International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.7, pp 01-17, 2015

# CBR and UCC Strength Characteristics of Expansive Soil Subgrade Stabilized with Industrial and Agricultural Wastes

**C.Rajakumar[1], Dr.T.Meenambal[2]**

[1] Department of Civil Engineering, Karpagam College of Engineering, Coimbatore-641032, Tamilnadu, India
[2]Department of Geotechnical Engineering, Government College of Technology, Coimbatore-641013, Tamilnadu, India

**Abstract:** An infrastructure project for instance highways, railways, water reservoirs, reclamation etc., requires earth material in very huge quantity. In urban areas, borrow earth is not easily available which has to be hauled from an elongated distance. Fairly often large areas are covered with highly plastic and clayey soil, which is not suitable for such purpose. Extensive laboratory and field trials have been carried out by various researchers and have shown promising results for application of such expansive soil after stabilization with traditional stabilizing agents such as cement, lime, bitumen etc. The growing cost of traditional stabilizing agents and the need for the economical utilization of industrial and agricultural wastes has prompted an investigation into the stabilizing prospective of coal ash, groundnut shell ash and bagasse ash in highly expansive soil.
In this study, an attempt has been made to utilize the industrial and agricultural wastes such as coal ash, groundnut shell ash and bagasse ash as stabilizing agent. The effect of industrial and agricultural wastes under equal proportioning on certain properties of soil such as Optimum Moisture Content, Maximum Dry Density, Unconfined Compressive Strength (UCC) and California Bearing Ratio (CBR) has been studied under both light and heavy compaction. It has been observed that 12%C.A + 12%GSA, 16%C.A + 16%B.A and 16%B.A + 16%GSA are the optimum percentage combinations, which give the maximum CBR value. The CBR value increased from 1.63% for native soil to 7.87%, 6.79% and 7.88% for respective combinations. The proportion increase was found to be 382.82%, 316.56% and 383.44%.
**Keywords:** Expansive soil, Coal ash, Bagasse ash, Groundnut shell ash, CBR.

## 1. Introduction

The need to bring down the cost of waste disposal and the growing cost of soil stabilizers has led to intense global research towards economic utilization of wastes for engineering purposes. The safe disposal of industrial and agricultural waste products demands urgent and cost effective solutions because of the debilitating effect of these materials on the environment and to the health hazards that these wastes constitute. In order to make deficient soils useful and meet geotechnical engineering design requirements, researchers have focused more on the use of potentially cost effective materials that are locally available from industrial and agricultural wastes in order to improve the properties of poor soils. The over dependence on industrially manufactured soil improving additives (cement, lime, bitumen, etc) have kept the cost of construction of stabilized road economically high. This previously have continued to deter the underdeveloped and poor nations of the world from providing accessible roads to meet the need of their rural dwellers who constitute large percentage of their population which are mostly rural farmers. In addition, the World Bank has been expending substantial amount of money on research aimed at harnessing industrial waste products for further usage. Thus, the possible use of industrial and agricultural wastes (such as Coal Ash, Bagasse Ash and Groundnut Shell Ash) will considerably reduce the cost of construction and as well as reduce or eliminate the environmental hazards caused by such waste (1, 2, 3, 4 and 11).

Disposed coal ash is result from the residual of coal refinery processes and become environmental important issues. Coal ash consists of bottom ash (5-15%) and fly ash (85-95%). In engineering practice, utilization of coal ash is limited and in small quantity while the disposal of coal ash is quite high (1). In our country there are about 130 thermal power plants, producing around 100millions tones of fly ash as waste material .Since the fly ash is having pozzolanic property. it can be utilized as an alternative cementations' material in civil engineering applications. The disposal problem of fly ash can be avoided up to certain extent by using it for the construction of roads, airfields, and embankments and in fly ash brick industry etc.Sugar-cane bagasse is a fibrous waste-product of the sugar distillation industry, along with ethanol vapor. This waste product is already causing serious environmental pollution, which calls for vital ways of handling the waste.Bagasse ash mainly contains aluminum ion and silica (11)**.** Groundnut shell is an agricultural waste obtained from milling of groundnut. The ash from groundnut shell has been categorized under pozzolanic. The utilization of this pozzolanic as a replacement for traditional stabilizers will go a long way in actualizing the dreams of most developing countries of scouting for cheap and readily available construction materials. Groundnut shell ash has been used in concrete as a partial replacement material for cement with a measure of success achieved (2).

Problematic soils such as expansive soils are normally encountered in foundation engineering designs for highways, embankments, retaining walls, backfills etc. Expansive soils are normally found in semi – arid regions of tropical and temperate climate zones and are plentiful, where the annual evaporation exceeds the precipitation and can be found anywhere in the world. Expansive soils are also referred to as "black cotton soil" in some parts of the earth. They are so named because of their appropriateness for rising cotton. Black cotton soils have varying colors, ranging from light grey to dark grey and black. The mineralogy of this soil is dominated by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa. Deposits of black cotton soil in the field show a general pattern of cracks during the dry season of the year. Cracks measuring 70 mm wide and over 1 m deep have been observed and may extend up to 3m or more in case of high deposits .The three most commonly used stabilizer for expansive clays are bitumen, lime and cement. Researchers attempted to stabilize this soil have reported that the stabilization of this soil with bitumen, lime or cement is effective. Unfortunately, the costs of these stabilizers are on the high side making them economically unattractive as stabilizing agents. Current trend in research works in the field of geotechnical engineering and construction materials focuses more on the search for cheap and locally available materials such as industrial and agricultural wastes, etc. as stabilizing agents for the purpose of full or partially replacement of traditional stabilizers. Industrial and agricultural waste is increasingly becoming a focus of researchers because of the enhanced pozzolanic capabilities of such waste when oxidized by burning. Thus, this study is aimed at evaluating the possibility of utilizing industrial and agricultural wastes in the stabilization of black cotton soils (1, 2, 3, 4, 7, 8 and 11).

## 2. Methodology

This part explains about the works carried out in this study .The effect of Industrial and Agricultural wastes such as Coal ash, Bagasse ash and Groundnut shell ash under equal proportioning in the sub grade of flexible pavement system were studied under both light and heavy compaction.

### 2.1 Soil sample collection

Bulk soil samples for the analysis were collected from NH 47, ongoing four laning project of Chengapalli to Walayar, at 143chainage length of Nilambur, Coimbatore, Tamilnadu state, India. The project site was located 18$^{th}$ km from Coimbatore.

### 2.2 Material collection

Industrial and Agricultural wastes such as Coal ash, Bagasse ash and groundnut shell ash are the materials collected for this study. Coal ash were collected from Neyveli Lignite Corporation (NLC) Ltd, Neyveli,tamilnadu state, India, Bagasse ash were collected from Sakthi Sugars at Bhavani,tamilnadu state, India and Groundnut shell ash were collected form M/s Siva Kumar Groundnut and Oil Mills at Pollachi,tamilnadu state, India.

**2.3 Tests on materials**

Laboratory test were conducted in the Geotechnical laboratory with the collected soil sample to classify the soil, to evaluate its physical and engineering properties and to study the compaction characteristics. Proctor's Compaction tests, Modified Proctor's Compaction tests,UCC tests, CBR (unsoaked and soaked) tests were conducted on samples under equal proportioning with 0%, 4%, 8%, 12%,16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations. All the tests were conducted on samples prepared under both light and heavy energy of compaction. The Standard Proctor's Compaction tests were conducted on the soil samples to evaluate the Optimum Moisture Content and Maximum dry unit weight of samples under light energy of compaction. Similarly Modified Proctor's Compaction tests were conducted on the soil to evaluate the Optimum Moisture Content and Maximum dry unit weight of samples under heavy energy of compaction.UCC tests were conducted on soil samples to determine the UCC strength and cohesion. The samples were also analyzed for the CBR value under both unsoaked and soaked condition. Results obtained were compared. Conclusions were made based on the results obtained.

