Performance Evaluation of Stabilized Soil for Pavements

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Abstract

Soil is a natural body consisting of layers that are primarily composed of minerals, mixed with at least some organic matter, which differs from their parent materials in their texture, structure, consistency, color, and other characteristics. Soil stabilization is the process of improving the shear strength parameters of soil and thus increasing the bearing capacity of the soil. An experimental investigation is carried out to study the effect of lime, cement, fly ash and cinder on Black Cotton Soil from four different locations to determine the index properties of soil. Various percentages of lime, cement ,fly ash (2%,4%,6%,8%) and Cinder(10%,20%,30%,40%) by its weights respectively have been used to improve the engineering behaviour of expansive soil. One ingredient at a time has been mixed with soil and index as well as engineering properties have been determined. From the experimental result it has been concluded that liquid limit & plastic limit of the soil is reduced by adding of each ingredient individually. The standard proctor parameters such as OMC (Optimum moisture content) and MDD(Maximum dry density) also increased. the free swelling index is decreased with the addition of admixtures and the unsoaked CBR(California bearing ratio) value is increased from 4% to 10% using lime ingredients individually Thus, it can be concluded that stabilization of expansive black cotton soil using lime, cement, fly ash and cement as admixtures is a good way of improving then engineering behavior expansive soil. Moreover, it is also cost effective by reducing the thickness of sub-base and a base layer of flexible pavement

Keywords - *Lime, cement, fly ash and Cinder, California Bearing ratio, Standard Proctor test, atterberg's limits and a Free swell index*

I. INTRODUCTION

In Geo-technical Engineering Soil are a composition of Mineral Particle, organic matter, Air, and water. The main objective of this paper is to determine the performance evaluation of stabilized soil (Black cotton soil) for pavements when it is treated with various admixtures. The soil deposits of India can be broadly classified into the following: Red soils, Laterite soils, alluvial soils, Desert soils, Saline and Alkaline soils, Peaty and marshy soils and Black cotton soils (Afrin, 2017).

Black cotton soil

In India, expansive soils are called as Black Cotton soil. The name “Black Cotton soil” has an agricultural origin. Most of these soils are black in colour and are good for growing Cotton and occurring in Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Parts of Andhra Pradesh and Tamilnadu. These are expansive in nature. On account of high swelling and shrinkage potential, these are difficult soils to deal with in foundation design

All the black soils are not expansive soils and all the expansive soils are not black in colour (Makusa, 2012).These soils possess high strength in summer and decreased rapidly in winter. The soil has a swelling property due to the presence of montmorillonite mineral. Black cotton soils possess high expansive characteristics. These soils are low shrinkage limit and with high optimum moisture content. They are highly sensitive to moisture changes.

A.Present Investigation

In this work, the black cotton soil is stabilized with lime, cement, fly ash and Cinder. The black cotton soil is extracted from four locations (Chickmagaluru, Bagalkot, Yadahgiri, and Koppal) and different engineering and index properties were studied. Varying dosage of Fly ash , lime , cement (2% , 4% , 6% , 8%) is added respectively and Cinder (10% , 20% , 30% , 40%) Is added

B.Scope of the work

The different properties of soil has to be studied:

Specific gravity, Wet sieve analysis, Atterberg’s limit, Free swell index, Standard Proctor test, Unconfined compression test, Permeability, California bearings ratio test

1. Standard Proctor test

Compaction tests were conducted on the lime, cement, fly ash and cinder mixes on the plain soil of varying percentage and evaluated to the maximum dry density (MDD) values and optimum moisture content (OMC) value

2. California bearing ratio (CBR)

The CBR tests were conducted on lime, cement, fly ash and cinder mixes on black cotton soil samples. It is noted that the CBR value of the admixtures in

various proportions has increased gradually from 4 to 10%

3. Atterberg's limits

Liquid limit (LL), plastic limit (PL), and shrinkage limit tests were conducted on the varying percentages of lime, cement, fly ash and cinder mixes in plain soil

4. Free swell index

The Free swell index tests were conducted on the lime, cement, fly ash and cinder mixes on black cotton soil samples. It is noted that the values of the admixtures in various proportions have decreased gradually

