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A Study on the Utilization of Cement-Sand Mixes on Red Soils as Sub-Base and Base Course Materials

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Abstract: The inter-connecting layer and their composition and characteristics can efficiently manage the load transfer mechanism. Red soil is clayey sand with low clay building particles which lose its strength on saturation. When structures like roads and embankments constructed on these soils subjected to distress and requires a lot of maintenance. In order to improve the strength and stability characteristics of red soil for supporting the road traffic, cement stabilization was proposed. In this process sand and cement have selected as a stabilizer to improve quality of red soil. From the test results, it is defined that as the percentage of Sand is increasing plasticity index and other characteristics are changing. It is further studied that the use of stabilized red soil as Base coarse material, cement has been added to improve strength characteristics. In this connection various percentage of cement was added to red soil, red soil-Sand mixes and compaction and strength and CBR characteristics are studied. Addition of cement rapidly increases CBR values. Addition of 20-30% of Sand and 2 percent of cement yielded high CBR values which are greater than 30 can be used as Sub-Base course material. Addition of 20-30% of Sand and 4 % of cement yielded high CBR values > 60 % can be used as Base-course material.
Keywords: Stabilization, Base-course material, Stabilizer, Strength Characteristics, Inter-connecting layers

I. INTRODUCTION

Red soils are abundantly available in the north coastal districts of Andhra Pradesh. These soils are product of tropical weathering i.e., wind and water born deposits. These contain large amounts of quartz, silica and oxides of iron, magnesium and hydrated alumina and low amounts of kaolinite and calcite. Most of these red soils are basically cohesionless, but they have a very small coating of clay or other bonding material. When these soils become saturated, the clay bond weakened and the soil collapse. As long as these soils are confined and in dry condition no settlements occur but when contact with water they lose their strength drastically. Red soil stabilization requires addition of pozzolanic materials in order to avoid collapsibility of soils on saturation. It has good compression and shear strength, but is brittle and therefore has low tensile strength, so it is prone to forming cracks. The soil properties like strength and durability are said to be improved upon soil stabilization. In order to increase the tensile strength and to change the soils from brittle to ductile, fibre is also added to red soil along with cement. Sand can be advantageously used in reinforced earth retaining walls, reinforced soil beds and reinforced flexible pavements as a fill material due to its stability, free draining nature and good frictional characteristics with synthetic reinforcement. Soosan et.al (2001) identified that sand exhibits high shear strength and is beneficial for its use as a geotechnical material. Praveen Kumar et.al (2006) conducted CBR and tri-axial tests on fly ash, coarse sand, stone dust and river bed materials for their use in the sub base materials of the flexible pavements. In this present study various percentage of cement was added to red soil for stabilization, and then the samples were tested for unconfined compressive strength for different curing periods and CBR characteristics are studied. Mixes of red soil-crusher dust and red soil-crusher dust-cement were also tested for strength, CBR characteristics.

II. METHODOLOGY

A. Material Used

1) Red Soil
2) Crusher dust

B. Laboratory testing

1) *Properties of soil:* The following tests were conducted on the soil. the index and engineering properties of soil were determined.
a) Grain size analysis confirming (IS: 2720-part 4, 1985)
b) Consistency limits or Atterberg's Limits using Uppals method confirming (IS: 2720-part 5, 1985)

c) Compaction test confirming (IS: 2720- Part 8: 1983)
d) California bearing ratio test confirming (IS: 2720- Part 16: 1987)
e) Direct Shear Test (IS: 2720- Part 17, 1986):
f) Unconfined compressive strength test

III.RESULTS AND DISCUSSIONS

To study the interaction between Red Soil, sand and cement particles, Red soil sample was collected from A.U Engineering College, Vishakhapatnam, sand from Godavari River and cement is OPC 53 grade from local markets.

A. Materials

Red Soil samples were collected from A.U Engineering College, Vishakhapatnam. These samples were subjected for Geotechnical Characterization such as Gradation, Compaction and Strength as per IS: 2720 and the results are listed below in the tables and figures.