**3. Laboratory Investigation**

This elaborates the various physical and engineering properties of sub grade soil namely natural moisture content, specific gravity, liquid limit, plastic limit, shrinkage limit, grain size distribution, optimum moisture content, maximum dry density ,unconfined compressive strength and CBR Along with the mineral composition of Coal ash, Bagasse ash and Groundnut shell ash. All the tests were carried out as per IS codes.

**3.1 Soil sampling**

Representative soil samples were collected from NH47, Ongoing four laning project of Chengapalli to Walayar, at 143chainage length of Nilambur, Coimbatore, Tamilnadu state, India. The site which was located $18^{th}$ KM from Coimbatore. The soil used for analysis is cohesive soil predominantly clay.

**3.2 Properties of sub grade soil**

The properties of the subgrade soil were determined by conducting various laboratory tests such as

1. Moisture Content test
2. Specific Gravity test
3. Grain Size Distribution
4. Atterberg Limit test
5. Standard Proctor's Compaction test
6. Unconfined Compressive strength test
7. California Bearing Ratio test

**3.2.1 Atterberg limit test**

Liquid limit and Plastic Limit test were conducted as per IS: 2720 (Part 5) –1985. Shrinkage limit is determined as per IS: 2720 (Part 6) – 1972 and the soil is classified based on plasticity chart as per Bureau of Indian Standards. The values are shown in table 1.

**Table.1 Consistency values of the soil sample**

| S.No | Description | Result | Remarks |
|---|---|---|---|
| 1 | Liquid limit($w_L$) | 62.09% | - |
| 2 | Plastic limit($w_P$) | 27.04% | - |
| 3 | Shrinkage limit($w_S$) | 23.19% | - |
| 4 | Toughness index($T_I$) | 3.10 | ($T_I$) >1 Soil nor friable at plastic state |
| 5 | Flow index($F_I$) | 11.31 | - |

| | | | |
|---|---|---|---|
| 6 | Plasticity index($I_P$) | 35.05 | ($I_P$) >17 Highly plastic |
| 7 | Liquidity index($I_L$) | -0.39 | ($I_L$)<0 Very stiff |
| 8 | Consistency index($I_C$) | 1.39 | ($I_C$)>1 Very stiff |
| 9 | Soil Classification | CH | Clay of High compressibility |

**3.2.2 Standard proctors compaction test**

The optimum water content (OMC) and maximum dry density (MDD) is obtained by conducting Standard Proctor's Test as per IS: 2720 (Part 7) – 1980. The relation between moisture content and dry density is obtained from compaction test is given in table 2.

**3.2.3Modified Proctor's Compaction Test**

The optimum water content and maximum dry density is obtained by conducting Modified Proctor's Test as per IS: 2720 (Part 8) – 1980. The relation between moisture content and dry density is obtained from compaction test is given in table2.

**3.2.4 Unconfined compressive strength test**

The Unconfined Compressive Strength and Cohesion is obtained by conducting Unconfined Compressive Strength test. The test was conducted as per IS 2720(Part 10): 1991.The test were conducted on soil samples prepared under bothlight and heavy energy of compaction. The relation between stress and strain obtained as a result of Unconfined Compressive Strength test is reported in table 2.

**3.2.5 California bearing ratio test**

The CBR tests were conducted as per IS 2720(Part 16) -1987. The CBR test is conducted under samples prepared with both light and heavy energy of compaction under both unsoaked and soaked condition. The CBR value obtained as a result of both unsoaked and soaked CBR test in soil under both light and heavy compaction is given in the table 2.

The Various Properties of the subgrade soil is summarized in table 2.

**Table.2 Properties of subgrade soil summary**

| S. No | Test conducted | Properties | Results |
|---|---|---|---|
| 1 | Determination of Moisture Content | Moisture Content | 13.29% |
| 2 | Determination of Specific Gravity | Specific Gravity | 2.63% |
| 3 | Grain Size Distribution | Percentage of sand | 26.25% |
| | | Percentage of silt | 21.39% |
| | | Percentage of clay | 52.36% |
| 4 | Attreberg Limit | Soil classification | CH |
| 5 | Compaction Test (Light compaction) | Optimum Moisture Content | 24.83% |
| | | Maximum Dry density | 1.522 g/cc |
| 6 | Heavy compaction | Optimum Moisture Content | 15.71% |
| | | Maximum Dry density | 1.73 g/cc |
| 7 | Determination of Unconfined Compressive Strength (Light compaction) | Unconfined Compressive Strength | $0.126 N/mm^2$ |
| | | Cohesive strength | $0.063 N/mm^2$ |
| 8 | Heavy compaction | Unconfined Compressive Strength | $0.201 N/mm^2$ |
| | | Cohesive strength | $0.101 N/mm^2$ |
| 9 | Determination of California Bearing Ratio(Light compaction and unsoaked condition) | CBR | 2.45% |
| | Light compaction and soaked condition | CBR | 1.63% |

| | | | |
|---|---|---|---|
| 10 | Heavy compaction and unsoaked condition | CBR | 5.88% |
| | Heavy compaction and soaked condition | CBR | 2.44% |

### 3.3 Mineral Composition of Coal ash, Bagasse ash and Groundnutshell ash

The mineral composition of Coal ash, Bagasse ash and Groundnut shell ash are reported in the following table.

**Table.3 Mineral Composition of Coal ash**

| Mineral Composition | Bottom ash (%) | Fly ash (%) |
|---|---|---|
| Silica (SiO2) | 33.25 | 50.40 |
| Alumina ($Al_2O3$) | 21.41 | 16.57 |
| Iron Oxide ($Fe_2O3$) | 30.37 | 7.95 |
| Calcium Oxide(CaO) | 6.44 | 6.07 |
| Magnesium Oxide (MgO) | 2.78 | 4.51 |
| Potassium Oxide ($K_2O$) | 1.10 | 1.17 |
| Sodium Oxide ($Na_2O$) | 1.32 | 1.31 |
| Titanium Oxide ($TiO_2$) | 0.80 | 0.62 |
| Loss of Ignition(LOI) | 0.76 | 9.75 |
| Phosphorous ($P_2O5$) | 0.58 | 0.19 |
| Sulphur ($SO_3$) | 0.24 | 1.10 |

**Table.4 Mineral Composition of Bagasse ash**

| Mineral Composition | Bagasse ash (%) |
|---|---|
| Silica (SiO2) | 77.34 |
| Alumina ($Al_2O3$) | 9.55 |
| Iron Oxide ($Fe_2O3$) | 3.61 |
| Calcium Oxide(CaO) | 2.15 |
| Manganese Oxide (MnO) | 0.13 |
| Potassium Oxide (K2O) | 3.46 |
| Sodium Oxide ($Na_2O$) | 0.12 |
| Titanium Oxide ($TiO_2$) | 0.50 |
| Loss of Ignition(LOI) | 0.42 |
| Phosphorous ($P_2O5$) | 1.07 |
| Barrium Oxide (BaO) | 0.16 |

**Table .5.Mineral Composition of Groundnut shell ash**

| Mineral Composition | Groundnut shell ash (%) |
|---|---|
| Silica (SiO2) | 41.36 |
| Alumina ($Al_2O3$) | 6.73 |
| Iron Oxide ($Fe_2O3$) | 3.16 |
| Calcium Oxide(CaO) | 8.91 |
| Magnesium Oxide (MgO) | 5.72 |
| Potassium Oxide ($K_2O$) + Sodium Oxide ($Na_2O$) | 17.38 |
| Carbonite ions(CO3) | 7.02 |
| Sulphur (SO3) | 5.4 |

## 4. Experimental Study

The experimental study involves Standard Proctor's Compaction tests, Modified Proctor's Compaction test, Unconfined Compressive Strength test and California Bearing Ratio tests on soil sample with varying percentage under equal proportioning of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash, Bagasse ash + Groundnut shell ash combinations. All the tests were conducted with light and heavy energy of compaction.