Determining Pavement thickness and cost analysis for treated and untreated soil:

Pavement thickness on untreated sub-base layer is 770 mm and thickness on treated soil 610mm. Pavement Thickness is reduced so as cost also decrease when CBR value increases and Composition thickness Comparisons on treated soil sample and untreated soil sample is done

II. LABORATORY STUDIES

In the present study, the following materials are used
Expansive soil (Black cotton soil)
Lime
Cement
Fly ash
Cinder (Molten Iron slag)

A. Materials

1. Expansive Soils

Type of soil used in this investigation is of having high clay content, Black cotton soil
Different Engineering properties are soil initially can be found by conducting corresponding the experiments according to IS code specification (Monica Malhotra, 2013)

2. Lime

Hydraulic lime is a general term for varieties of lime or slaked lime, used to make lime mortar which set through hydration and therefore they are called hydraulic. Hydraulic lime provides a faster initial set and higher compressive strength. The terms hydraulic lime and hydrated lime are quite similar and may be confused but are not necessarily the same material (Ankith Singh, 2013)

3. Cement

Cement is used in this analysis is OPC 53grade and in which Varying dosage of cement is added to black cotton soils. By utilizing this zero costing material for the purpose of stabilization. This soil is stabilized with the cement (A. K. Sinha, 2012)

4. Fly ash

Fly ash is a by-product from burning pulverized coal in electric power generating plants. During combustion, mineral impurities in the coal fuse in suspension and float out of the combustion chamber with the exhaust gases (N.Krithiga, 2017)

5. Cinder

Cinder is a waste material generated as coal residues from the blast furnace of the power plant. This material has potential in the construction of the road. The material was investigated for the utilization in road construction viz. embankment and sub grade layers (Vasant g havangi, 2015).

TABLE 1
Basic test conducted on soil sample

Sl. no	Test	Soil Sample 1	Soil Sample 2	Soil Sample 3	Soil Sample 4
1	Specific gravity	2.14	2.26	2.40	2.42
2	Liquid limit	69%	60%	64%	72%
3	Plastic limit	45%	32%	45%	48%
4	Shrinkage limit	12%	12%	11%	12%
5	Plasticity index	24%	26%	15%	20%
6	MDD g/cc	1.55	1.81	1.81	1.9
7	OMC	10%	18%	10%	12%
8	Free swell index	20%	40%	40%	20%
9	CBR Unsoaked	4.00%	4.85%	3.92%	4.23%
10	CBR soaked	2.06%	1.86%	1.55%	2.17%
11	Unconfined compression strength kg/cm2	1.41	1.2	1.24	1.5