B. Geotechnical Characteristics of Red Soil

Table 1 Geotechnical Characteristics of Red Soil

Gradation properties	
Gravel (%)	0
Sand (%)	68
Fines (%)	32
Index properties	
Liquid limit (%)	30
Plastic limit (%)	20
Plasticity index (I_p)	10
IS classification	SC
Compaction characteristics	
Optimum moisture content (%)	11
Maximum dry density (g/cc)	1.94
Strength characteristics	
California bearing ratio (%) (soaked)	5

C. Gradation Characteristics

Table 2 Gradation of Red Soil

Sieve Sizes (mm)	% Finer
4.75	100
2.36	99
1.18	97
0.6	90
0.425	81
0.3	63
0.15	40
0.075	32
0.002	12
D_{10}	0.0017
D_{30}	0.055
D_{60}	0.27
C_u	158.82
C_c	6.59

Fig 1 Gradation Curve of Red Soil

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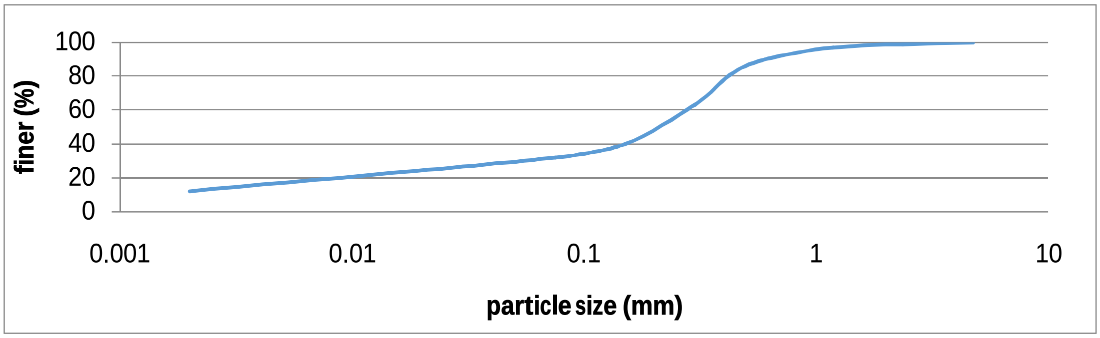


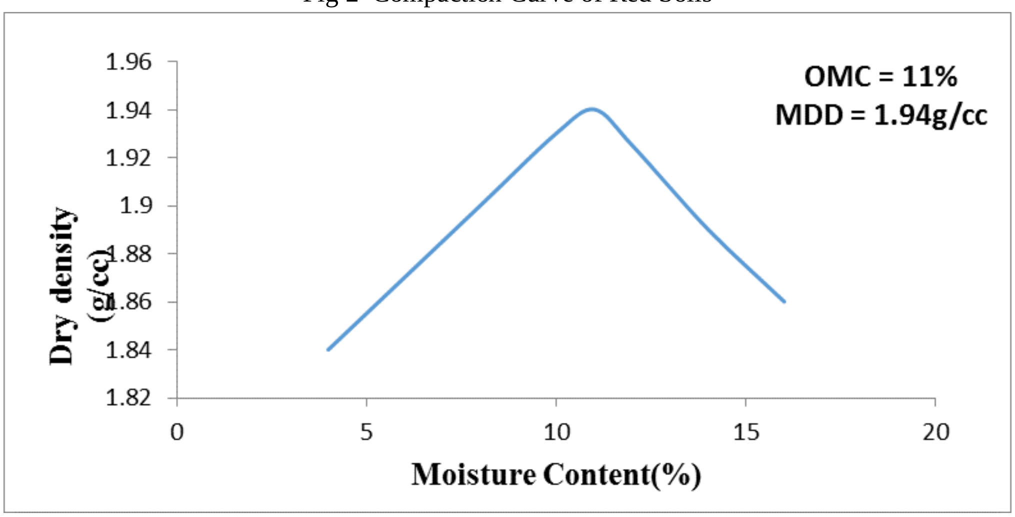
D. Consistency Characteristics

Table 3 Index Properties of red soil

Consistency Limits	VSKP
Liquid Limit (W_L) %	30
Plastic Limit (W_p) %	20
Plasticity Index (I_P) %	10
IS Classification	SC

E. Compaction Characteristics

Fig 2 Compaction Curve of Red Soils



From the test results it is identified that a red soil contains 68% of sand particles (4.75mm to 0.075mm) and 32% of fines including 8% clay and 24% silt particles. From the consistency test data it has liquid limit of 30% and plastic limit of 20% and plasticity index of 10%. From BIS classification it is classified as SC with medium plasticity characteristics (Ip = 7 to 15). From the compaction test data it attained a Maximum Dry Density of 1.94 g/cc at Optimum Moisture Content of 11%. It shows that the above red soil attained high densities in presence of considerable fine particles. It also attained a soaked CBR of 5%. From MORTH specifications it is identified as this material cannot be used as sub-base course material since CBR value is less than 30 and also cannot be used as base course material since its CBR is less than 60.