### 4.1 Standard Proctor's Compaction tests

Standard Proctor's Compaction tests is conducted on soil samples under equal proportioning with 4%,8%,12%,16%,20% ofCoal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations to determine the optimum moisture content and maximum dry density of soil sample.

The optimum moisture content and maximum dry density of soil under equal proportioning with varying percentage of Coal ash+ Groundnut shell ash, Coal ash+ Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 6,7 and 8.

**Table.6 Standard Proctor's Compaction test results of soil+ Coal ash+ Groundnut shell ash (Light compaction)**

| **Percentage of C.A+GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| OMC % | 24.83 | 17.74 | 19.77 | 23.83 | 25.86 | 27.89 |
| MDD g/cc | 1.522 | 1.46 | 1.39 | 1.266 | 1.187 | 1.05 |

**Table.7 Standard Proctor's Compaction test results of soil+ Coal ash + Bagasse ash (Light compaction)**

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| OMC % | 24.83 | 19.77 | 23.83 | 27.89 | 31.95 | 33.92 |
| MDD g/cc | 1.522 | 1.094 | 1.003 | 0.927 | 0.868 | 0.814 |

**Table.8 Standard Proctor's Compaction test results of soil + Bagasse ash + Groundnut shell ash (Light compaction)**

| **Percentage of B.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| OMC % | 24.83 | 19.77 | 21.8 | 25.86 | 25.86 | 31.95 |
| MDD g/cc | 1.522 | 1.284 | 1.202 | 1.174 | 1.033 | 0.941 |

### 4.2 Modified Proctor's Compaction tests

Modified Proctor's Compaction tests is conducted on soil samples under equal proportioning with 4%,8%,12%,16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations to determine the optimum moisture content and maximum dry density of soil sample.

The optimum moisture content and maximum dry density of soil under equal proportioning with varying percentage of Coal ash+ Groundnut shell ash, Coal ash+ Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 9,10 and 11.

**Table.9 Modified Proctor's Compaction test results of soil+ Coal ash+ Groundnut shell ash**

| **Percentage of C.A+GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| OMC % | 15.71 | 17.74 | 21.8 | 23.83 | 25.86 | 27.89 |
| MDD g/cc | 1.73 | 1.68 | 1.53 | 1.41 | 1.32 | 1.27 |

**Table.10 Modified Proctor's Compaction test results of soil+ Coal ash + Bagasse ash**

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| OMC % | 15.71 | 19.77 | 21.8 | 23.83 | 23.83 | 25.86 |
| MDD g/cc | 1.73 | 1.55 | 1.43 | 1.312 | 1.284 | 0.939 |

**Table.11 Modified Proctor's Compaction test results of soil Bagasse ash + Groundnut shell ash**

| **Percentage of B.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| OMC % | 15.71 | 19.77 | 21.8 | 23.83 | 25.86 | 25.86 |
| MDD g/cc | 1.73 | 1.433 | 1.362 | 1.25 | 1.203 | 1.054 |

### 4.3 Unconfined Compressive Strength Tests (light compaction)

Unconfined Compressive Strength tests is conducted on soil samples prepared under light compaction to determine the unconfined compressive strength and cohesion of soil with varying percentage of Coal ash+Groundnut shell ash,Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations . The test is conducted on soil samples under equal proportioning with ,4%,8%,12%,16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations.

The UCC strength and cohesion of light compaction under Coal ash+ Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 12,13 and 14.

**Table.12 UCC strength test results of soil+ Coal ash+Groundnut shell ash (light compaction)**

| Percentage of C.A + GSA | 0% | 4% | 8% | 12% | 16% | 20% |
|---|---|---|---|---|---|---|
| UCC $N/mm^2$ | 0.126 | 0.174 | 0.211 | 0.258 | 0.247 | 0.264 |
| Cohesion $N/mm^2$ | 0.063 | 0.087 | 0.1055 | 0.129 | 0.124 | 0.132 |

Table.13 UCC strength test results of soil+ Coal ash + Bagasse ash(light compaction)

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| UCC $N/mm^2$ | 0.126 | 0.145 | 0.173 | 0.184 | 0.176 | 0.173 |
| Cohesion $N/mm^2$ | 0.063 | 0.073 | 0.0867 | 0.092 | 0.088 | 0.087 |

**Table.14 UCC strength test results of soil Bagasse ash + Groundnut shell ash(light compaction)**

| **Percentage of B.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| UCC $N/mm^2$ | 0.126 | 0.163 | 0.198 | 0.234 | 0.262 | 0.255 |
| Cohesion $N/mm^2$ | 0.063 | 0.082 | 0.99 | 0.117 | 0.131 | 0.128 |

### 4.4 Unconfined Compressive Strength Tests (Heavy compaction)

Unconfined Compressive Strength tests is conducted on soil samples prepared under heavy compaction to determine the unconfined compressive strength and cohesion of soil with varying percentage of Coal ash+ Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations . The test is conducted on soil samples under equal proportioning with ,4%,8%,12%,16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations.

The UCC strength and cohesion of heavy compaction under Coal ash+ Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 15,16 and 17.

**Table.15 UCC strength test results of soil+ Coal ash+ Groundnut shell ash (heavy compaction)**

| **Percentage of C.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| UCC $N/mm^2$ | 0.201 | 0.258 | 0.2996 | 0.347 | 0.327 | 0.352 |
| Cohesion $N/mm^2$ | 0.1005 | 0.129 | 0.1498 | 0.174 | 0.164 | 0.176 |

**Table.16 UCC strength test results of soil+ Coal ash + Bagasse ash(heavy compaction)**

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| UCC $N/mm^2$ | 0.201 | 0.248 | 0.278 | 0.316 | 0.350 | 0.337 |
| Cohesion $N/mm^2$ | 0.1005 | 0.124 | 0.139 | 0.158 | 0.175 | 0.169 |

**Table.17 UCC strength test results of soil Bagasse ash + Groundnut shell ash (heavy compaction)**

| **Percentage of B.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| UCC $N/mm^2$ | 0.201 | 0.251 | 0.284 | 0.309 | 0.343 | 0.336 |
| Cohesion $N/mm^2$ | 0.1005 | 0.126 | 0.142 | 0.155 | 0.172 | 0.168 |

**4.5 Unsoaked California Bearing Ratio Tests (Light compaction)**

Unsoaked California Bearing Ratio Tests are conducted on soil samples prepared under Light compaction under unsoaked condition to determine CBR value of soil with varying percentage of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations. The test is conducted on soil samples with 4%,8%,12%,16%,20% of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations, to determine the optimum percentage of combinations.

The Un soaked CBR value of soil + Coal ash + Groundnut shell ash, Coal ash +Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 18,19 and 20.

**Table.18Unsoaked CBR test results of soil+ Coal ash + Groundnut shell ash (Light compaction)**

| **Percentage of C.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Un soaked CBR % | 2.45 | 6.796 | 7.88 | 8.97 | 8.698 | 9.24 |

**Table.19Un soaked CBR test results of soil+ Coal ash + Bagasse ash(Light compaction)**

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Un soaked CBR % | 2.45 | 6.11 | 6.93 | 7.34 | 7.48 | 7.07 |

**Table.20Un soaked CBR test results of soil+ Bagasse ash + Groundnut shell ash(Light compaction)**

| **Percentage of B.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Un soaked CBR % | 2.45 | 6.25 | 7.07 | 8.02 | 8.698 | 8.563 |

**4.6 Soaked California Bearing Ratio Tests (Light compaction)**

Soaked California Bearing Ratio Tests are conducted on soil samples prepared under Light compaction under soaked condition to determine CBR value of soil with varying percentage of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations. The test is conducted on soil samples with 4%,8%,12%,16%,20% of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations, to determine the optimum percentage of combinations.

The Soaked CBR value of soil + Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 21,22 and 23.

