Use of Industrial Byproducts as A Sustainable Technique for Strength Improvement of Red and Black Soils Based on Initial Properties

Vinjamuri Sri Vaishnavi [1] | M. Yashwanth Reddy[2] | G. Dasu[3] | Dr. Dumpa Venkateswarulu[4]

[1,2,3] UG Students, Department of Civil Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India.

[4]Department of Civil Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India.

Abstract: Soil is the irreplaceable element of this nature. The word "soil" is derived from the Latin word "solium". The term soil in soil engineering is defined as an unconsolidated material, composed of solid particles formed by disintegration of rocks. In general, soil is used as a basic construction material. Red soil is formed due to weathering of ancient parent metamorphic rocks and crystalline rocks. 10.6% of the India's territory (about 3.5 lakhs sq.km) is covered by red soil. Red soil can be found in different textures that can vary from clay to sand, mostly in the form of loam. Black soil is a highly expansive soil which expands when it comes in contact with water due to presence of a clay mineral called "Montmorillonite". About 20% (0.8 million sq.km) of Indian land area in India is covered by black soils. This type of soil is available up to a depth of 3.7 meters on an average. These soils are famous for cotton cultivation. These soils have been found to be most troublesome from engineering considerations and poses a challenge to the civil engineers. Chemical stabilization is one of the oldest methods of stabilization of problematic soils. The aim of this project is to determine the index and engineering properties of red soil sample as well as black soil sample and to study and compare the samples thoroughly in all aspects and suggest the most efficient soil in civil engineering point of view. This project presents various laboratory experiments conducted on red and black soil samples respectively; They are: Atterberg Limits, Specific gravity, Grain size analysis (Index properties), Optimum Moisture Content (OMC), Maximum Dry Density (MDD), California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and Differential Free Swell Index (DFSI). The results of conducted experiments have shown significant differences between the values for the samples of both red and black soils respectively. From this, we want to conclude by suggesting that virgin red soil is the most suitable and efficient soil when compared with the black soil, while Black soil is the best when replaced with 30%Fly Ash and added by 6%Lime.

KEYWORDS: Atterberg Limits, Black soil, California Bearing Ratio (CBR), Differential Free Swell Index (DFSI), Fly Ash, Grain size analysis, Lime, Red soil, Specific gravity, Standard Proctor Compaction, Unconfined Compressive Strength (UCS).

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I. INTRODUCTION

1.1 SOIL

Soil is the irreplaceable element of this nature. It has attachment with everyone in one or the other way. According to the Civil Engineering, soil means all the naturally occurring, relatively unconsolidated organic or inorganic earth materials lie above the earth surface. The soil mechanics is the branch of Civil Engineering that uses the principles of mechanics, hydraulics and chemistry to solve engineering problems related to soil. The word "soil" is derived from the Latin word "solium", which means the upper layer of the earth that may be dug or ploughed; mostly loose surface material of earth in which plants grow. The term soil in soil engineering is defined as an unconsolidated material, composed of solid particles formed by disintegration of rocks.

Soil Formation:

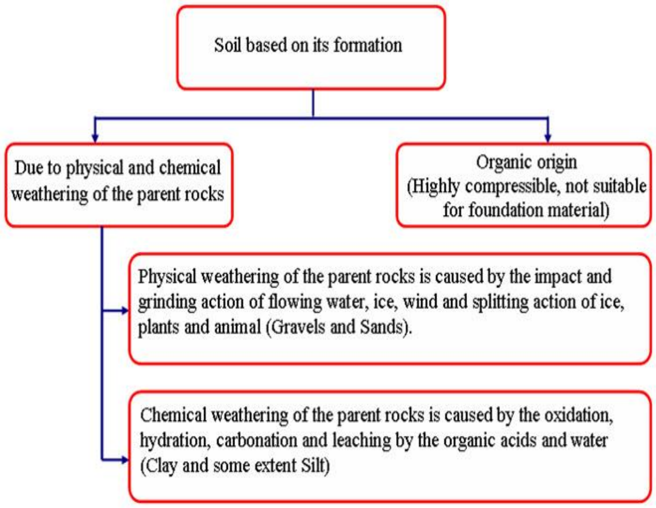


Fig.1-Soil Formation

Depending upon the type of formation, transported soil can be divided into five types:

- Alluvial soil.
- Marine soil.
- Aeolian soil.
- Lacustrine soil.
- Glacial soil.

Alluvial soils are formed from suspension of flowing water. The soils that are transported by wind are called Aeolian soils. Soils that are transported by ice are called Glacial soils. Lacustrine soils are formed from the suspension of parent rocks in still and fresh water lakes. Marine soils are formed from suspension in sea water.

Common Soils in India:

Common Indian soils are listed below:

a) Marine soils: These soils are found along the coastal regions. These soils are very fine and soft with high compressibility and low shear strength. Construction of structures on these soils is very difficult.

b) Red soils: Red soil is formed due to weathering of ancient parent metamorphic rocks and crystalline rocks of the Deccan plateau region in India.

c) Black soils: These soils are highly expansive, mostly found in Maharashtra, Madhya Pradesh, Karnataka, Tamil Nadu, Gujarat, Andhra Pradesh and Uttar Pradesh.

d) Laterite soils: These soils are found in, Karnataka, Kerala, Maharashtra, West Bengal and Orissa. These soils are formed due to weathering of parent rocks and is reddish in color.

e) Alluvial soils: Alluvial soils are formed from suspension of flowing water. These are mostly found in northern India. These soils have different layers of sand, silt and clay.

f) Boulder deposits: These are found in the sub-Himalayan regions of Himachal Pradesh and Uttar Pradesh.

g) Desert soils: These are mostly found in deserted areas where water is scarce and soil hot and dry. Found in large parts of Rajasthan.

1.2 RED SOIL

Red soil is formed due to weathering of ancient parent metamorphic rocks and crystalline rocks of the Deccan plateau region in India.

The soil is red in color when it contains ferric oxides; whereas soil tends to be in yellow color when it contains limonite in a hydrated state. Usually, surface soils are red in color while the horizon under it gets yellowish color. Red soil changes its colors according to the topography of the states in India. It may vary from red, green, white and sometimes it can also be black and blue in color. It has enormous amounts of iron present in it. pH of the red soil varies from acidic to neutral. 10.6% of the India's territory (about 3.5 lakhs sq. km) is covered by red soil. Red soil can be found in different textures that can vary from clay to sand, mostly in the form of loam.

Their chemical composition is as follows: non-soluble material 90.47%, iron 3.61%, aluminum 2.92%, organic matter 1.01%, magnesium 0.70%, lime 0.56%, carbon dioxide 0.30%, potash 0.24%, soda 0.12%, phosphorous 0.09% and nitrogen 0.08%.

Nature of Red Soil:

Red soils possess with a high concentration of sesquixides of iron and/or alumina and are tropically weathered soils. They have low content of alkalis and alkaline earth materials. Silica content varies from low to medium. Exists usually as kaolinite, whenever it is found in considerable amounts.

- **Other Characteristic Features:**
- Red soil in Andhra Pradesh is locally called as 'Chalka'.
- The fine-grained red and yellow soils are usually very fertile, while the coarse-grained soils found in dry regions are not so fertile.
- These soils are airy having more void spaces and need irrigation for cultivation.
- Intense leaching is the major problem in these soil areas.
- **Suitable Crops**: In places where irrigation facilities are available, the crops cultivated are wheat, cotton, pulses, tobacco, millets, oilseeds, potato, maize, groundnut and orchards.

The **Indian Council of Agricultural Research (ICAR)** has divided red soils into four categories:

- Red soils,
- Red Gravelly soils,
- Red and Yellow soils, and
- Mixed Red and Black soils.

The characteristics of red soil has its impact on strength and imperviousness. After conducting suitable tests, red soil is found to be as a suitable admixture for concrete which can be used in construction of buildings.

Fig.2-Red soil.

1.3 BLACK SOIL:

Black soil is a highly expansive soil which expands when it comes in contact with water. This sudden expansion and sudden contraction is the major reason for failure of black soil strata. About 20% (0.8 million sq.km) of Indian land area in India is covered by black soils. This type of soil is available up to a depth of 3.7 meters on an average.

- **Formation**: These are mainly formed from the Deccan Trap rocks called as the Zonal Soils.
- These soils are locally called as the 'Black soil' or 'Regur Soil', While Internationally called as 'tropical chernozems'.
- **Soil Color:** These soils are black in color due to presence of iron and aluminum compounds.
- **Soil Texture:** Black soil is highly clayey in its texture due to presence of montmorillonite mineral. It is impermeable and deep and has high water retention capacity.
- **Suitable Crops:** These soils are highly fertile and provides good yield, thus, well suited to cultivation of cotton, sugarcane, pulses, millets, tobacco, linseed, vegetables and citrus fruits.
- Due to high water retention capacity of black soil for a very long time, helps the crops to sustain even during the dry season (especially the rain fed ones). Example: Paddy.
- Chemically, black soils are rich in lime, iron, magnesia and alumina along with traces of Titanium Oxide and potash. But they lack in phosphorous, nitrogen and organic matter.
- Black soils possess a clay mineral called, "Montmorillonite", which provides high swelling and high contracting character to the soil due to the presence of weak Vander Waal forces of attraction between the between two structural units.