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F. Geo Technical Characteristics of Sand:

Sand was obtained from Godavari river, Andhra Pradesh and tested for various Geotechnical characterization such as Gradation, Compaction and Strength as per IS: 2720 and the results are listed below in the tables and figures.

Table 4 Geotechnical Characteristics of Godavari Sand

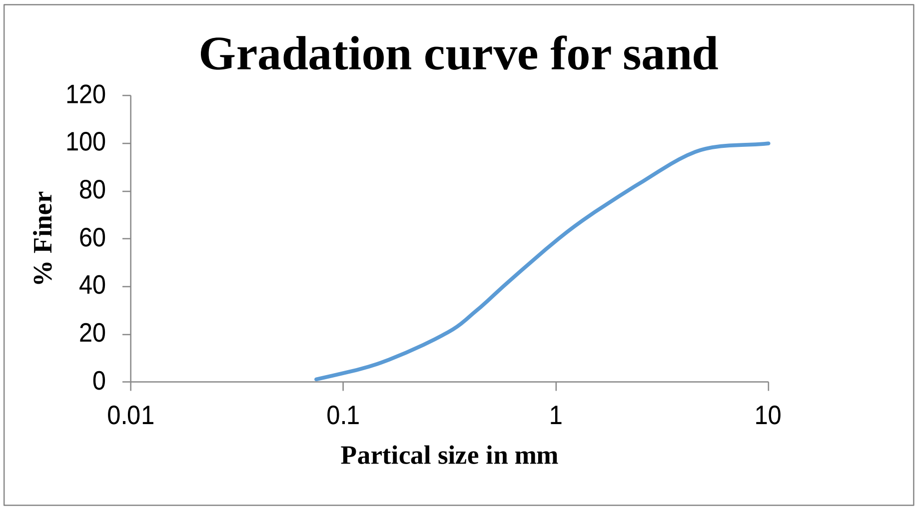
Property	Values
Grain size distribution	
Red Soil (%)	03
Sand (%)	96
Fines (%)	01
a. Silt(%)	04
b. Clay(%)	0
Consistency	
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I.S Classification	SP
Specific gravity	2.66
Compaction characteristics	
Optimum moisture content (OMC) (%)	5
Maximum dry density (MDD) (g/cc)	1.88
Shear parameters	
Angle of shearing resistance(deg)	36
California bearing ratio (CBR) (%) (Soaked condition)	10.0

G. Gradation Characteristics

Table 5 Gradation Characteristics

SAND	
Sieve sizes(mm)	% Finer
10	100
4.75	97
2.36	82
1.18	64
0.6	42
0.425	30
0.3	20
0.15	8
0.075	1
C_u	5.56
C_c	1.03
CBR	10
Ø undrained	36
Ø drained	33

Fig 3 Gradation curve of Sand

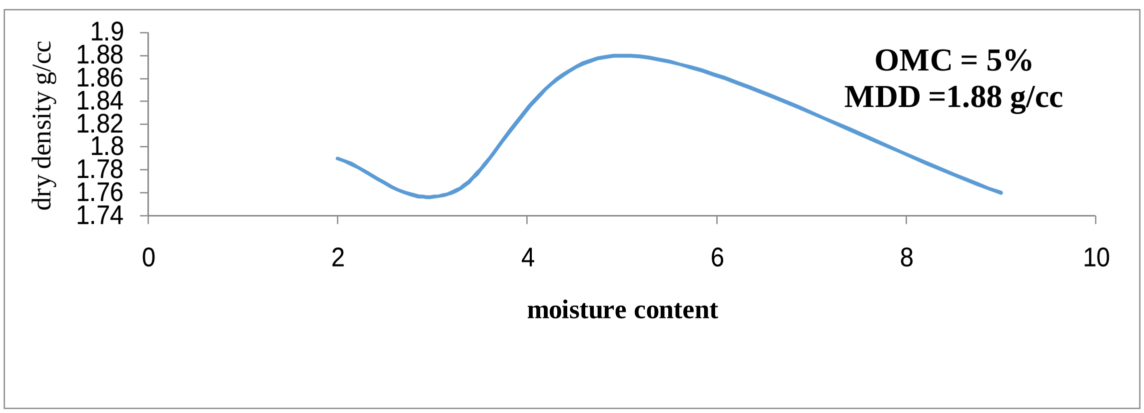


H. Compaction Characteristics

Table 6 Compaction Characteristics of Sand

Water content (%)	Dry density(g/cc)
2	1.79
3.2	1.76
5	1.88
9	1.76

Fig 4 Compaction curve of Sand



From the test results it is identified as the above sand can be categorised as zone-2 and attained high maximum dry density of 1.88g/cc. This high dry density is due to well graded nature of sand with no fines.