**Table.21 Soaked CBR test results of soil+ Coal ash + Groundnut shell ash (Light compaction)**

| **Percentage of C.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Soaked CBR % | 1.63 | 4.757 | 6.116 | 7.88 | 7.339 | 7.747 |

**Table.22 Soaked CBR test results of soil+ Coal ash + Bagasse ash(Light compaction)**

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Soaked CBR % | 1.63 | 3.81 | 5.165 | 6.524 | 6.796 | 6.524 |

**Table.23 Soaked CBR test results of soil+ Bagasse ash + Groundnut shell ash(Light compaction)**

| **Percentage of B.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Soaked CBR % | 1.63 | 4.35 | 5.71 | 6.524 | 7.883 | 7.475 |

**4.7 Unsoaked California Bearing Ratio Tests (Heavy compaction)**

Unsoaked California Bearing Ratio Tests are conducted on soil samples prepared under heavy compaction under unsoaked condition to determine CBR value of soil with varying percentage of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations. The test is conducted on soil samples with 4%,8%,12%,16%,20% of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations, to determine the optimum percentage of combinations.

The Un soaked CBR value of soil + Coal ash + Groundnut shell ash, Coal ash +Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 24,25 and 26.

**Table.24Un soaked CBR test results of soil+ Coal ash + Groundnut shell ash (Heavy compaction)**

| **Percentage of C.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Un soaked CBR % | 5.88 | 8.43 | 9.513 | 10.87 | 10.60 | 11.42 |

**Table.25 Un soaked CBR test results of soil+ Coal ash + Bagasse ash (Heavy compaction)**

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Un soaked CBR % | 5.88 | 8.02 | 9.24 | 10.33 | 11.96 | 11.009 |

**Table.26Un soaked CBR test results of soil+ Bagasse ash + Groundnut shell ash (Heavy compaction)**

| **Percentage of B.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Un soaked CBR % | 5.88 | 8.29 | 9.378 | 10.6 | 11.69 | 11.55 |

### 4.8 Soaked California Bearing Ratio Tests (Heavy compaction)

Soaked California Bearing Ratio Tests are conducted on soil samples prepared under Heavy compaction under soaked condition to determine CBR value of soil with varying percentage of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations. The test is conducted on soil samples with 4%,8%,12%,16%,20% of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations, to determine the optimum percentage of combinations.

The Soaked CBR value of soil + Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations are reported in Table 27, 28 and 29.

**Table.27 Soaked CBR test results of soil+ Coal ash + Groundnut shell ash (Heavy compaction)**

| **Percentage of C.A + GSA** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Soaked CBR % | 2.24 | 6.755 | 7.883 | 8.97 | 8.834 | 9.106 |

**Table.28 Soaked CBR test results of soil+ Coal ash + Bagasse ash (Heavy compaction)**

| **Percentage of C.A + B.A** | **0%** | **4%** | **8%** | **12%** | **16%** | **20%** |
|---|---|---|---|---|---|---|
| Soaked CBR % | 2.24 | 6.12 | 7.48 | 8.70 | 9.79 | 9.65 |

**Table.29 Soaked CBR test results of soil+ Bagasse ash + Groundnut shell ash (Heavy compaction)**

| Percentage of B.A + GSA | 0% | 4% | 8% | 12% | 16% | 20% |
|---|---|---|---|---|---|---|
| Soaked CBR % | 2.24 | 6.524 | 7.883 | 8.698 | 9.242 | 9.106 |

## 5. Results and Discussion

This elaborates the results obtained from the above tests on soil sample with Coal ash + Groundnutshell ash, Coal ash + Bagasse ash, Bagasse ash + Groundnut shell ash combinations.The optimum of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash content is obtained based on the results of CBR tests and UCC tests.

### 5.1 Properties of soil

The Various Properties of the subgrade soilnamely natural moisture content, specific gravity, liquid limit, plastic limit, shrinkage limit, grain size distribution, optimum moisture content, maximum dry density, unconfined compressive strength and CBR obtained from chapter 4 are summarized in Table 30.

**Table.30 Properties of Soil**

| **S.no** | **Properties** | **Results** |
|---|---|---|
| 1 | Natural Moisture Content | 13.29% |
| 2 | Specific Gravity | 2.63 |
| 3 | Percentage of sand | 26.25% |
| | Percentage of silt | 21.39% |
| | Percentage of clay | 52.36% |

| | | |
|---|---|---|
| 4 | Soil classification | CH |
| 5 | Optimum Moisture Content (Light compaction) | 24.83% |
| | Maximum Dry density ( Light compaction) | 1.52 g/cc |
| 6 | Optimum Moisture Content ( Heavy compaction) | 15.71% |
| | Maximum Dry density ( Heavy compaction) | 1.73 g/cc |
| 7 | Unconfined Compressive Strength (Light compaction) | 0.126N/mm$^2$ |
| | Cohesion | 0.063N/mm$^2$ |
| 8 | Unconfined Compressive Strength (Heavy compaction) | 0.201N/mm$^2$ |
| | Cohesion | 0.1005 N/mm$^2$ |
| 9 | CBR(Unsoaked condition, Light compaction) | 2.45% |
| | CBR(Soaked condition, Light compaction) | 1.63% |
| 10 | CBR(Unsoaked condition, Heavy compaction) | 5.88% |
| | CBR(Soaked condition, Heavy compaction) | 2.24% |

### 5.2 Standard proctors compaction test.

Standard Proctor's Compaction tests are conducted on soil samples under equal proportioning with 4%,8%,12%,16%,20% of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations. The maximum dry density and optimum moisture content corresponding to various percentages of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations were elaborated in chapter 5.The variation in maximum dry density and optimum moisture content with addition of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations under light compaction is shown in Figure1, 2and 3.