Swelling and shrinkage of expansive soil cause differential settlements resulting in loss of strength and severe damage to various infrastructures. Chemical stabilization is one of the oldest methods of stabilization of problematic soils.

Fig.3-Black soil.

LITERATURE REVIEW

Poonia and Niederbudde 1990: It may be mentioned that the dominant soils in the semi-arid tropics are black soils and associated red soils. All these soils are dominated by montmorillonite and kaolinite minerals and their properties are studied.

Bhattacharyya et al. 1993; Pal and Deshpande 1987a, 1987b; Pal et al. 1989, 2000: Presence of smectite increases the SCD (Soil Conservation District) of soils, which offers greater scope of carbon sequestration in these soils. Black soils, therefore, may reach a higher quasi-equilibrium value (>2%) compared to red soils, dominated by kaolinites with low SCD. Bhattacharyya and Pal (1998) reported 2–5% of SOC (soil organic carbon) in black soils in the surface soils from Mandla and Dindori districts of Madhya Pradesh. More recently, it was also indicated the scope of higher SOC content in the shrink-swell soils of Australia. To find out the sufficient and deficient zones for SOC in different agro-ecoregions.

Alfisols of eastern India, Saikh et al. 1998a,b , Bhattacharyya and Pal 1998; Naitam and Bhattacharyya 2001: Recent studies of red soils (Alfisols of eastern India, Saikh et al. 1998a,b) and associated red and black soils (Bhattacharyya and Pal 1998; Naitam and Bhattacharyya 2001) indicate that soil organic carbon (SOC) content of soils sharply declines when put to cultivation. Reduction of SOC level is significant even within 15 to 25 years of cultivation. These authors have hypothesized that irrespective of the initial organic carbon levels of these red soils, there is a tendency to reach the quasi-equilibrium value of 1 to 2% SOC. These values could be as high as 2–5% for black soils. Since such studies are limited to a specific geographical region, a generalized view about carbon-carrying capacity of the soils may not be advisable, because quality of soil substrate and its surface charge density (SCD) varies from one place to another. It has been reported that increase in SOC increases the SCD of soils and the ratio of internal/external exchange sites.

Pallavi, Pradeep Tiwari and Dr. P D Poorey: concluded that on adding 20% fly ash and 0.75% nylon fibres in black soil the value of soaked California bearing ratio increased to 7.18, which was 4.2 times greater than that of plain soil.

Ghosh and Subbaro (2007): found that the strength of lime treated soil is increased and is dependent on curing period and compaction energy.

Terhreemna and Kalita (2013): investigated the effect of class F fly ash and lime on the strength property of the red soil by experimentation.

SCOPE AND OBJECTIVE

The aim of this project is follows;

- Determination of the engineering properties of red soil sample as well as black soil sample.
- Determination of index properties like Atterberg limits (liquid limit, plastic limit, plasticity index) of red soil and black soil samples.
- Determination of chemical composition of red soil as well as black soil samples. To study difference in behavior of red soil and black soil.
- To study and compare the samples of red soil and black soils thoroughly in all aspects and suggest the most efficient soil in civil engineering point of view.
- To stabilize the soil samples by partially replacing the soil with Fly Ash and by adding Lime for their utilization in the construction of pavements.

MATERIALS AND METHODOLOGY

4.1 MATERIALS

Red soil:

Red soil is formed due to weathering of ancient parent metamorphic rocks and crystalline rocks of the Deccan plateau region in India. The soil sample for our project has been collected from Godavari Institute of Engineering and Technology(GIER), Rajanagaram, Rajahmundry. The sample was collected from a soil pit at depth of 1 m to avoid the inclusion of organic matter. A disturbed sample has been collected.

Black soil:

Black soil is a highly expansive soil which expands when it comes in contact with water due to presence of a clay mineral called "Montmorillonite". The soil sample for our project has been collected from Jaggampeta, East Godavari. The sample was collected from a soil pit at depth of 1 m to avoid the inclusion of organic matter. A disturbed sample has been collected.

Fly Ash and Lime:

Fly ash is one of the best additives to improve the soil properties. Hence we have collected the fly ash from International Paper mill, Rajahmundry. Lime is a locally available material and works at its best when added to the soil along with fly ash. Fly ash and lime are added to the soil samples to stabilize them and to improve their engineering properties so as to suit in construction of pavements.

4.2 EXPERIMENTAL WORK-METHODOLOGIES

The following list of experiments should be carried out;

1. Index Properties:

a) Grain size analysis
b) Specific gravity test
c) Atterberg limits
i. Liquid limit
ii. Plastic limit
iii. Shrinkage limit

2. Engineering Properties:

a) Standard Proctor Compaction test
- Optimum moisture content
- Maximum dry density

b) California Bearing Ratio (CBR)
c) Unconfined compression test
d) Differential Free Swell Index (DFSI)

1.Index Properties:

a) Grain Size Analysis:

Sieve analysis is performed to determine the distribution of the coarser, larger-sized and finer particles. This distribution of grain sizes affects the engineering properties of soil sample. Grain size analysis helps in classifying the soil.

Indian Standard Specifications: IS 2720 (Part III)–1985.

Formulae:

- Percentage retained on any sieve = (weight of soil retained / total weight) *100
- Cumulative percentage retained = sum of percentages retained on any sieve on all coarser sieves.
- Percentage finer than any sieve= 100 percent minus cumulative Size, N percentage retained.

b) Specific Gravity Test:

Specific gravity (G) is defined as the ratio of the weight of soil solids to weight of equal volume of distilled water at same temperature.

Indian Standard Specifications: IS 2720 (Part III) – 1980.

Formulae:

Specific gravity, G: $G= (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$

Where, W_1= weight of empty bottle

W_2= weight of bottle + dry soil

W_3= weight of bottle + soil + water

W_4= weight of bottle + water

c) Atterberg Limits:

Atterberg limits are basic amount of the water content present in fine-grained soil. They are also called as consistency limits. Consistency of fine-grained soils is the relative ease with which a soil can be remolded.

i. Liquid Limit:

Liquid limit as the minimum water content at which a pat of soil cut by a groove of standard dimension will flow together for a distance of 12 mm (1/2 inch) under an impact of 25 blows in the device.

Indian Standard Specifications: IS: 2720(Part V)-1985.

Formulae:

- Flow Index, $I_f=(w_1-w_2)/\log (N_2/N_1)$
- Water content, $w= [(W_2-W_3)/(W_3-W_1)]\times100$

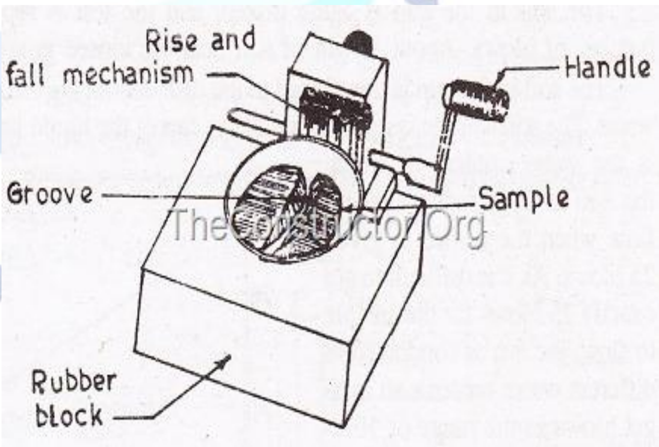


Fig.4-Schematic diagram of Casagrande apparatus for Liquid limit.

ii. Plastic Limit:

Plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic state.

Indian Standard Specifications: IS: 2720 (Part V)–1985.

Formula: Plasticity index = $w_p - w_l$

iii. Shrinkage Limit:

Shrinkage limit is the water content where further loss of moisture will not reduce the volume of the soil mass.

Indian Standard Specifications: IS 2720(Part VI)-1972.

Formulae:

- Shrinkage limit, (W_s) is $W_s = [(M_0-M_S)-(V_0-V_d)\rho_w]M_s$.
- Shrinkage ratio, $S_r = ((V_0-V_d)/V_0)x100$.