Figure 1 Liquid limit test

Figure 2 CBR test

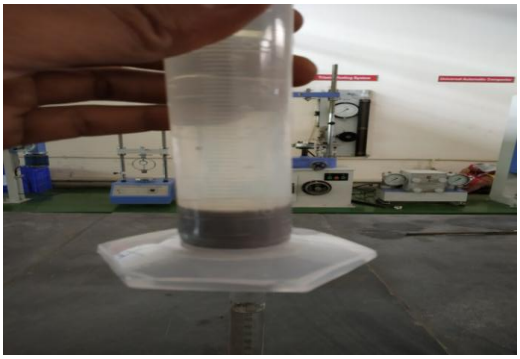


Figure 3 FSI test

Figure 4 Compaction test

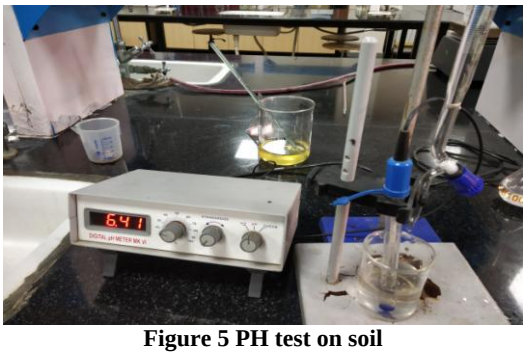
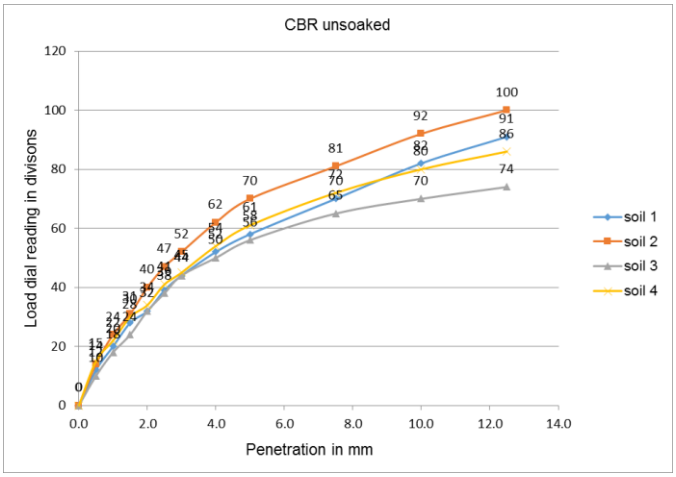
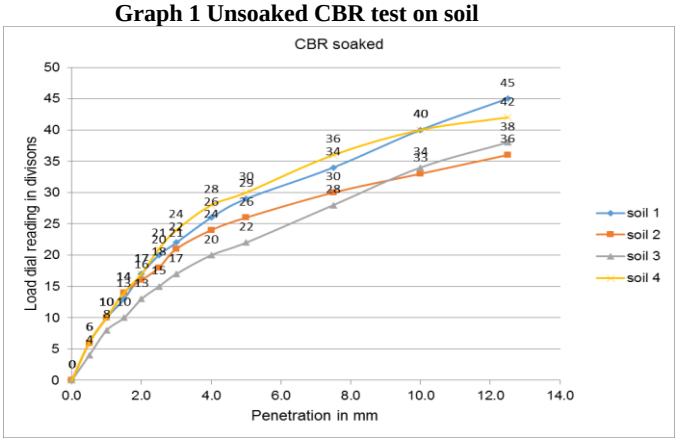


Figure 5 PH test on soil

Figure 5 Electrical conductivity test on soil



Graph 1 Unsoaked CBR test on soil



Graph 2 soaked CBR test on soil

III. Analysis of Test Results and Discussion

TABLE 2

Test conducted on soil sample additive Lime

Test	2%	4%	6%	8%
Soil Sample 1				
OMC	12%	12%	12%	12%
MDD	1.46 g/cc	1.57 g/cc	1.53 g/cc	1.63 g/cc
LL	61	50	45	48
PL	39	38	28	32

CBR	6.29%	6.70%	7.32%	8.04%
Soil Sample 2				
OMC	18%	18%	18%	18%
MDD	1.68 g/cc	1.78 g/cc	1.79 g/cc	1.86 g/cc
LL	51	45	54	44
PL	38	26	26	23
CBR	8.35%	8.77%	9.28%	9.49%
Soil Sample 3				
OMC	12%	12%	14%	14%
MDD	1.60 g/cc	1.61 g/cc	1.71 g/cc	1.86 g/cc
LL	60	46	55	44
PL	43	26	32	28
CBR	6.60%	7.01%	7.63%	7.73%
Soil Sample 4				
OMC	14%	14%	14%	14%
MDD	1.66 g/cc	1.68 g/cc	1.72 g/cc	1.85g/cc
LL	53	58	56	60
PL	30	35	35	39
CBR	6.39%	6.91%	7.53%	8.25%