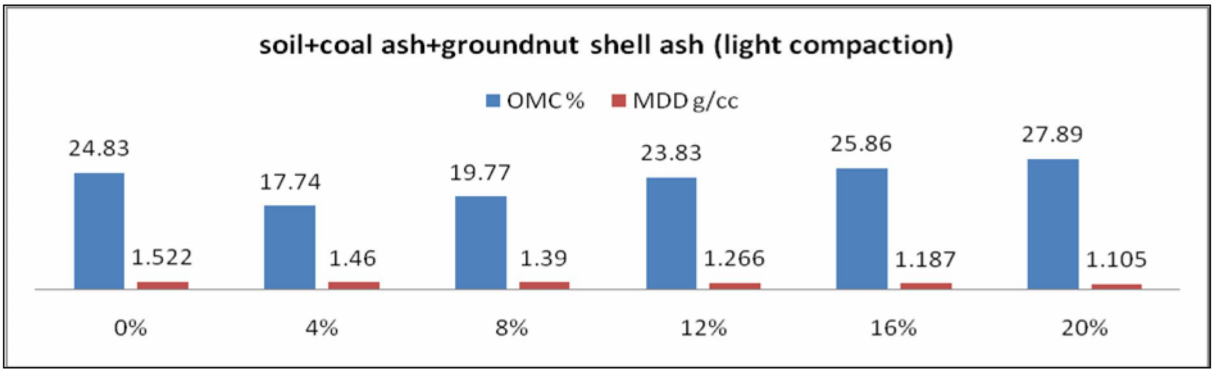


**Figure.1**

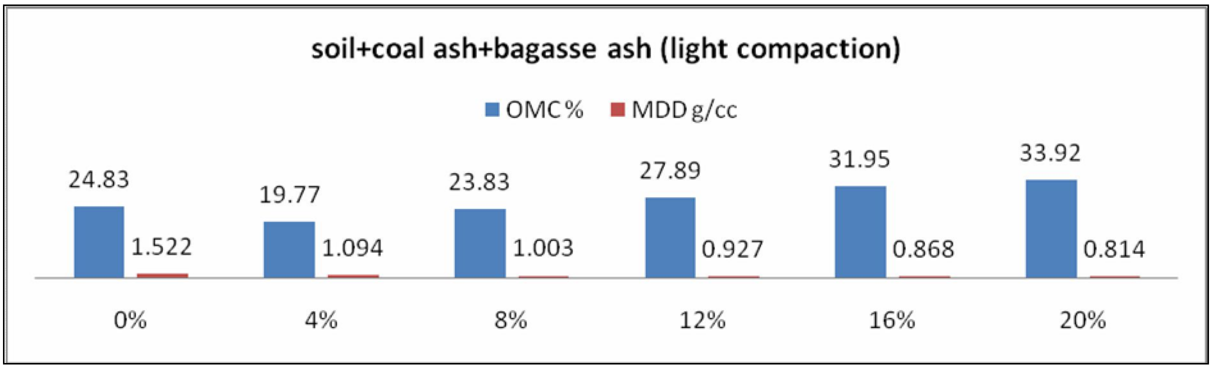


**Figure.2**

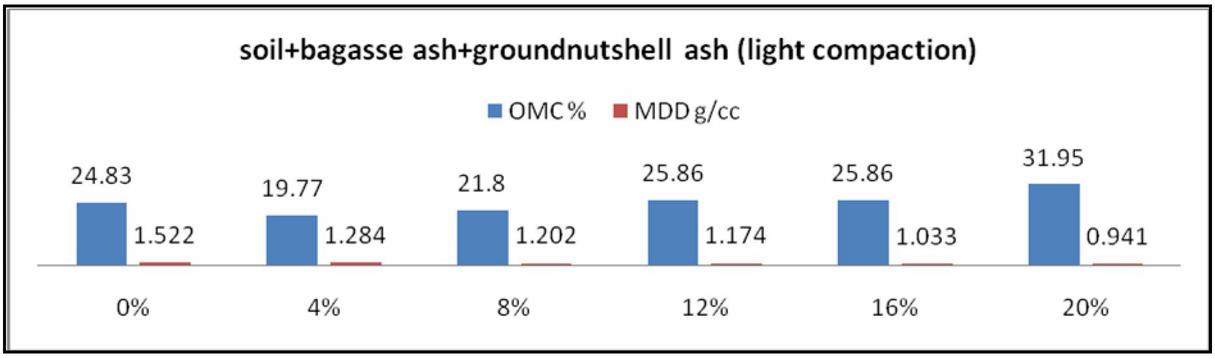


**Figure.3**

The variation in maximum dry density and optimum moisture content with addition of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations under heavy compaction is shown in Figure 4,5 and 6.

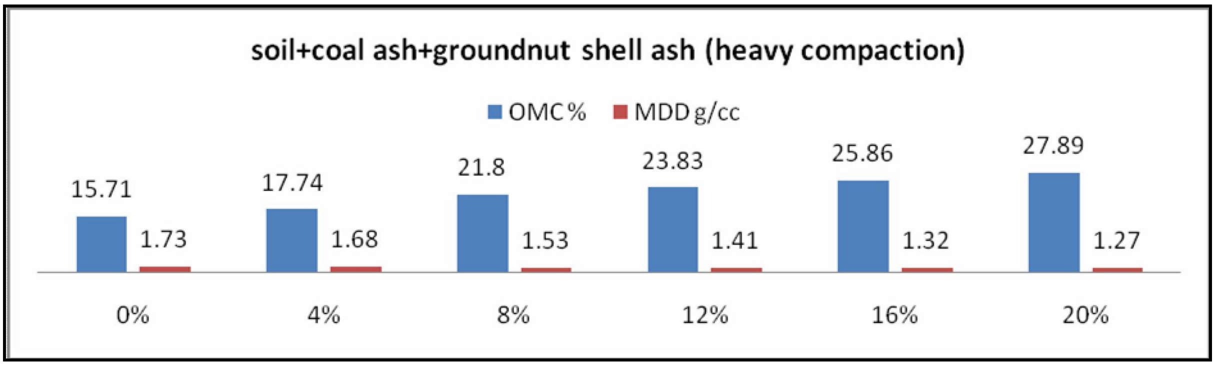


**Figure.4**

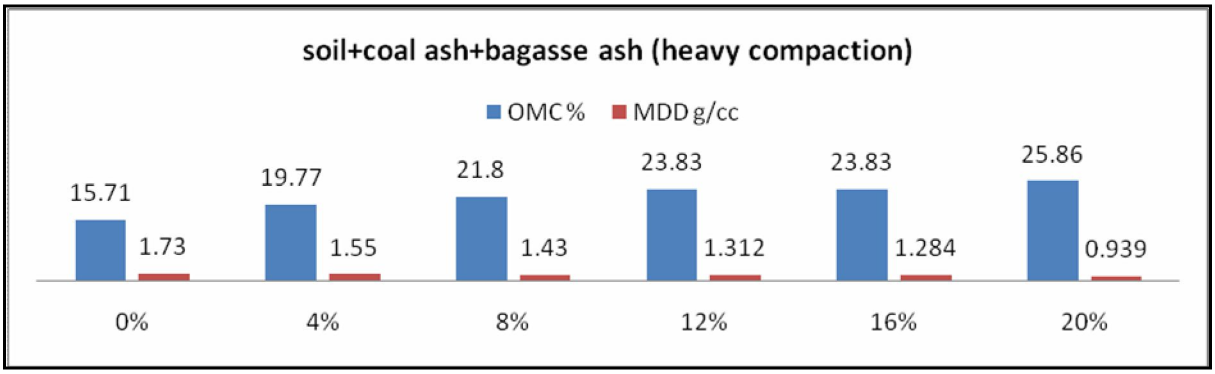


**Figure.5**

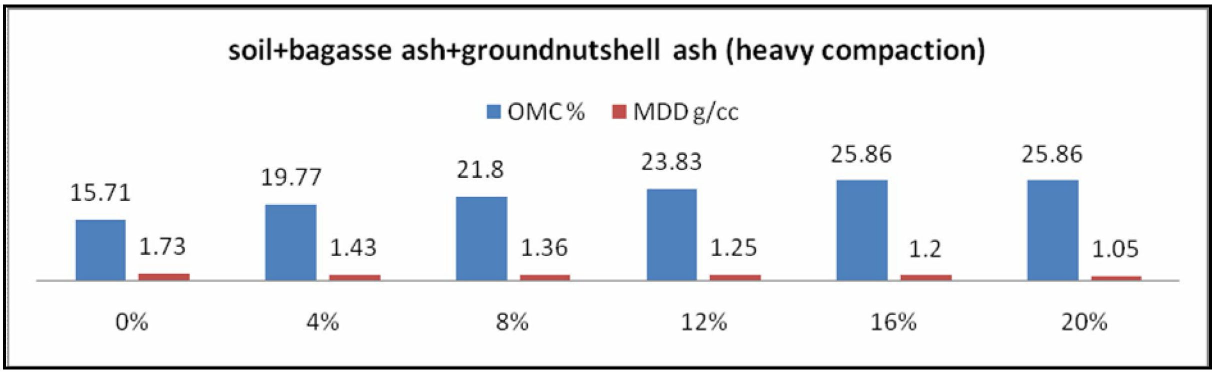


**Figure.6**

**5.3 Unconfined compressive strength test.**

Unconfined compressive strength tests are conducted on soil samples with 4%,8%,12%,16%,20% of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut Shell ash combinations. The tests were carried out on samples prepared under both light and heavycompaction.The unconfined compressive strength and cohesion corresponding to various percentages of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut Shell ash combinations, were elaborated in chapter 5.The variation in unconfined compressive strength and cohesion with addition of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut Shell ash combinations, under light compaction is shown in Figure7,8 and 9.