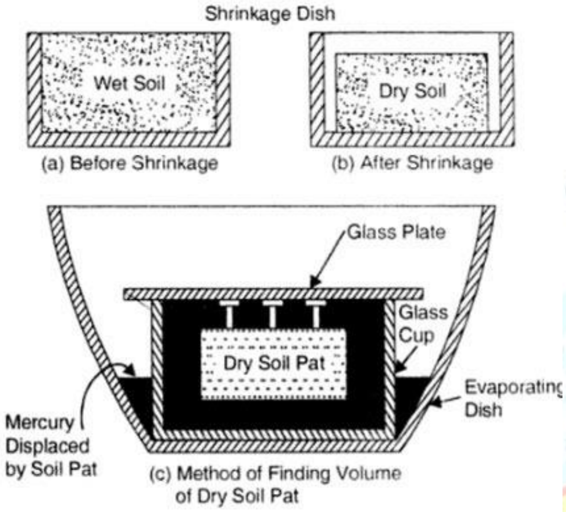


Fig.5- Schematic diagram for Shrinkage limit.

2.Engineering Properties:

a) Standard Proctor Compaction Test:

Compaction is application of mechanical energy to a soil so as to rearrange its particles in order to reduce its void ratio.

Indian Standard Specifications: IS 2720(part VII)-1980.

Formulae:

- Bulk density $\rho_b = (M_2-M_1)/V$
- Dry density $\rho_d = \rho_b/(1 + w)$
- Dry density (ρ_d) for zero air voids line: $\rho_d = G\rho_w/[1 + (wG/S)]$

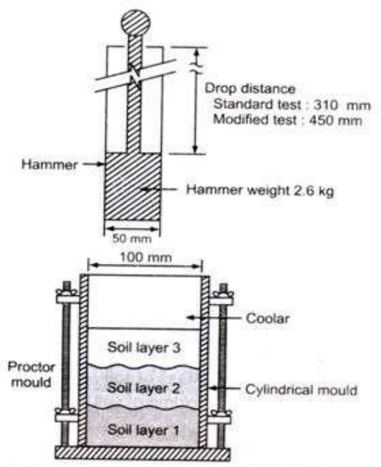


Fig.6- Schematic diagram for Standard Proctor Compaction Test.

b) California Bearing Ratio (CBR):

CBR test is the measure of resistance of soil specimen to penetration of a standard plunger under controlled density and moisture conditions. It was developed by the California Division of Highways as a method of classifying soil- subgrade and base course materials for pavement construction.

Indian Standard Specifications: IS 2720(Part XVI)-1973.

Formula: CBR = (Test load/Standard load) *100

Fig.7-Schematic diagram for California Bearing ratio Test.

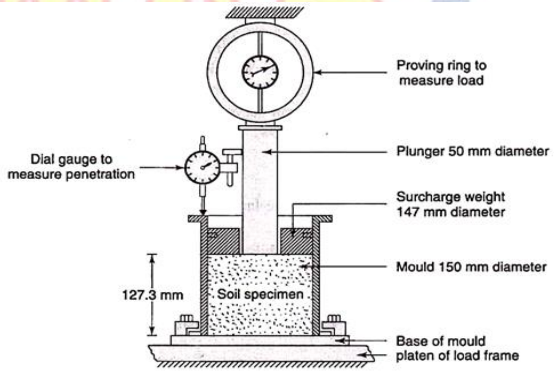
c)Unconfined Compression Test(UCS):

The unconfined compressive strength (q_u) is the load per unit area at which the cylindrical specimen of a cohesive soil undergoes compression.

Indian Standard Specifications: IS 2720 (Part X)-1973

Formulae:

- The axial strain, $\sigma\% = (\gamma L/L_0)100$, Where, γL = change in length of specimen. L_0 = Initial length of specimen.
- Corrected area A, $A = A_0/(1-\gamma)$, Where, A_0 = initial sectional area op the specimen.



- Compressive stress, (which is the principal stress) is = P/A, where P = axial load.
- Unconfined compressive strength= q_u
- Shear strength, $S = q_u/2$.

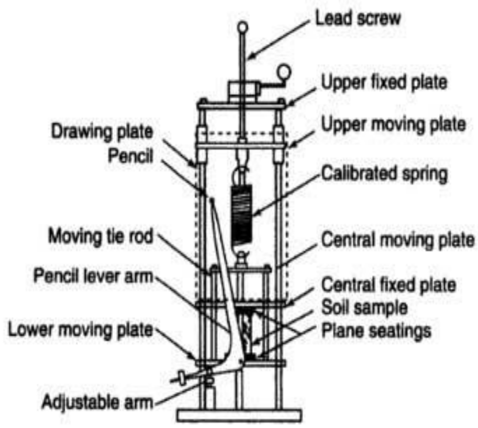


Fig.8- Schematic diagram UCS Experimental Setup.

d)Differential Free Swell Index (DFSI):

Free Swell is the increase in volume of soil without any external restriction upon submergence in water and kerosene for a span of 24 hours.

Indian Standard Specifications: IS 2720(Part40)-1977.

Formula:

Free swell index= $(V_d-V_k)/V_k)$ *100, where

V_d = Volume of soil sample noted from graduated cylinder with distilled water.

V_k = Volume of the soil sample noted from graduated cylinder with kerosene.

I. OBSERVATIONS AND RESULTS

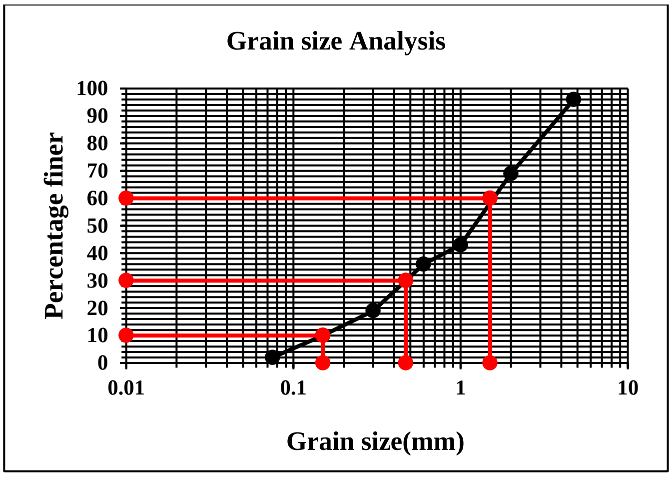
5.1 INDEX PROPERTIES OF RED SOIL

a.) Grain Size Analysis:

S. No	IS Sieve (mm)	Particle size (mm)	Mass retained (gm.)	Corrected Mass retained (gm)	Cumulative Mass retained (gm)	Cumulative %Retained	% of finer
1	4.75	4.75	20	20	20	4	96
2	2.00	2.00	135	135	155	31	69
3	1.00	1.00	130	130	285	57	43
4	0.60	0.60	35	35	320	64	36
5	0.30	0.30	85	85	405	81	19
6	0.15	0.15	45	45	450	90	10
7	0.075	0.075	40	40	490	98	2
8	pan	-	10	10	500	100	0

Table-1

- Mass of the sample taken for analysis, W= 500 gm
- %Gravel = 4%
- %Sand = 94%
- %Silt= 2%
- D_{10}= 0.15
- D_{30}= 0.47
- D_{60}= 1.5
- Coefficient of uniformity, $C_u = D_{60}/D_{10} = 10$
- Coefficient of Curvature, $C_c = D_{30}^2 /(D_{60} x D_{10}) = 0.98$



Graph-1

b.) Specific Gravity:

S.no	Description	Trail-1(gm)	Trail-2(gm)	Trail-3(gm)
1	Weight of density bottle (W_1), g	26.52	26.52	26.52
2	Weight of bottle + dry soil (W_2), g	51.49	51.57	51.51
3	Weight of bottle + soil + water (W_3), g	66.53	66.75	66.87
4	Weight of bottle + water (W_4), g	51.96	51.96	51.96
5	Specific gravity (G)= (W_2-W_1) /$[(W_4-W_1)-(W_3-W_2)]$	2.400	2.470	2.479
6	Average G,$(G_1+G_2+G_3)/3$	2.449		

Table-2

c.) Atterberg Limits:

i. Liquid Limit:

Table-3

- Flow Index, $I_f=(w_1-w_2)/\log(N_2/N_1) = 35.83$
- Liquid Limit= 48.83%

Graph-2

Trail No	1	2	3
Number of blows(N)	30	18	12
Weight of container(W_1)	10.9	22.1	28.7
Weight of container + wet soil(W_2)	17	27.2	37.3
Weight of container + dry soil (W_3)	15	25.5	34
Water content (%)w $=(W_2-W_3)/(W_3-W_1)$	48	50	62.26
Water content, w = $(w_1+w_2+w_3+w_4)/4$	53.42%		

ii. Plastic Limit:

Trail No	1	2	3	4
Weight of container(W_1)	15.6	9.5	16.0	14.9
Weight of container + wet soil(W_2)	16.4	10.6	16.9	16.0
Weight of container + dry soil (W_3)	16.3	10.4	16.8	15.8
Water content (%)$w=(W_2-W_3)/(W_3-W_1)$	14.286	22.22	12.50	22.21
Water content, $w = (w_1+w_2+w_3+w_4)/4$	49.25 %			

Table-4

Plasticity index = w_p - w_l = 31.04%

iii. Shrinkage Limit:

S.no	Description	Value
1	Mass of shrinkage dish (M_3) ,g	43
2	Mass of shrinkage dish with wet soil(M_1),g	79
3	Mass of shrinkage dish with dry soil(M_2),g	73
4	Mass of dry soil $M_s=(M_2-M_3)$,g	30
5	Mass of wet soil $M_0=(M_1-M_3)$,g	36
6	Mass of shrinkage cup with mercury, g	317
7	Mass of mercury, g	275
8	Mass of displaced mercury, g	90
9	Volume of wet soil(V_0)(mass of mercury/density of mercury-13.56gm/cc) (cc)	20.28
10	Volume of dry soil(V_d)(mass of displaced mercury/density of mercury-13.56gm/cc)(cc)	6.63
11	Shrinkage limit (Ws)= $[(M_0-M_s)-(V_0-V_d)\ \varrho_w]M_s$	5.54
12	Shrinkage ratio, $S_r = ((V_0-V_d)/V_0)x100$	67.3%

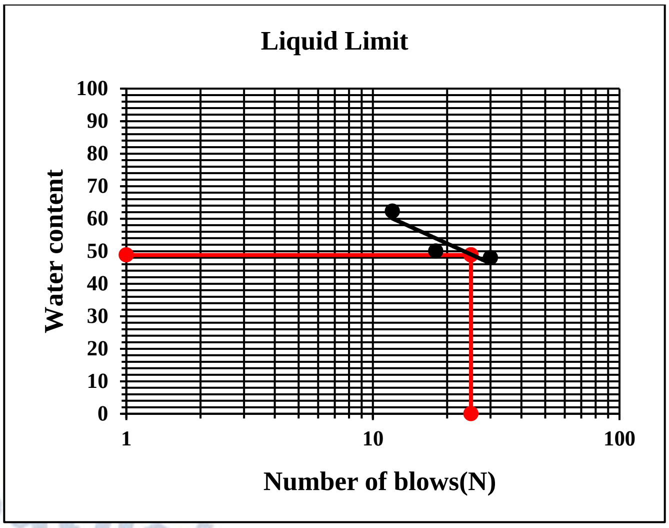


Table-5

5.2 Engineering Properties of Red Soil

a.) Standard Proctor Compaction Test:

S.no	Description	Trail-1	Trail-2	Trail-3	Trail-4
1	Mass of empty mould M_1(gm)	2840	2840	2840	2840
2	Volume of mould V (mm^3)	2.290	2.290	2.290	2.290
3	Height of empty mould H (mm)	125	125	125	125
4	Diameter of mould D (mm)	150	150	150	150
5	Mass of mould+ wet soil M_2 (gm)	7940	7850	7780	7700
6	Mass of wet soil ($M=M_2-M_1$) gm	5100	5010	4940	4860
7	Bulk Density ϱ_b (g/cc)	2.30	2.26	2.23	2.20
8	Water content %	13.13	13.69	17.21	18.80
9	Dry Density ϱ_d	1.99	2.06	1.90	1.85

	(g/cc)				

Table-6

- Optimum moisture content= 2.06 gm/cc
- Maximum dry density of soil = 13.69%

Graph-3

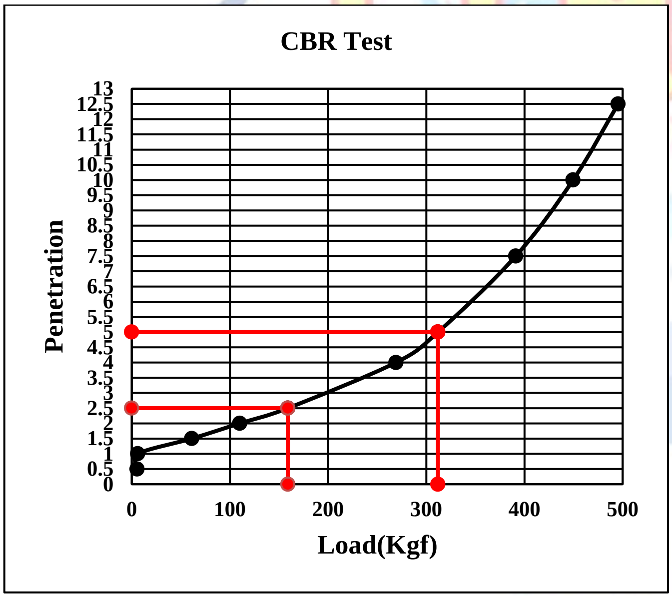
b.) California Bearing Ratio (CBR) Test:

CBR at 2.5mm= 11.6% (Un soaked)

CBR at 5.0mm= 15.17%

Penetration	Load dial reading	Total Load	CBR(%)
0.5	0.18	5.5	
1.0	0.2	6.11	
1.5	2	61.16	
2.0	3.6	110.09	
2.5	5.2	159.02	11.6%
4.0	8.8	269.11	
5.0	10.2	311.92	15.17%
7.5	12.8	391.14	14.88%
10.0	14.7	449.54	14.13%
12.5	16.2	495.41	13.76%

Table-7



Graph-4

c.) Unconfined Compression Strength (UCS) Test:

S.No	Deformation (cm)	Axial Load P(kN)	Axial Strain (%)	Corrected area, A(cm²)	Stress σ=P/A (kN/cm²)
1	0.015	0.03	0.1205	11.35	2.70
2	0.030	0.061	0.3615	11.38	5.40
3	0.045	0.089	0.7229	11.42	7.90
4	0.060	0.118	1.2048	11.47	10.4
5	0.075	0.128	1.4458	11.50	11.2
6	0.1	0.140	1.6868	11.53	12.2
7	0.15	0.146	1.8072	11.54	12.7
8	0.3	0.148	1.9277	11.56	12.8
9	0.45	0.144	2.0482	11.57	12.5
10	0.60	0.143	2.1687	11.59	12.4

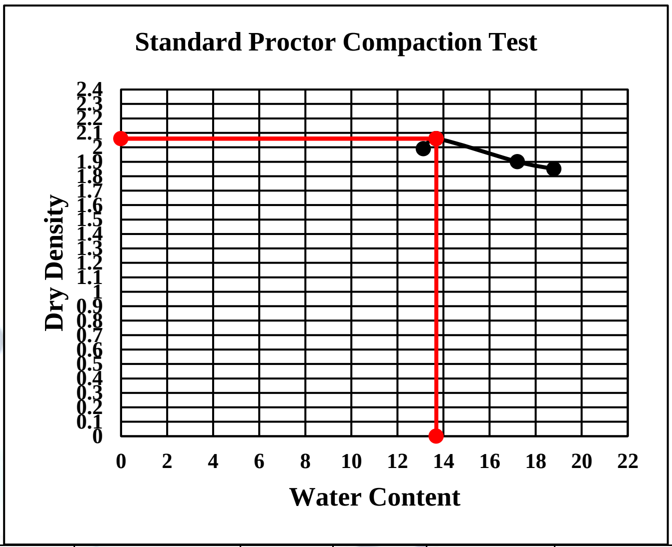
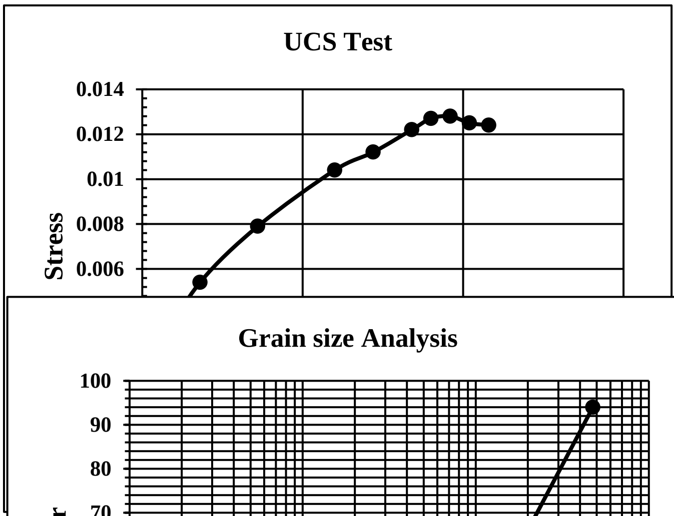
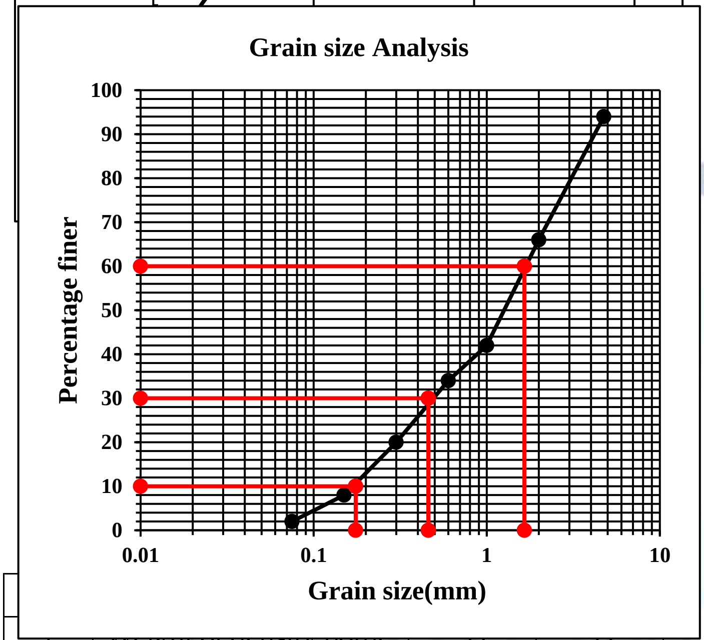