TABLE 3
Test conducted on soil sample additive Cement

Test	2%	4%	6%	8%
Soil Sample 1				
OMC	14%	14%	14%	14%
MDD	52 g/cc	1.53 g/cc	1.56 g/cc	1.57 g/cc
LL	66	50	48	45
PL	34	32	26	27
CBR	5.98%	6.81%	7.01%	7.73%
Soil Sample 2				
OMC	18%	20%	20%	20%
MDD	1.74 g/cc	1.75 g/cc	1.76 g/cc	1.86 g/cc
LL	58	51	50	40
PL	27	26	30	25
CBR	8.25%	8.46%	8.97%	9.28%
Soil Sample 3				
OMC	14%	14%	14%	14%
MDD	1.69 g/cc	1.73 g/cc	1.78 g/cc	1.82 g/cc
LL	55	50	52	41
PL	25	28	30	26
CBR	6.39%	7.32%	8.04%	8.56%
Soil Sample 4				
OMC	14%	14%	14%	14%
MDD	1.72 g/cc	1.75 g/cc	1.85 g/cc	1.92 g/cc
LL	65	59	51	40
PL	29	26	29	26
CBR	6.70%	7.22%	7.84%	9.18%

TABLE 4
Test conducted on soil sample additive fly ash

Test	2%	4%	6%	8%
Soil Sample 1				
OMC	12%	14%	14%	14%
MDD	1.43 g/cc	1.45 g/cc	1.51 g/cc	1.55 g/cc
LL	65	56	55	42
PL	43	38	40	29
CBR	4.50%	5.26%	5.47%	5.67%
Soil Sample 2				
OMC	18%	18%	18%	20%
MDD	1.62 g/cc	1.65 g/cc	1.73 g/cc	1.83 g/cc
LL	50	48	46	40
PL	26	21	25	19
CBR	6.19%	6.70%	7.32%	7.73%
Soil Sample 3				
OMC	12%	12%	12%	12%
MDD	1.69 g/cc	1.72 g/cc	1.77 g/cc	1.84 g/cc
LL	60	57	52	47

PL	33	30	27	22
CBR	4.95%	5.16%	5.81%	6.08%
Soil Sample 4				
OMC	12%	14%	14%	14%
MDD	1.7 g/cc	1.73 g/cc	1.75 g/cc	1.91 g/cc
LL	66	50	50	44
PL	38	33	34	26
CBR	6.91%	7.12%	7.22%	7.53%

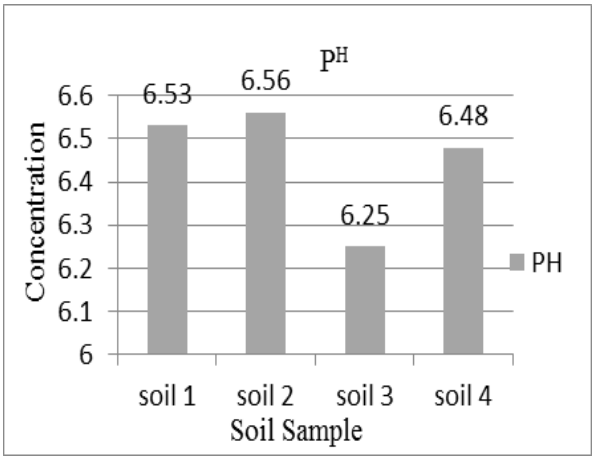
TABLE 5
Test conducted on soil sample additive cinder

Test	2%	4%	6%	8%
Soil Sample 1				
OMC	12%	12%	12%	14%
MDD	1.59 g/cc	1.54 g/cc	1.53 g/cc	1.57 g/cc
LL	40	45	50	62
PL	26.46	24.96	26.94	38.29
CBR	4.33%	4.74%	4.90%	5.26%
Soil Sample 2				
OMC	18%	18%	18%	18%
MDD	1.60 g/cc	1.73 g/cc	1.71 g/cc	1.82 g/cc
LL	54	66	45	46
PL	35.69	40.40	22.99	24.69
CBR	4.64%	4.85%	5.16%	5.47%
Soil Sample 3				
OMC	12%	12%	12%	12%
MDD	1.79 g/cc	1.70 g/cc	1.76 g/cc	1.81 g/cc
LL	45	47	52	62
PL	24.24	32.38	35.69	43
CBR	3.92%	4.23%	5.05%	5.67%
Soil Sample 4				
OMC	14%	14%	14%	14%
MDD	1.74 g/cc	1.76 g/cc	1.89 g/cc	1.91 g/cc