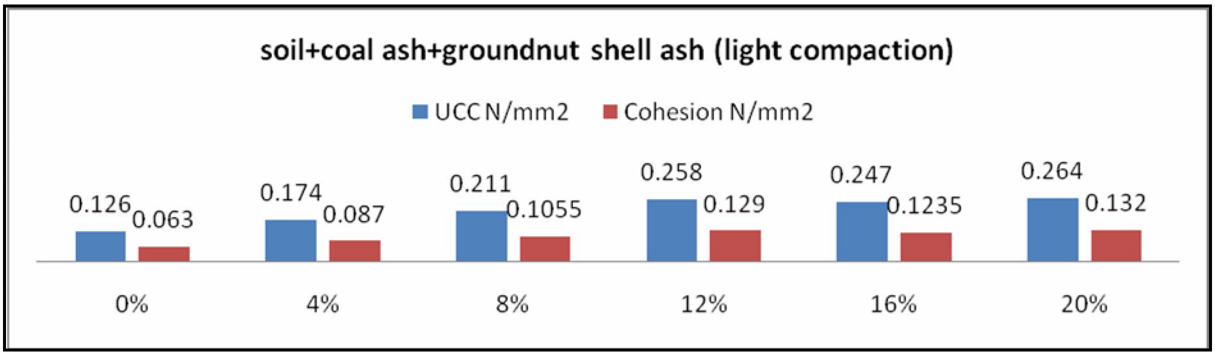


**Figure.7**

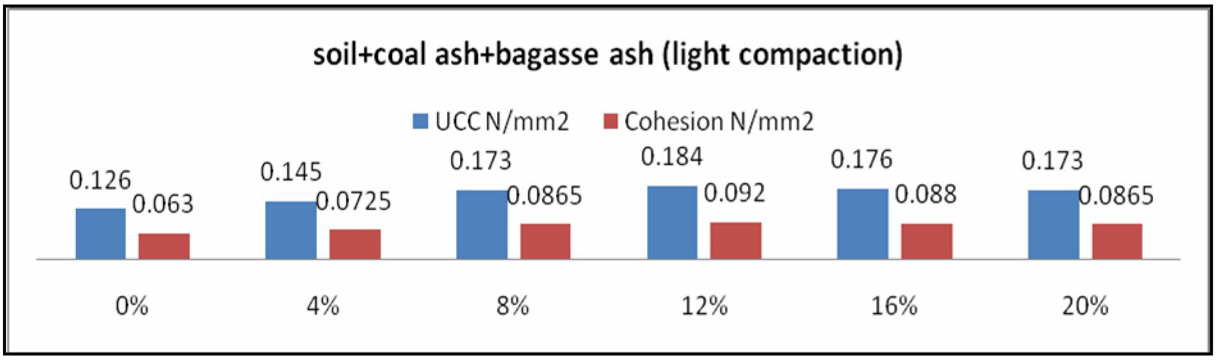


**Figure.8**

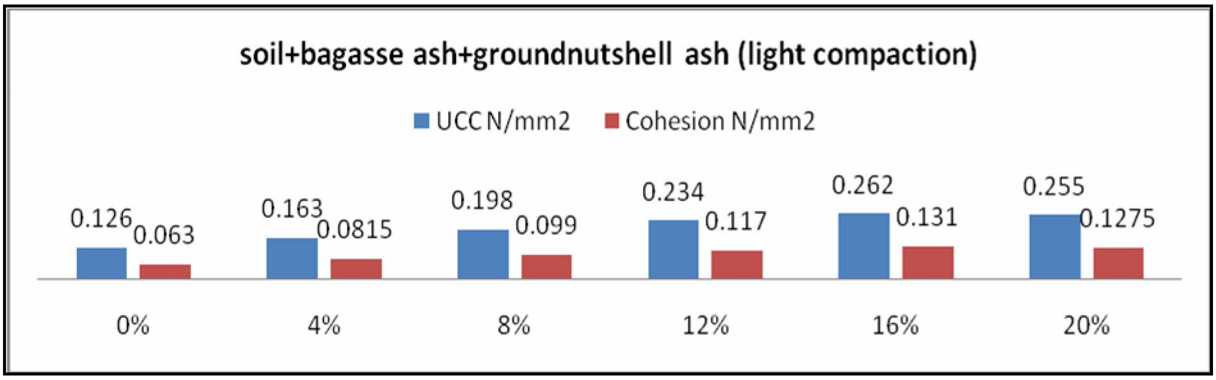


**Figure.9**

The variation in unconfined compressive strength and cohesion with addition of Coal ash + Groundnutshell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut Shell ash combinations, under heavy compaction is shown in Figure10, 11 and 12.