Table-8

- Initial Length= 83mm
- Initial Diameter= 38mm
- Initial Area= 1134mm²
- Initial Mass of specimen= 75.8g
- Initial density= 1.76g/cc
- Initial Water content = 15.5%





1	Weight of density bottle (W1), g	[illegible]	[illegible]
2	Weight of bottle + dry soil (W2), g	55.3	56.7
3	Weight of bottle + soil + water (W3), g	87.3	87.9
4	Weight of bottle + water (W4), g	74.4	74.4
5	Specific gravity (G)= (W2-W1) /[(W4-W1) -(W3-W2)]	2.37	2.32
6	Average G,(G1+G2+G3)/3	2.345	

- Rate of strain dropped= 1.27mm/min

Graph-5

- Unconfined compressive strength q_u = 0.105N/mm^2
- Undrained shear strength CU = $q_u/2$ =0.064N/mm^2

d.) Differential Free Swell Index (DFSI):

Table-9

5.3 INDEX PROPERTIES OF BLACK SOIL

a.) Grain Size Analysis:

S. No	IS Sieve (mm)	Particle size (mm)	Mass retained (gm.)	Corrected Mass retained (gm)	Cumulative Mass retained (gm)	Cumulative %Retained	% of finer
1	4.75	4.75	30	30	30	6	94
2	2.00	2.00	140	140	170	34	66
3	1.00	1.00	120	120	290	58	42
4	0.60	0.60	40	40	330	66	34
5	0.30	0.30	70	70	400	80	20
6	0.15	0.15	60	60	460	92	8
7	0.075	0.075	30	30	490	98	2
8	pan	-	10	10	500	100	0

Table-10

- Mass of the sample taken for analysis, W= 500g
- %Gravel = 6%
- %Sand = 92%
- %Silt= 2%
- D_{10}= 0.175
- D_{30}= 0.46
- D_{60}= 1.65
- Coefficient of uniformity, $C_u = D_{60}/D_{10}$ =9.42
- Coefficient of Curvature, $C_c = D_{30}^2 / (D_{60} x D_{10})$ = 0.73

Graph-6

b.) Specific Gravity:

Table-11

c.) Atterberg Limits:

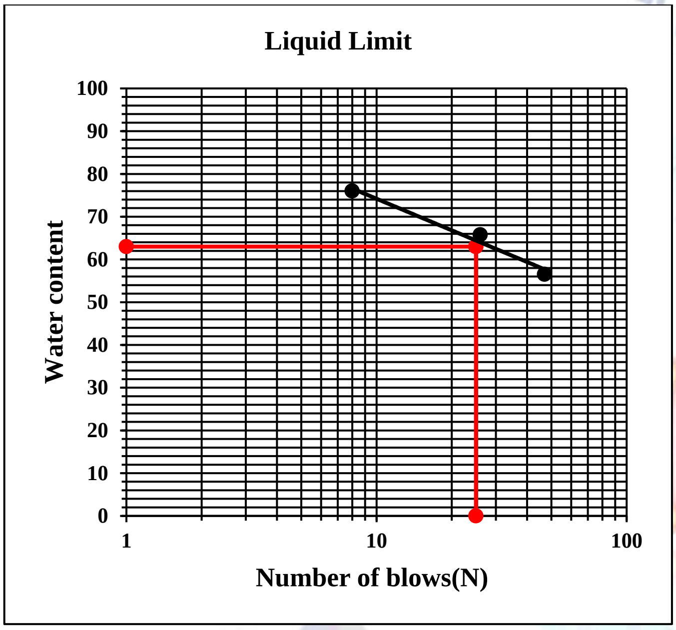
i. Liquid Limit:

Table-12

S.no	Description	Value
1	V_d	12ml
2	V_k	10ml
3	V_d- V_k	2ml
4	Free swell index=[(V_d- V_k)/v_k]x100	20%

Trail No	1	2	3
Number of blows(N)	47	26	8
Weight of container(W_1)	41.7	44.2	41.15
Weight of container + wet soil(W_2)	59.7	74.2	72.3
Weight of container + dry soil (W_3)	53.2	63.3	59.11
Water content (%)w=(W_2-W_3)/(W_3-W_1)	56.52	65.74	76
Water content, w = (w_1+w_2+w_3)/3	66		

- Flow Index, I_f =(w_1-w_2)/log (N_2/N_1) = 25.33
- Liquid Limit= 63%



Graph-7

ii. Plastic Limit:

Table-13

Plasticity index = w_p - w_l = 13.75%

iii. Shrinkage Limit:

S.no	Description	Value
1	Mass of shrinkage dish (M_3) ,g	63.2
2	Mass of shrinkage dish with wet soil(M_1),g	103.3
3	Mass of shrinkage dish with dry soil(M_2),g	90.1
4	Mass of dry soil M_s=(M_2-M_3),g	26.9
5	Mass of wet soil M_0=(M_1-M_3),g	40.1
6	Mass of shrinkage cup with mercury, g	484.4
7	Mass of mercury, g	397.9
8	Mass of displaced mercury, g	29.25
9	Volume of shrinkage dish=volume of wet soil(V_0)ml	162.8
10	Volume of dry soil(V_d),ml	11.92
11	Shrinkage limit (W_s)= [(M_0-M_s)-(V_0-V_d) ϱ_w]M_s	12.22
12	Shrinkage ratio, S_r = ((V_0-V_d)/V_0)x100	92.67

Table-14

5.4 ENGINEERING PROPERTIES OF BLACK SOIL

a.) Standard Proctor Compaction Test:

Trail No	1	2	3
Weight of container(W_1)	43.3	47.3	35.7
Weight of container + wet soil(W_2)	47.8	49.5	40.2
Weight of container + dry soil (W_3)	46.5	48.7	38.7
Water content(%) w=(W_2-W_3)/(W_3-W_1)	40.62	57.14	50
Water content, w = (w_1+w_2+w_3+w_4)/4	49.25		

S.no	Description	Trail-1	Trail-2	Trail-3	Trail-4
1	Mass of empty mould M_1(gm)	3885	3885	3885	3885
2	Volume of mould V (mm^3)	981.74	981.74	981.74	981.74
3	Height of empty mould H (mm)	120	120	120	120
4	Diameter of mould D (mm)	102	102	102	102
5	Mass of mould+ wet soil M_2 (gm)	5785	6040	6045	5195
6	Mass of wet soil ($M=M_2-M_1$) gm	1900	2155	2160	1310
7	Bulk Density ρ_b (g/cc)	1.93	2.19	2.20	1.33
8	Water content %	7.48	11.91	16.76	20.51
9	Dry Density ρ_d (g/cc)	1.79	1.93	1.83	1.06

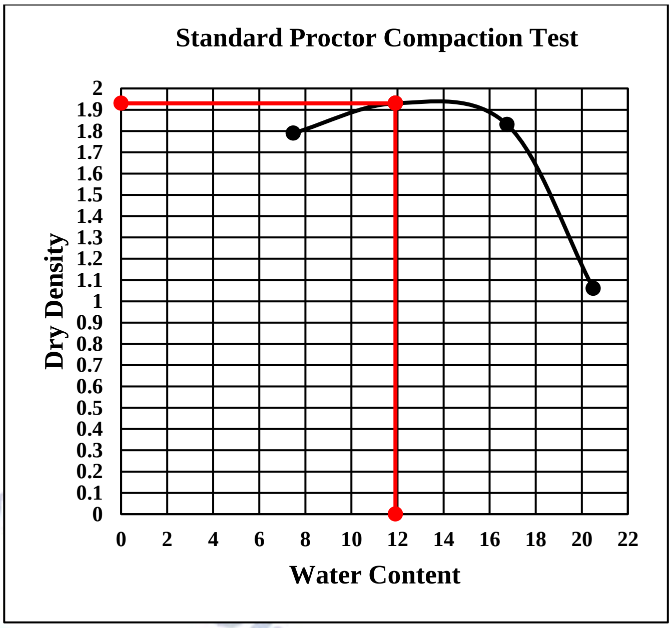
Table-15

Water content:

Trail No	1	2	3	4
Weight of container(W_1)	44.43	42.2	47.37	44.78
Weight of container + wet soil(W_2)	93.7	75.27	96.61	90.84
Weight of container + dry soil (W_3)	90.27	71.75	89.54	83
Water content $w=(\%)(W_2-W_3)/(W_3-W_1)$	7.48	11.91	16.76	20.51

Table-16

- Optimum moisture content= 11.91%



- Maximum dry density of soil =1.93g/cc

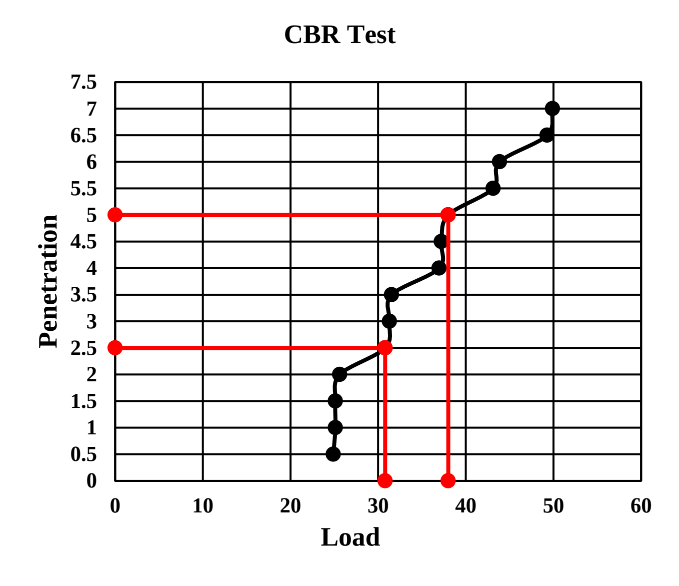
Graph-8

b.) California Bearing Ratio (CBR)Test:

S.no	Dial Gauge reading	Penetration	Provision reading	Loading
1	50	0.5	20.2	24.889
2	100	1.0	20.4	25.13
3	150	1.5	20.4	25.13
4	200	2.0	20.8	25.62
5	250	2.5	25	30.8
6	300	3.0	25.4	31.29
7	350	3.5	25.6	31.54
8	400	4.0	30	36.96
9	450	4.5	30.2	37.21
10	500	5.0	30.9	38
11	550	5.5	35	43.12
12	600	6.0	35.6	43.86
13	650	6.5	40	49.28
14	700	7.0	40.5	49.90

Table-17

- CBR at 2.5mm= 8.2% (Un soaked)
- CBR at 5.0mm=10%



Graph-9

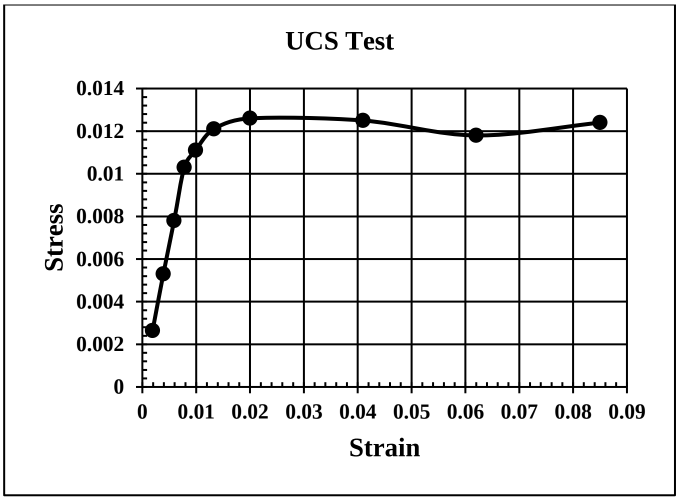
c.) Unconfined Compression Strength(UCS)Test:

- Initial Length= 7.6cm
- Initial Diameter= 3.8cm
- Initial Area= 11.34cm^2
- Initial Mass of specimen= 120gm
- Initial Water content = 14%
- Rate of strain dropped= 1.27mm/min

S.No	Deformation (cm)	Axial Load P(kN)	Axial Strain (%)	Corrected area, A(cm^2)	Stress σ=P/A (kN/cm^2)
1	0.015	0.03	0.19	11.36	2.64
2	0.030	0.061	0.39	11.38	5.30
3	0.045	0.089	0.59	11.40	7.80
4	0.060	0.118	0.78	11.43	10.3
5	0.075	0.128	0.99	11.45	11.1
6	0.1	0.140	1.33	11.49	12.1
7	0.15	0.146	2.0	11.57	12.6
8	0.3	0.148	4.1	11.82	12.5
9	0.45	0.144	6.2	12.10	11.8
10	0.60	0.143	8.5	12.40	11.5

Table-18

- Unconfined compressive strength qu = 0.092N/mm^2
- Undrained shear strength CU = qu/2 = 0.062N/mm^2



Graph-10

d.) Differential Free Swell Index (DFSI):

S.no	Description	Value
1	V_d	36ml
2	V_k	20ml
3	V_d- V_k	16ml
4	Free swell index=[(V_d- V_k)/v_k]x100	80%

Table-19

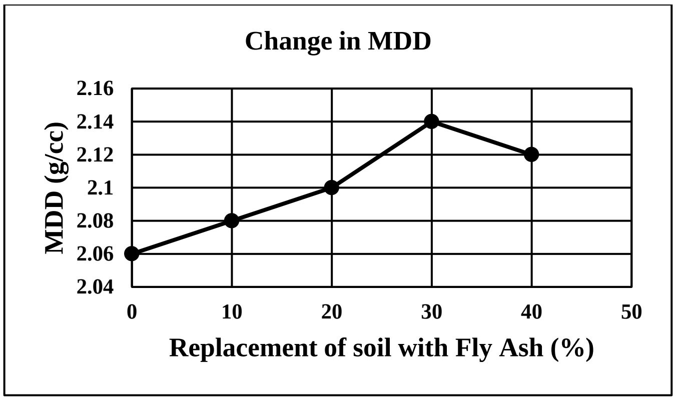
From the above observations, we can clearly say that Virgin Red soil is the best when compared with Black soil and hence can be used as a construction material. But, the CBR values for soaked samples are less than 8%, which cannot be used in the construction of pavements. As per **Ministry of Road Transport and Highways (MORTH)** Specifications **(IRC 37-2012)**, the minimum soaked CBR value for subgrade material must be 8%. So as to meet the requirement, we need to introduce fly ash as a replacement for certain percentage of soil. CBR, UCS, OMC and MDD values must be determined for both red and black soil samples.

5.5 RED SOIL+ FLY ASH

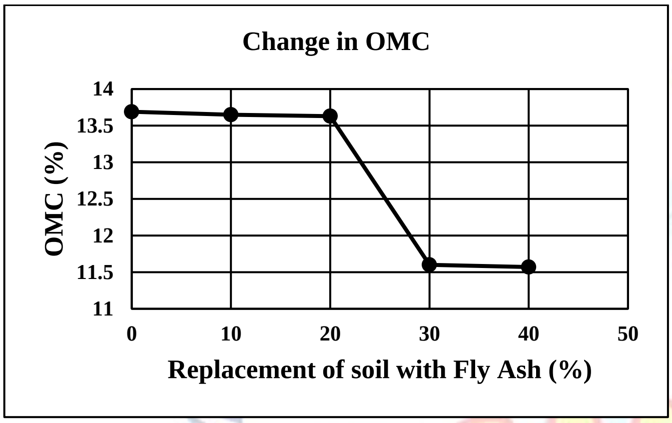
a)Optimum Moisture Content and Maximum Dry Density:

S.No	Replacement of soil with Fly Ash (%)	MDD (g/cc)	OMC (%)
1	0	2.06	13.69
2	10	2.08	13.65
3	20	2.10	13.63
4	30	2.14	11.60
5	40	2.12	11.57