I. I Properties of Cement

Cement was collected from local available markets that is OPC 53 grade and tested for various properties. The test results are mentioned in following figures and tables.

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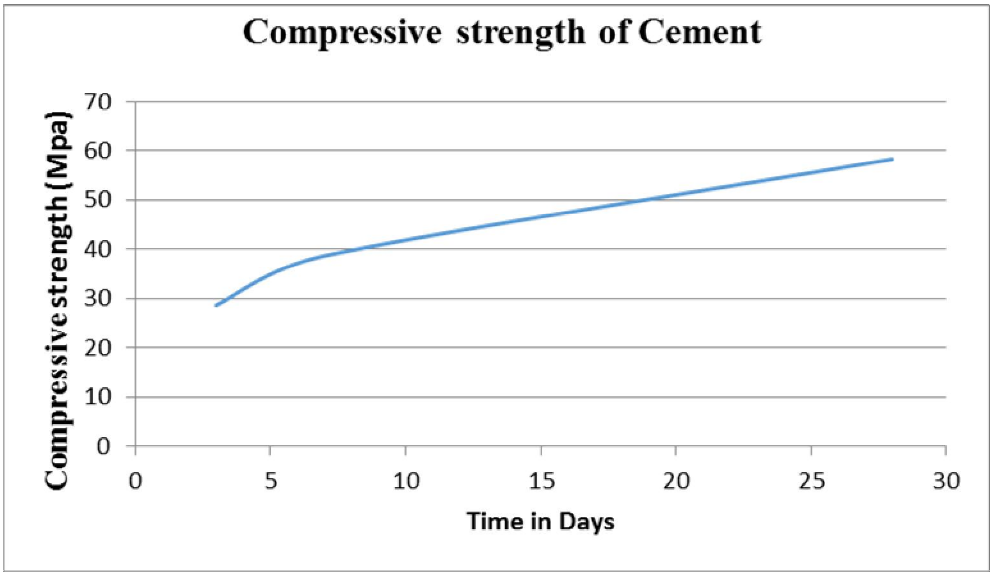
Table 7 Properties of Cement

1	Standard Consistency (%)	32
2	Initial setting time (minutes)	134
3	Final setting time (minutes)	292
4	Fineness (by sieving)(%)	2.50
5	Specific gravity	3.12
6	Ultimate compressive strength of average of three standard cement mortar cubes	
	a) At the age of three days(Mpa)	28.6
	b) At the age of seven days(MPa)	38.6
	c) At the age of twenty eight days(Mpa)	58.2

Fig 5 compressive strength of cement with respect to time



J. Variation of Geotechnical Characteristics of Red Soil and Cement Mixes

Table 8 Variation of Geotechnical characteristics of Red soil and cement mixes

Cement (%)	OMC (%)	MDD (g/cc)	Unconfined Compressive strength(kg/cm^2)			CBR (%)
			3	7	28	7
0	11	1.94	1.8	-	-	5
1	11.2	1.95	2.8	5.2	8.9	18
2	11.4	1.96	4.09	8.4	13.0	25
3	11.6	1.97	6.24	11.78	16.4	36
4	11.7	1.98	8.65	14.76	19.1	48
5	11.8	1.99	10.6	17.45	23.6	66
6	12	2	12.4	19.84	26.9	80
7	12.2	2.01	14.7	23.63	29.6	93
8	12.5	2.02	16.2	25.86	32.8	100

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Fig.6 Variation of OMC with different percentage of cement