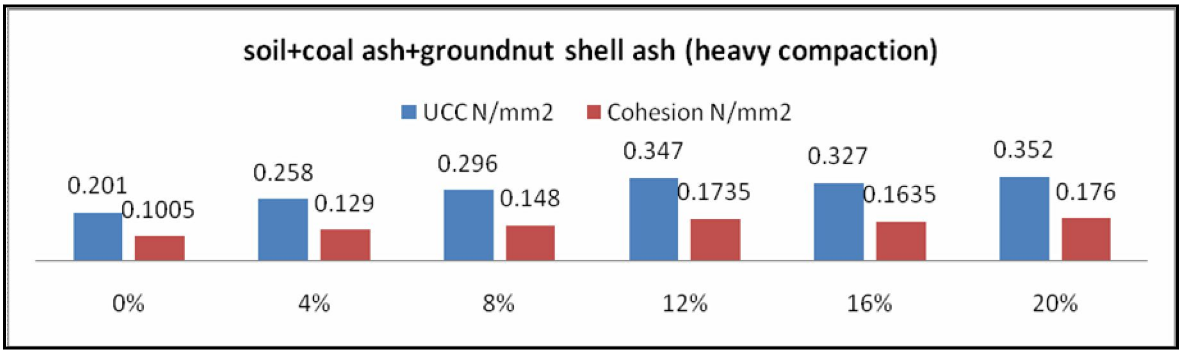


**Figure.10**

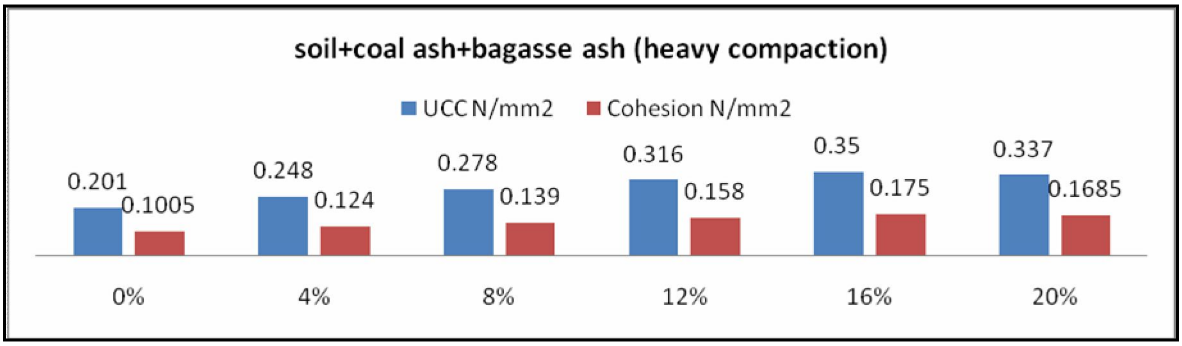


**Figure.11**

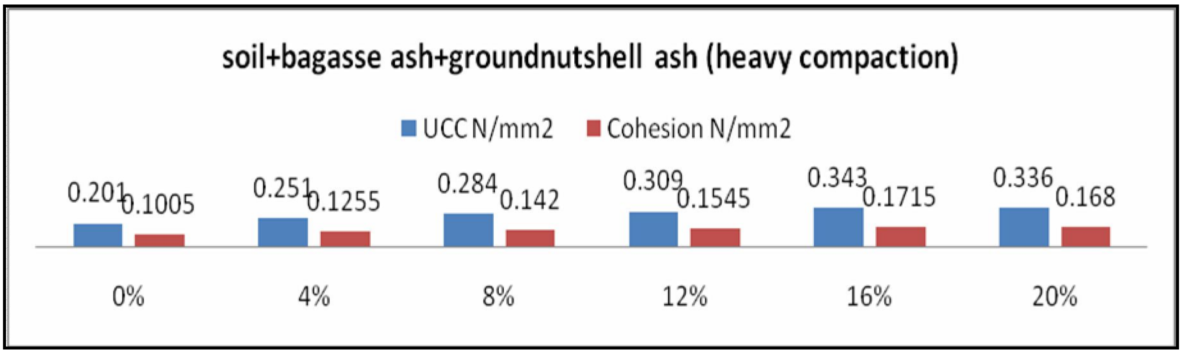


**Figure.12**

### 5.4 California bearing ratio test

California bearing ratio tests are conducted on soil samples and on soil samples with 4%,8%, 12%,16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut Shell ash combinations. The tests were carried out on samples prepared under both light and heavy compaction and both unsoaked and soaked condition. The CBR value corresponding to various percentages of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash +Groundnut Shell ash combinations, were elaborated in chapter 5.

The variation in the unsoaked and soaked CBR value with addition of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut Shell ash combinations under light compaction is shown in Figure13,14 and 15.

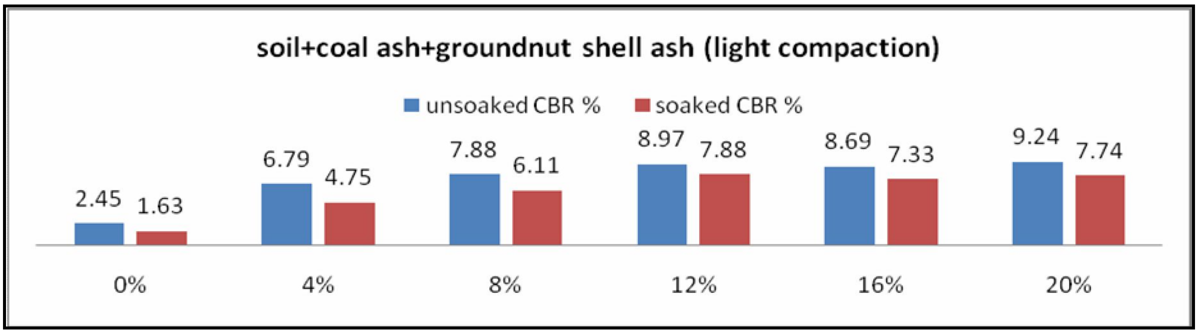


**Figure.13**

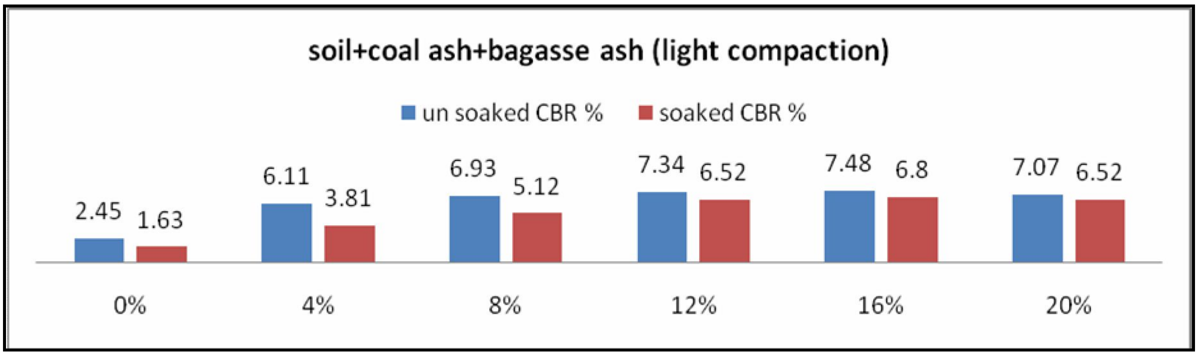


**Figure.14**

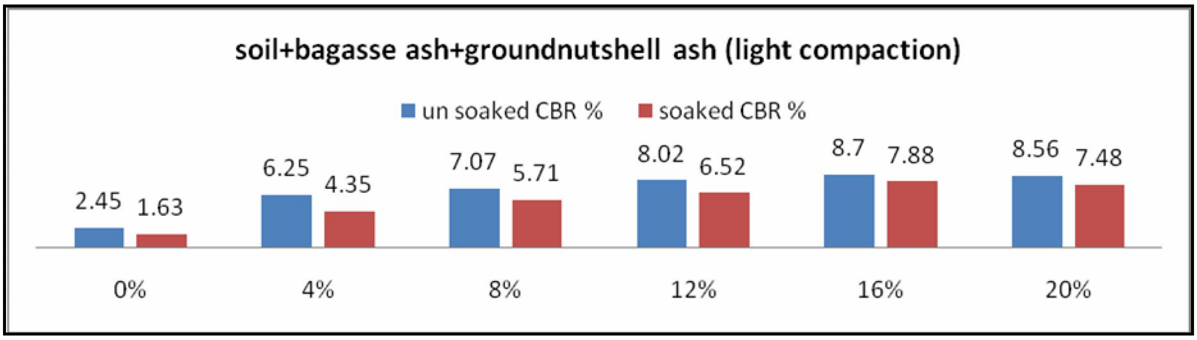


**Figure.15**

The variation in the unsoaked and soaked CBR value with addition of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut Shell ash combinations under heavy compaction is shown in Figure16, 17 and 18.

