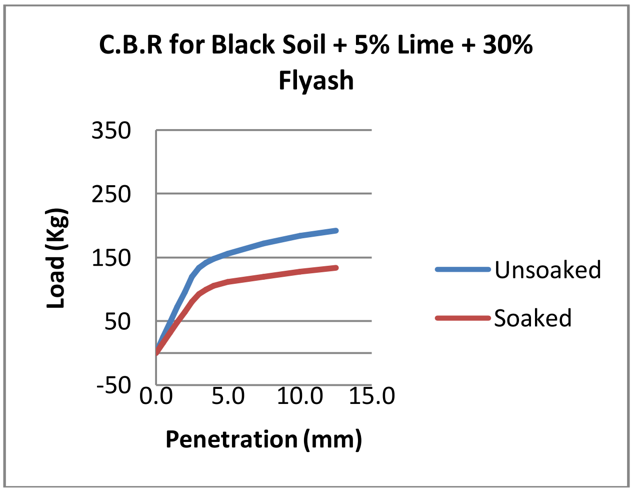

| C.B.R for Black Soil + 5% Lime + 10% Fly ash | | |
|---|---|---|
| Penetration | Load (Unsoaked) | Load (Soaked) |
| 0.0 | 0 | 0 |
| 0.5 | 20 | 12 |
| 1.0 | 36 | 24 |
| 1.5 | 52 | 36 |
| 2.0 | 68 | 48 |
| 2.5 | 81 | 60 |
| 3.0 | 92 | 70 |
| 3.5 | 100 | 76 |
| 4.0 | 108 | 80 |
| 5.0 | 116 | 84 |
| 7.5 | 126 | 90 |
| 10.0 | 132 | 96 |
| 12.5 | 140 | 102 |



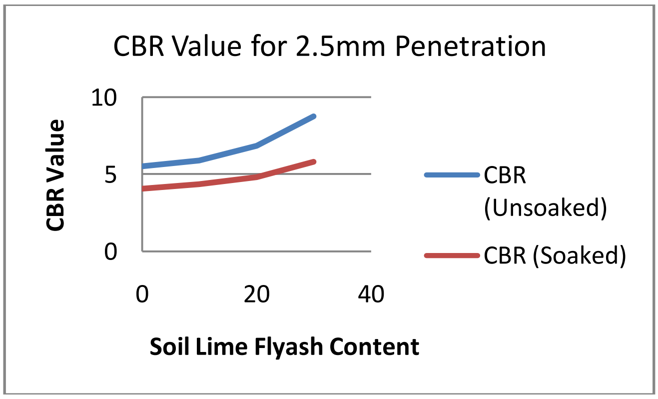

| C.B.R for Black Soil + 5% Lime + 20% Fly ash | | |
|---|---|---|
| Penetration | Load (Unsoaked) | Load (Soaked) |
| 0.0 | 0 | 0 |
| 0.5 | 24 | 15 |
| 1.0 | 42 | 28 |
| 1.5 | 60 | 42 |
| 2.0 | 78 | 55 |
| 2.5 | 94 | 66 |
| 3.0 | 106 | 75 |
| 3.5 | 116 | 82 |
| 4.0 | 123 | 88 |
| 5.0 | 132 | 96 |
| 7.5 | 144 | 106 |
| 10.0 | 152 | 115 |
| 12.5 | 158 | 120 |



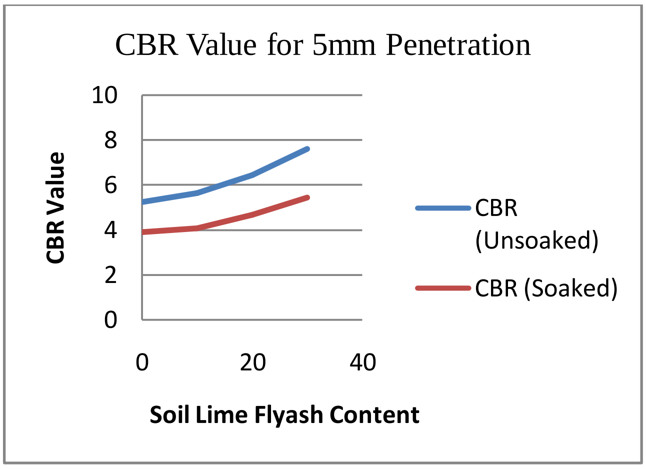
| C.B.R for Black Soil + 5% Lime + 30% Flyash | | |
|---|---|---|
| **Penetration** | **Load (Unsoaked)** | **Load (Soaked)** |
| 0.0 | 0 | 0 |
| 0.5 | 25 | 16 |
| 1.0 | 48 | 32 |
| 1.5 | 72 | 48 |
| 2.0 | 95 | 64 |
| 2.5 | 120 | 80 |
| 3.0 | 134 | 92 |
| 3.5 | 142 | 100 |
| 4.0 | 148 | 106 |
| 5.0 | 156 | 112 |
| 7.5 | 172 | 120 |
| 10.0 | 184 | 128 |
| 12.5 | 192 | 134 |