Table-20



Graph-11

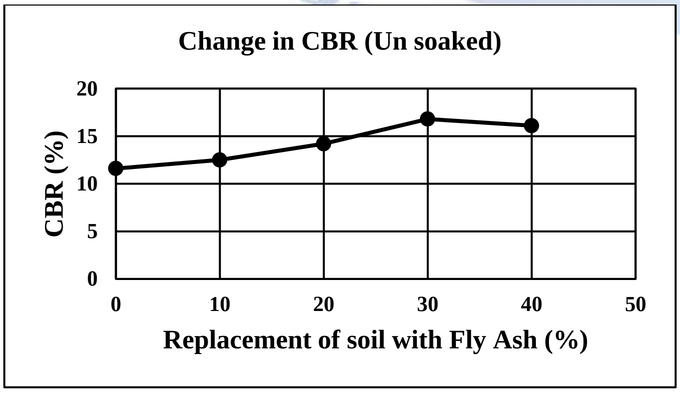


Graph-12

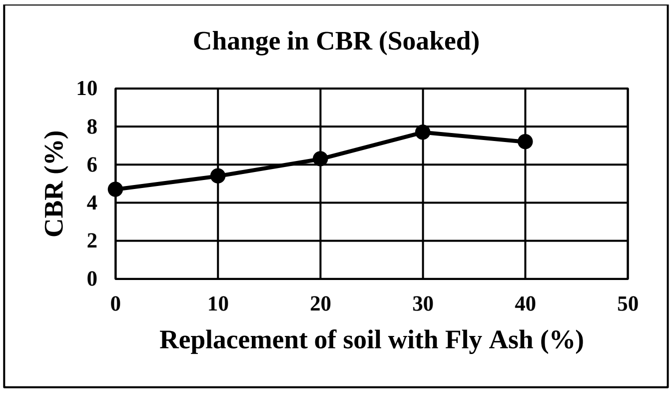
b) California Bearing Ratio Test:

S.No	Replacement of soil with Fly Ash (%)	CBR for Un soaked sample(%)	CBR for soaked sample(%)
1	0	11.6	4.7
2	10	12.5	5.4
3	20	14.2	6.3
4	30	16.8	7.7
5	40	16.1	7.2

Table-21



Graph-13

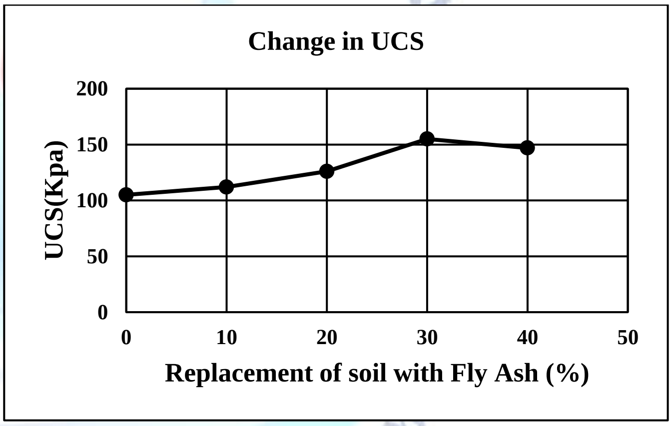


Graph-14

c) Unconfined Compression Test:

S.No	Replacement of soil with Fly Ash (%)	UCS(Kpa)
1	0	105
2	10	112
3	20	126
4	30	155
5	40	147

Table-22



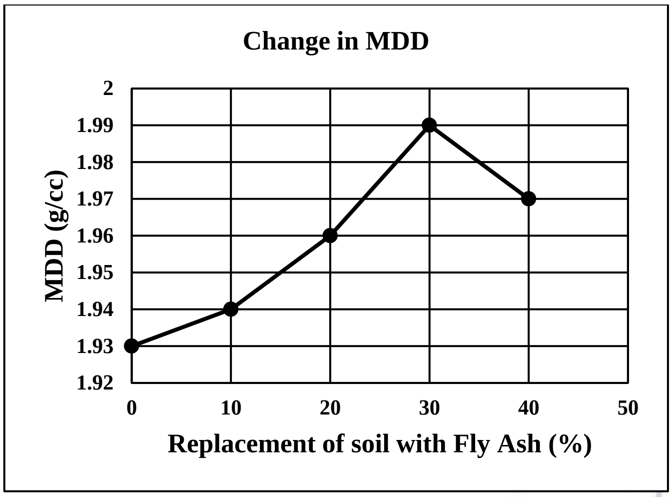
Graph-15

5.6 BLACK SOIL+ FLY ASH

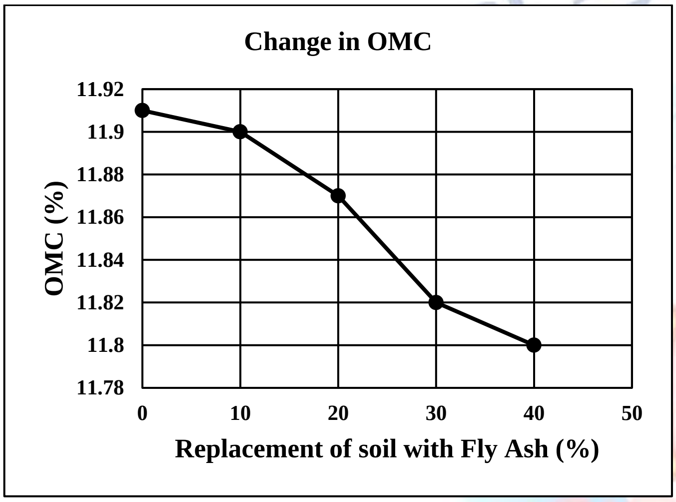
a)Optimum Moisture Content and Maximum Dry Density:

S.No	Replacement of soil with Fly Ash (%)	MDD (g/cc)	OMC (%)
1	0	1.93	11.91
2	10	1.94	11.90
3	20	1.96	11.87
4	30	1.99	11.82
5	40	1.97	11.80

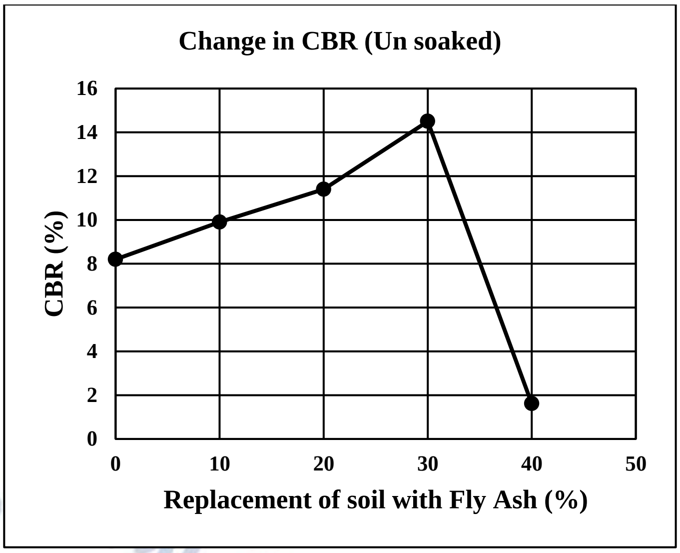
Table-23



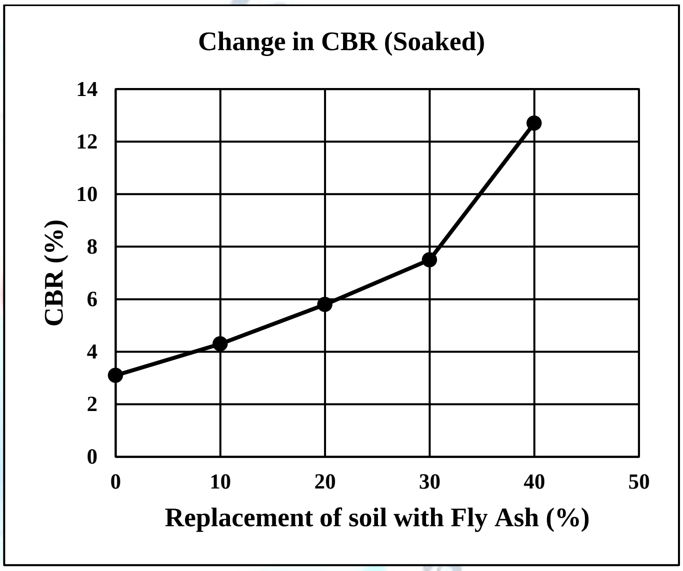
Graph-16



Graph-17



Graph-18



Graph-19

b) California Bearing Ratio Test:

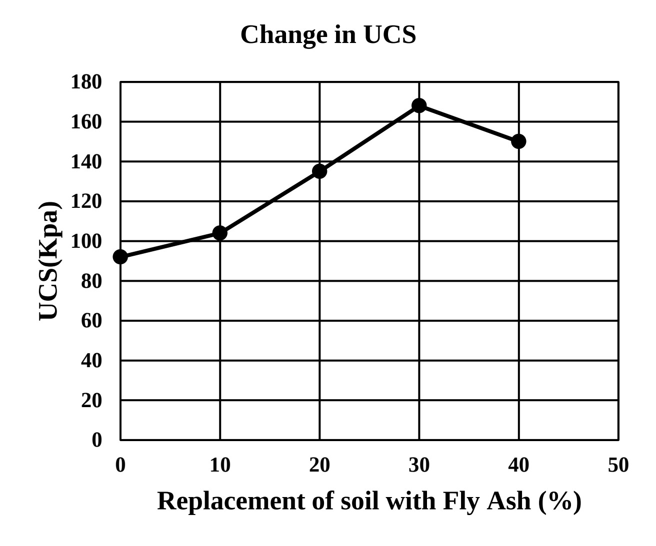
S.No	Replacement of soil with Fly Ash (%)	CBR for Un soaked sample(%)	CBR for soaked sample(%)
1	0	8.2	3.1
2	10	9.9	4.3
3	20	11.4	5.8
4	30	14.5	7.5
5	40	12.7	7.0

Table-24

c) Unconfined Compression Test:

S.No	Replacement of soil with Fly Ash (%)	UCS(Kpa)
1	0	92
2	10	104
3	20	135
4	30	168
5	40	150

Table-25



Graph-20

In the present study on treating the soil samples with fly ash, the CBR values for soaked soil specimens have been increased but they are not up to required value (<8%) as per **Ministry of Road Transport and Highways (MORTH)** Specifications **(IRC 31-2012)**. Hence from the literature, majority findings stated that lime can be added along with fly ash, whose optimum values vary from 6%-9%. We have taken the lower side of optimum i.e; 6% of lime.

All the optimum samples are mixed with required quantities of fly ash and lime and are compacted at their OMC and MDD values in their respective molds for conducting CBR and UCS tests by covering with moist cloth for 24 hours so as to provide adequate time for the chemical reactions taking place in between lime and the soil samples respectively.

As we obtain maximum values for replacement of soil with 30% of Fly Ash in OMC, MDD, CBR and UCS, hence we conduct the above experiments for the 30% fly ash soil samples by adding 6% of lime.

5.7 RED SOIL+ FLY ASH+ LIME

a)Optimum Moisture Content and Maximum Dry Density:

S.No	Fly Ash+ Lime added to soil(%)	MDD (g/cc)	OMC (%)
1	0	2.06	13.69
2	30% Fly Ash+ 0% Lime	2.12	10.89
3	30% Fly Ash + 6% Lime	2.16	10.83

Table-26

b) California Bearing Ratio Test:

S.No	Fly Ash+ Lime added to soil(%)	CBR for Un soaked sample(%)	CBR for Soaked sample(%)
1	0	11.6	4.7
2	30% Fly Ash+ 0% Lime	17.3	7.7
3	30% Fly Ash + 6% Lime	17.7	8.1

Table-27

c) Unconfined Compression Test:

S.No	Fly Ash+ Lime added to soil(%)	UCS(Kpa)
1	0	105
2	30% Fly Ash+ 0% Lime	155
3	30% Fly Ash+ 6% Lime	178

Table-28

5.7 BLACK SOIL+ FLY ASH+ LIME

a)Optimum Moisture Content and Maximum Dry Density:

S.No	Fly Ash+ Lime added to soil(%)	MDD (g/cc)	OMC (%)
1	0	1.93	11.91
2	30% Fly Ash+ 0% Lime	1.99	10.9
3	30% Fly Ash + 6% Lime	2.03	10.87

Table-29

b) California Bearing Ratio Test:

S.No	Fly Ash+ Lime added to soil(%)	CBR for Un soaked sample(%)	CBR for Soaked sample(%)
1	0	8.2	3.1
2	30% Fly Ash+ 0% Lime	14.5	7.5
3	30% Fly Ash + 6% Lime	18.8	8.4

Table-30

c) Unconfined Compression Test:

S.No	Fly Ash+ Lime added to soil(%)	UCS(Kpa)
1	0	92
2	30% Fly Ash+ 0% Lime	168
3	30% Fly Ash+ 6% Lime	206

Table-31

II. CONCLUSION

We have determined all the Index properties and Engineering properties of Red soil and Black soil samples respectively in the laboratory according to Indian Standard Code Specifications and have tabulated the results accordingly. From the results, we can observe that:

- Specific Gravity of Red soil (2.449) is greater than that of Black soil (2.345).
- Liquid Limit of Black soil (63%) is higher than the Liquid Limit of Red soil (48.83%) with the Flow Indices of 25.33 and 38.83 respectively.
- Plastic Limit of Black soil (49.25%) is higher than the Plastic Limit of Red soil (17.79%) with the Plasticity Indices of 13.75 and 31.04 respectively which shows that Black soil is Medium Plastic (7-17 of I_P) and Red soil is Highly Plastic (>17 of I_P).
- Shrinkage Limit of Black soil (12.22) is greater than that of Red soil (5.54) with the Shrinkage Ratios of 67.3% and 92.67% respectively.
- Optimum Moisture Content and Maximum Dry Density values of Black soil are 11.91% and 1.93 g/cc respectively and are less than that of values of Red soil which are 13.69% and 2.06g/cc respectively.
- California Bearing Ratio (CBR) @ 2.5mm penetration for an Un soaked Red soil specimen is 11.6% which is quite higher than the value of 8.2% for Black soil specimen.
- California Bearing Ratio (CBR) @ 2.5mm penetration for a Soaked Red soil specimen is 4.7% which is greater than the value of 3.1% for Black soil specimen.
- From Unconfined Compressive Strength (UCS) values of Red soil and Black soils (105kN/m^2 and 92kN/m^2), we can observe that Red soil sample is of stiff consistency, (100-200kN/m^2→ Stiff soil) while Black soil sample is of medium consistency (50-100Kn/m^2) with an Undrained Shear Strength of 0.064N/mm^2 for Red soil and 0.062N/mm^2 for Black soil.
- From the values of Differential Free Swell Index for Red soil and Black soil samples, we can state that Black soil is highly Expansive (80%) than that of Red soil (20%).

From the above, we can conclude that Virgin Red soil is the best when compared with Black soil and hence can be used as a construction material. The characteristics of red soil has its impact on strength and imperviousness. After conducting suitable tests, red soil is found to be as a suitable admixture for concrete which can be used in construction of buildings.

As per **Ministry of Road Transport and Highways (MORTH)** Specifications **(IRC 31-2012)**, the minimum soaked CBR value for subgrade material must be 8%. From the literatures, we have found that Fly Ash is the best additive and can be replaced with the soil by some amount to improve its Engineering properties.

On replacing 30% of Red soil with Fly Ash:

- There is decrement of 15.26% in OMC
- There is an improvement of 3.88% in MDD.
- There is an improvement of 44.82% in CBR for Un soaked specimen.
- There is an improvement of 38.96% in CBR for Soaked specimen.
- There is an improvement of 47.62% in UCS.

On replacing 30% of Black soil with Fly Ash:

- There is decrement of 0.75% in OMC
- There is an improvement of 3.10% in MDD.
- There is an improvement of 76.82% in CBR for Un soaked specimen.
- There is an improvement of 141.93% in CBR for Soaked specimen.
- There is an improvement of 82.6% in UCS.

To improve the Soaked CBR value to the required value of 8%, we have added 6%Lime to 30%Fly Ash soil samples.

For Red soil:

- There is decrement of 20.89% in OMC
- There is an improvement of 4.84% in MDD.
- There is an improvement of 52.58% in CBR for Un soaked specimen.
- There is an improvement of 72.34% in CBR for Soaked specimen.
- There is an improvement of 69.52% in UCS.

For Black soil:

- There is decrement of 8.73% in OMC
- There is an improvement of 5.18% in MDD.
- There is an improvement of 129.26% in CBR for Un soaked specimen.
- There is an improvement of 170.96% in CBR for Soaked specimen.
- There is an improvement of 123.91% in UCS.

The maximum dry density and optimum moisture content was increased effectively due to the addition of the lime in the Black soil because it acted as pore filler and hydration reaction initiator. The load bearing capacity of Black soil was enhanced more than that of Red soil as the CBR and UCS values showed increment by adding lime and Fly Ash. From the above results, we can conclude that Black soil can be stabilized more efficiently than Red soil when replaced with 30% Fly Ash and by addition of 6% Lime.

6.1 FUTURE SCOPE:

- Results showed a drastic increase in CBR and UCS values for both Red soil and Black soil when replaced with 30% Fly Ash and by addition of 6% Lime. Hence in future higher percentages of lime and Fly Ash may be added to see the variation in results.
- Many types of additives like Stone dust, Rice husk, etc can be utilized to stabilize Red soil and Black soil to improve their Engineering properties with same tests i.e; CBR test and UCS test.

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