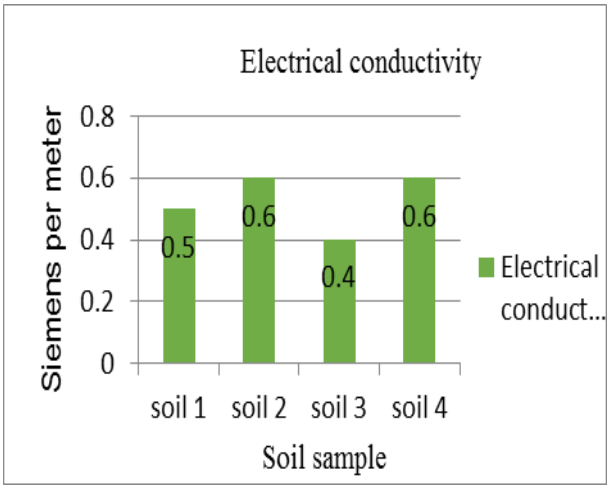
LL	65	55	54	68
PL	49.85	32.94	21.62	33
CBR	5.57%	5.78%	6.08%	6.19%

TABLE 6
Chemical analysis on soil sample

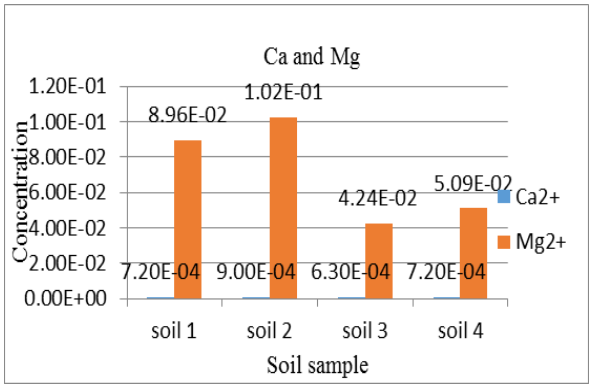
Test	Soil 1	Soil 2	Soil 3	Soil 4
P^H	6.53	6.56	6.25	6.48
EC	0.5	0.6	0.4	0.6
Ca2+	7.20E-04	9.00E-04	6.30E-04	7.20E-04
Mg2+	8.96E-02	1.02E-01	4.24E-02	5.09E-02



Graph 3 PH test results



Graph 4 Electrical conductivity test results



Graph 5 Ca+ and Mg+ Concentration test results

Cost Benefit analysis:

The rural road width of 3.75m and length of 1km is considered for the cost Benefit analysis purpose
The thickness of pavement where refer from IRC 37-2012 for CBR of 4% and 10% for 100msa traffic
PMGSY (Pradhan Mantri Gram Sadak Yojana) scheduled rates 2007-08 is refer for materials rates in cubic meter There is reduction in pavement thickness and overall

IV. DISCUSSION

Soil sample 1

A. Lime

From the test results it was observed that 1.55 g/cc is the maximum dry density for soil sample 1 with addition of 8% lime the MDD observed was 1.63 g/cc hence there is increase of 5.16% in MDD
From the test results it was observed that the liquid limit=69 and Plastic limit =45 for soil sample 1 with addition of 8% lime the liquid limit =48, Plastic limit =32 hence there is decrease of 43.75% and 40.62% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 1 is 4% with addition of 8% lime the CBR observed was 8.03% thus there is increase in 100% in CBR

B. Cement

From the test results it was observed that 1.55 g/cc is the maximum dry density for soil sample 1 with addition of 8% cement the MDD observed was 1.57 g/cc hence there is increase of 1.29% in MDD
From the test results it was observed that the liquid limit =69 and Plastic limit =45 for soil sample 1 with addition of 8% cement the liquid limit =66, Plastic limit =34 hence there is decrease of 4.54% and 32.35% in liquid limit & Plastic limit respectively

From the test results the unsoaked CBR for soil 1 is 4% with addition of 8% cement the CBR observed was 7.73% thus there is increase in 93.25% in CBR