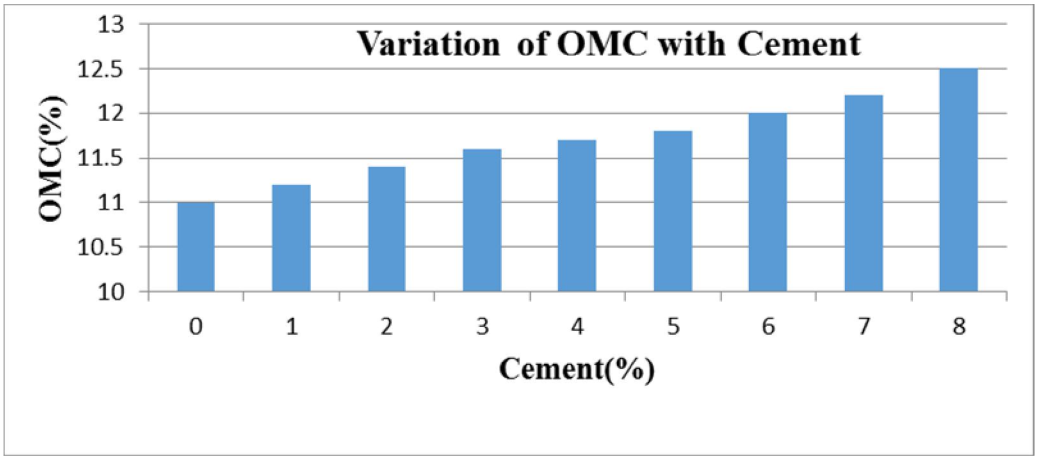

Fig.7 Variation of MDD with different percentage of cement

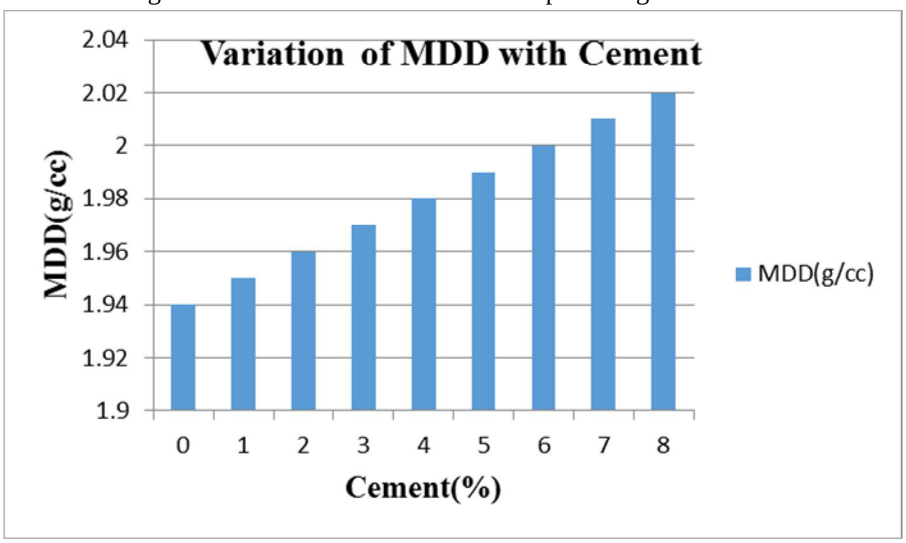

Fig 8 Variation of Unconfined Compressive strength with different percentage of cement