| CBR Value for 2.5mm Penetration | | |
|---|---|---|
| **Percentage** | **CBR (Unsoaked)** | **CBR (Soaked)** |
| 0 | 5.54 | 4.08 |
| 10 | 5.91 | 4.37 |
| 20 | 6.86 | 4.81 |
| 30 | 8.759 | 5.83 |




| CBR Value for 5mm Penetration | | |
|---|---|---|
| **Percentage** | **CBR (Unsoaked)** | **CBR (Soaked)** |
| 0 | 5.25 | 3.89 |
| 10 | 5.64 | 4.08 |
| 20 | 6.42 | 4.67 |
| 30 | 7.59 | 5.45 |




## VII. RESULTS OF SOILS USED

The soil samples have been investigated at Geotechnical Laboratory in our college for various Engineering properties. The results of the various routine tests and strength characteristics of soils found during investigations have already been mentioned above.

- The liquid limit, plastic limit & plasticity Index varies for Alluvial soil ranges from 29.20 to 39.04, 24.01 to 27.47 and 5.19 to 13.90 respectively.
- The liquid limit, plastic limit & plasticity Index varies for Black Soil ranges from 40.80 to 57.70, 32.81 to 45.21 and 7.99 to 12.49 respectively.
- The optimum moisture content of the Alluvial soil varies between *17.125%* to *18.04%* while maximum dry density varies between 1.76 gm/ cc to 1.865 gm/ cc.
- The optimum moisture content of the Black soil varies from *21.25%* to *30.95%* while maximum dry density varies from 1.66 gm/ cc to 1.8 gm/ cc.
- The CBR values for Alluvial Soil ranges between 7.73% to 11.67% for 2.5 mm penetration and 7.29% to 7.68% for 5 mm penetration in unsoaked condition.
- CBR values for Alluvial Soil in soaked condition for 96 hours ranges from 6.13% to *9.63%* for 2.5 mm penetration and *5.64% to 9.44%* for 5 mm penetration.
- The CBR values for Black Soil ranges between *5.54% to 8.759%* for 2.5 mm penetration and

*5.25% to 7.59%* for 5 mm penetration in un-soaked condition.

- CBR values for Black Soil in soaked condition for 96 hours ranges from 4.08% to *5.83%* for 2.5 mm penetration and *3.89% to 5.45%* for 5 mm penetration.

## VIII. CONCLUSIONS

With the use of Fly Ash and Lime in Alluvial soil & Black Cotton Soil, there is a great change in Index properties. It further leads towards stabilization of soil. With the help of this stabilization of soil, pavements can be designed economically such that sub-base thickness can be reduced with varying percentage of Fly Ash and Lime.

## IX. SUGGESTIONS / RECOMMENDATIONS

1. Based on the above conclusions it can be suggested that the natural soil of Pune should be stabilized with Fly ash & Lime on the commercial basis.
2. The lime & fly ash together act as a better stabilizing material.
3. Since the more percentage reduction in pavement thickness has been achieved, by mixing Fly ash & Lime but use of it in highways and rural roads will certainly yield in terms of economy because a large amount of fly ash can be shifted from thermal power plants and a great problem of its disposal as well as environmental pollution would be solved.
4. The sites used for dumping fly ash can be used for better purposes.

## X. SCOPE OF FUTURE INVESTIGATION

1. Effects of Fly ash to contamination of underground water.
2. Natural soil has been stabilized with fly ash and lime. Percentage of mixing these stabilizing materials should be extended to get the optimum minimum thickness of pavement for economical design of pavement.

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