C. Fly ash

From the test results it was observed that 1.55 g/cc is the maximum dry density for soil sample 1 with addition of 8% fly ash the MDD observed was 1.55 g/cc hence there is no change in MDD
From the test results it was observed that the liquid limit =69 and Plastic limit =45 for soil sample 1 with addition of 8% fly ash the liquid limit =42, Plastic limit=29 hence there is decrease of 47.61% and 55.17% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 1 is 4% with addition of 8% fly ash the CBR observed was 5.67% thus there is increase in 41.75% in CBR

D. Cinder

From the test results it was observed that 1.55 g/cc is the maximum dry density for soil sample 1 with addition of 8% cinder the MDD observed was 1.57 g/cc hence there is increase of 1.29% in MDD
From the test results it was observed that the liquid limit =69 and Plastic limit =45 for soil sample 1 with addition of 8% cinder the liquid limit =62, Plastic limit =38.29 hence there is decrease of 11.29% and 17.52% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 1 is 4% with addition of 8% cinder the CBR observed was 5.26% thus there is increase in 31.5% in CBR

Soil sample 2

A. Lime

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 2 with addition of 8% lime the MDD observed was 1.85 g/cc hence there is increase of 2.20% in MDD
From the test results it was observed that the liquid limit =58 and Plastic limit =32 for soil sample 2 with addition of 8% lime the liquid limit =44, Plastic limit =23 hence there is decrease of 31.81% and 39.13% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 2 is 4.85% with addition of 8% lime the CBR observed was 9.49% thus there is increase of 95.67% in CBR

B. Cement

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 2 with addition of 8% cement the MDD observed was 1.86 g/cc hence there is increase of 2.76% in MDD
From the test results it was observed that the liquid limit =58 and PL=32 for soil sample 2 with addition of 8% cement the liquid limit =40, Plastic limit =25 hence there is decrease of 45% and 28% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 2 is 4.85% with addition of 8% cement the CBR observed was 9.28% thus there is increase of 91.34% in CBR

C. Fly ash

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 2 with addition of 8% fly ash the MDD observed was 1.83 g/cc hence there is increase of 1.10% in MDD

From the test results it was observed that the liquid limit =58 and Plastic limit =32 for soil sample 2 with addition of 8% fly ash the liquid limit =40, Plastic limit =19 hence there is decrease of 45% and 68.42% in L liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 2 is 4% with addition of 8% fly ash the CBR observed was 7.73% thus there is increase of 59.38% in CBR

D. Cinder

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 2 with addition of 8% cinder the MDD observed was 1.82 g/cc hence there is increase of 0.55% in MDD
From the test results it was observed that the liquid limit =58 and Plastic limit =32 for soil sample 2 with addition of 8% cinder the liquid limit =46, Plastic limit =24 hence there is decrease of 26.08% and 33.33% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 2is 4.85% with addition of 8% cinder the CBR observed was 5.47% thus there is increase of 12.78% in CBR

Soil sample 3

A. Lime

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 3 with addition of 8% lime the MDD observed was 1.86 g/cc hence there is increase of 2.76% in MDD
From the test results it was observed that the liquid limit =64 and Plastic limit =45 for soil sample 3 with addition of 8% lime the liquid limit =44, Plastic limit =23 hence there is decrease of 45.45% and 39.13% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 3 is 3.92% with addition of 8% lime the CBR observed was 7.73% thus there is increase in 97.19% in CBR

B. Cement

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 3 with addition of 8% cement the MDD observed was 1.82 g/cc hence there is increase of 0.55% in MDD
From the test results it was observed that the liquid limit =64 and Plastic limit =45 for soil sample 3 with addition of 8% cement the liquid limit =41, Plastic limit =26 hence there is decrease of 56.09% and 73.07% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 3 is 3.92% with addition of 8% cement the CBR observed was 8.56% thus there is increase of 118.36% in CBR

A. Fly ash

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 3 with addition of 8% fly ash the MDD observed was 1.84 g/cc hence there is increase of 1.65% in MDD
From the test results it was observed that the liquid limit =64 and Plastic limit =45 for soil sample 3 with addition of 8% fly ash the liquid limit =47, Plastic limit =22 hence there is decrease of 36.17% and 104.54% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 3 is 3.92% with addition of 8% fly ash the CBR observed was 6.08% thus there is increase of 55.10% in CBR