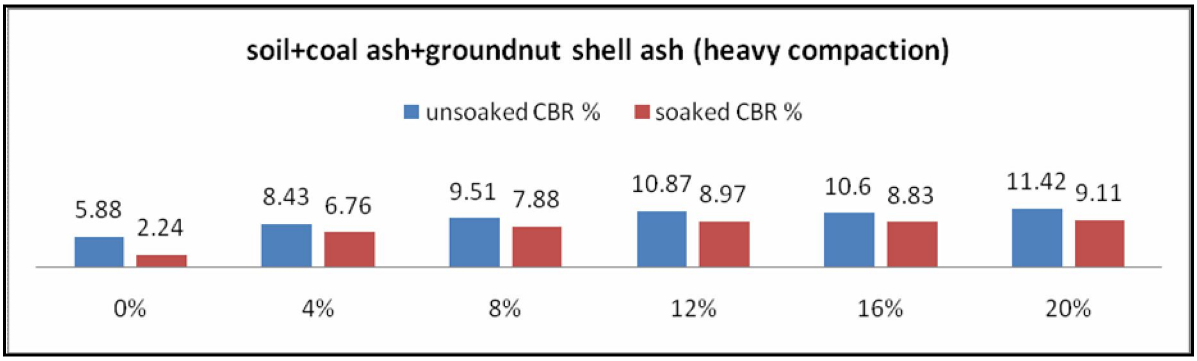


**Figure.16**

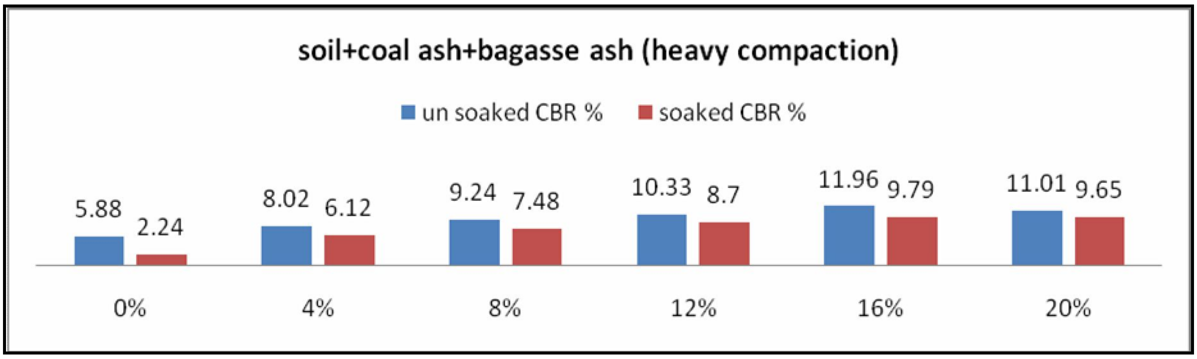


**Figure.17**

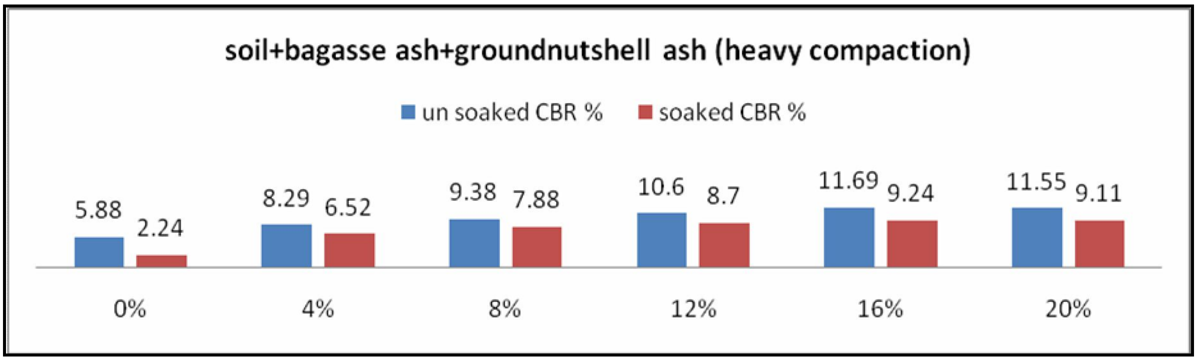


**Figure.18**

## 6. Conclusion

Based on the experimental studies the following conclusions were drawn.

- Sub grade soil used in this project was classified as clay of high plasticity.
- The soaked CBR value of untreated soil is 1.63% and 2.24% under both light and heavy compaction and hence it requires to be stabilized.
- The CBR values increased for 4%,8%,12%,16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ashand Bagasse ash + Groundnut shell ash combinations with uniform proportions.
- The UCC strength also increased for 4%,8%,12%,16%,20% of Coal Ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations with uniform proportions.
- The CBR values increased upto addition of 12%Coal ash +12%Groundnutshell ash,16%Coal ash + 16%Bagasse ash and 16%Bagasse ash + 16% Groundnut shell ash and decreased with further increase in Coal ash, Bagasse ash and Groundnut shell ash content.
- From the CBR values and UCC values the optimum percentage of combinations are 12%Coal ash +12%Groundnutshell ash,16%Coal ash + 16%Bagasse ash and 16%Bagasse ash + 16% Groundnut shell ash.
- The percentage increase in the unconfined compressive strength value is 104.76%, 97.62% and 107.94% for respective combinations under light compaction.
- The percentage increase in the soaked CBR value is 383.44%, 316.933%, 383.62% for respective combinations under light compaction condition.
- The percentage increase in the soaked CBR value is 300.45%, 337.05%, 312.59%for respective combinations under heavy compaction.

## References

1. Ahmad rifa'i, Noriyuki Yasufuku and Kazuyoshi tsuji, 2009, Characterization and effective utilization of coal ash as soil stabilization on road application, Geotechnical Society of Singapore (GeoSS).
2. Oriola, Folagbade & Moses, George, 2010, Groundnut Shell Ash Stabilization of Black Cotton Soil, EJGE Vol.15, Bund.E

3. Mohammed Abdullahi MU'AZU, 2007, Influence of Compactive Effort on Bagasse Ash with Cement Treated Lateritic Soil, Leonardo Electronic Journal of Practices and Technologies.
4. Dr. D S V Prasad, Dr. G V R Prasada Raju, M Anjan Kumar,2009,Utilization of Industrial Waste in Flexible Pavement Construction, Electronic Journal of Geotechnical Engineering.
5. Ahmad rifa'i, Noriyuki yasufuku, Kiyoshi omine and Kazuyoshi tsuji, 2009, Experimental study of coal ash utilization for road application on soft soil, Geotechnical Society of Singapore (GeoSS).
6. Prof.S.Ayyappan, Ms.K.Hemalatha and Prof.M.Sundaram, 2010, Investigation of Engineering Behavior of Soil, Polypropylene Fibers and Fly Ash -Mixtures for Road Construction, International Journal of Environmental Science and Development.
7. D.Neeraja and prof .A.V.Narasimha rao, 2010, Use of certain admixtures in the construction of pavement on expansive clayey subgrades,International Journal of Engineering Science and Technology.
8. Dr. Robert M. Brooks, 2009, Soil stabilization with flyash and rice husk ash, International Journal of Research and Reviews in Applied Sciences.
9. Olugbenga O. Amu, Opeyemi S. Owokade, Olakanmi I. Shitan,2011,Potentials of Coconut Shell and Husk Ash on the Geotechnical Properties of Lateritic Soil for Road Works,International Journal of Engineering and Technology Vol.3 (2).
10. Koteswara rao.D, 2011, The efficacy of reinforcement technique on the fly ash stabilizedexpansive soil as a subgrade embankment for highways,International Journal of Engineering Science and Technology (IJEST).
11. Amu, O.O., Ogunniyi, S.A. and Oladeji, O.O., 2011, Geotechnical properties of lateritic soil stabilized with sugarcane straw ash, American journal of scientific and industrial research.
12. M. Anjan Kumar, D. S.V. Prasadand G. V. R. Prasada Raju, 2010, Performance evaluation of stabilized flyash subbases, ARPN Journal of Engineering and Applied Sciences Asian Research Publishing Network (ARPN).
13. V. S. Aigbodion, S. B. Hassan, T. Ause and G.B. Nyior, 2010, Potential Utilization of Solid Waste (Bagasse Ash), Journal of Minerals & Materials Characterization & Engineering.
14. Jaganatha Rao, P and Jai Bagwan, 2001. Fly ash as structural fill in highway embankments – a measure for geo-environmental hazard. IGC, 14-16 December.
15. Krishna Swamy,N.R and Santhosha Rao,N., 1995. Experimental studies on model embankments made of reinforced fly ash.IGC, Vol. No. I.
16. Praveen Kumar, Mehndiratta and Siddhartha Rokade, 2005. Use of reinforced fly ash in highway embankments. Highway Research Bulletin, Vol.No.73.
17. Raza, S.A. and Chandra, D., 1995. Strength of soil-fly ash mixtures with geo-textile reinforcement. IGC-95, Vol. No. I.
18. Sharma, R.K., 2005. Behaviour of reinforced soil under cyclic loading. Highway Research Bulletin, Vol.No.73.
19. Sikdar, P.K and Guru Vital, U.K., 2004. Economics of using fly ash in road construction. Indian Highways, January 2004.
20. Sinha, U.N., Ghosh,A., Bhargave,S.N.,and Dalip Kumar, 1995. Geotechnical investigation of earth-fly ash embankment of fly ash pond .IGC, Vol. No. I.
21. Sudip Basak, Amartya Kumar and Paira, L.K., 2004. Utilization of fly ash in rural road construction in India and its costeffectiveness. EJGE paper 2004 –0436.
22. M. Alhassan and A.M. Mustapha, 2007, Effect of rice husk ash on cement stabilized laterite, Leonardo Electronic J. Practice and Technol., vol. 6, no. 11, pp. 47-58.
23. M. Alhassan, 2008, Potentials of rice husk ash for soil stabilization, Assumption University Journal of Technology, vol. 11, no. 4, pp. 246-250.


*****