B. Cinder

From the test results it was observed that 1.81 g/cc is the maximum dry density for soil sample 3 with addition of 8% cinder the MDD observed was 1.81 g/cc hence there is no increase of MDD
From the test results it was observed that the liquid limit =64 and Plastic limit =45 for soil sample 3 with addition of 8% cinder the liquid limit =62, Plastic limit =43 hence there is decrease of 3.22% and 4.65% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 3 is 3.92% with addition of 8% cinder the CBR observed was 5.67% thus there is increase of 44.64% in CBR

Soil sample 4

A. Lime

From the test results it was observed that 1.9 g/cc is the maximum dry density for soil sample 4 with addition of 8% lime the MDD observed was 1.95 g/cc hence there is increase of 2.63% in MDD
From the test results it was observed that the liquid limit =72 and Plastic limit =48 for soil sample 4 with addition of 8% lime the liquid limit =44, Plastic limit =28 hence there is decrease of 63.63% and 71.42% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 4 is 4.85% with addition of 8% lime the CBR observed was 8.25% thus there is increase in 70.10% in CBR

B. Cement

From the test results it was observed that 1.9 g/cc is the maximum dry density for soil sample 4 with addition of 8% cement the MDD observed was 1.92 g/cc hence there is increase of 1.05% in MDD
From the test results it was observed that the liquid limit =72 and Plastic limit L=48 for soil sample 4 with addition of 8% cement the liquid limit =41, Plastic limit =26 hence there is decrease of 75.60% and 84.61% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 4 is 4.85% with addition of 8% cement the CBR observed was 9.18% thus there is increase of 89.27% in CBR

C. Fly ash

From the test results it was observed that 1.9 g/cc is the maximum dry density for soil sample 4 with addition of 8% fly ash the MDD observed was 1.91 g/cc hence there is increase in 0.52% in MDD
From the test results it was observed that the liquid limit =72 and Plastic limit =48 for soil sample 4 with addition of 8% fly ash the liquid limit =44, Plastic

limit =26 hence there is decrease in 63.63% and 84.61% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 4 is 4.85% with addition of 8% fly ash the CBR observed was 7.53% thus there is increase in 55.25% in CBR

D. Cinder

From the test results it was observed that 1.9 g/cc is the maximum dry density for soil sample 4 with addition of 8% cinder the MDD observed was 1.91 g/cc hence there is increase of 0.52% in MDD
From the test results it was observed that the liquid limit =72 and Plastic limit =48 for soil sample 4 with addition of 8% cinder the liquid limit =68, Plastic limit =33 hence there is decrease in 5.88% and 45.45% in liquid limit & Plastic limit respectively
From the test results the unsoaked CBR for soil 4 is 4.85% with addition of 8% cinder the CBR observed was 6.19% thus there is increase in 27.62% in CBR

Chemical analysis

From the test results it was observed that with increase in concentration of lime, cement, fly ash and cinder the value of P^H increases for soil samples
From the test results it was observed that with increase in concentration of additives the value EC increases for soil sample
The Ca2+ and Mg2+ concentration varies with varying dosage of additives

V. CONCLUSIONS

- By addition of lime ,cement ,fly ash and cinder to the soil samples the maximum dry density increase with increase in varying dosages
- The liquid limit and plastic limit decrease with increase in the additives/admixtures percentage to the soil samples
- The CBR value increases with increase in percentage of lime ,cement , fly ash and cinder to the soil samples respectively
- From chemical analysis the value P^H increase with increase in concentration of admixtures
- Hence the soil samples were turning into basic in nature
- The value of electrical conductivity also increase with increase in pH of the soil samples by the concentration of admixtures
- The concentration Ca2+ and Mg2+ shows variation in PPM(parts per million) by addition of lime ,cement , fly ash and cinder to the soil samples
- Maximum CBR value 9.5% is achieved for an additive lime of 8% dosage
- By designing single lane road treated with additive having 10% CBR it is found that reduction in sub base layer thickness and overall cost of 10,02,066/- rupees pavement is reduced

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