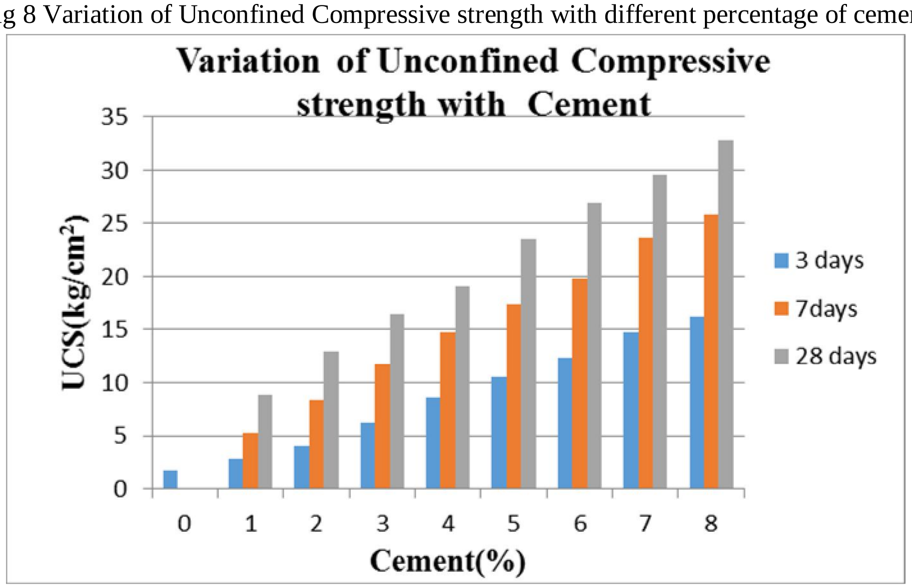

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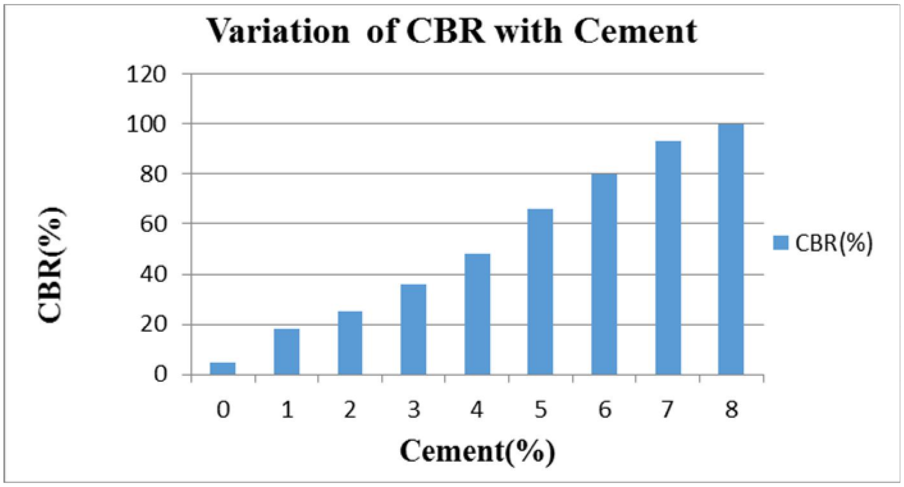
Fig 9 Variation of CBR with different percentage of cement



From test results it is identified that as the percentage of cement is increasing OMC and MDD values are increasing. It is also identified that UCS and CBR values are increasing. At 3% of cement it attained a CBR value 36 (CBR>30%) can be used as Sub-Base material and at 5% of cement CBR value is 66% (CBR>60%) can be used as Base –course material.

K. Variation of Geotechnical Characteristics of Red Soil and Sand Mixes

To study the interaction between Red Soil and sand particles various percentages of sand such as 10%, 20% and 30% were added and tested for plasticity, compaction and CBR characteristics as per IS : 2720.

1) Consistency Characteristics of Red soil-Sand Mixe

Table 9 Consistency characteristics of Red Soil-sand mixes

2) Compaction Characteristics of Red Soil-Sand Mixes

MIXES	SAND (%)	LIQUID LIMIT (W_L)	PLASTIC LIMIT (W_p)	PLASTICITY INDEX (I_P)
M_0	0	30	20	10
M_1	10	27	19	8
M_2	20	24	19	5
M_3	30	NP	NP	NP

Table 10 Compaction and strength characteristics of Red Soil and Sand Mixes

MIXES	SAND (%)	OMC (%)	MDD(g/cc)	CBR (%)
M_0	0	11	1.94	5
M_1	10	10.8	1.93	6
M_2	20	10.5	1.92	8
M_3	30	10.2	1.91	10

From the test results it is identified that as the percentage of sand is increasing liquid limit and plastic limit values are decreasing. It is also identified that OMC values are decreasing and MDD values are decreasing and CBR values are increasing. Addition of 20% sand to Red Soil achieved CBR value 8 which is less than 30 cannot be used as sub-base course material. To achieve further higher CBR values various percentages of cement are added to red soil-sand mixes.

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L. Variation of geotechnical characteristics of red soil-sand-cement mixes

To use the red soil as sub base course material which requires a minimum CBR of 30% and to use the red soil as base course material which requires a minimum CBR of 60%, sand and cement (53grade) were added to Red Soil sample. Various percentages of cement such as 1%,2%.....5% were added to Red Soil-sand samples and IS Heavy Compaction was performed. These samples were cured for 7 days (controlled curing). After required curing period the samples were tested for CBR values as per IS 2720.

Table 11 Red Soil-Sand-Cement Mixes

MIX	COMPOSITION (Red Soil + Sand)	CEMENT (%)
M_1	R.S+20	1,2,3,4,5
M_2	R.S+30	1,2,3,4,5

Table 12 Variation of OMC when 20% sand is added to red soil with varying percentages of cement

	Cement (%)	Optimum Moisture (%)	Maximum Dry Density (g/cc)	CBR (%)
MIX (M_1) Red Soil + 20% sand	0	10.5	1.92	8
	1.0	10.7	1.93	23
	2.0	10.9	1.94	35
	3.0	11.1	1.96	50
	4.0	11.3	1.97	66
	5.0	11.6	1.98	84

Fig 10 Variation of OMC with M_1 + cement

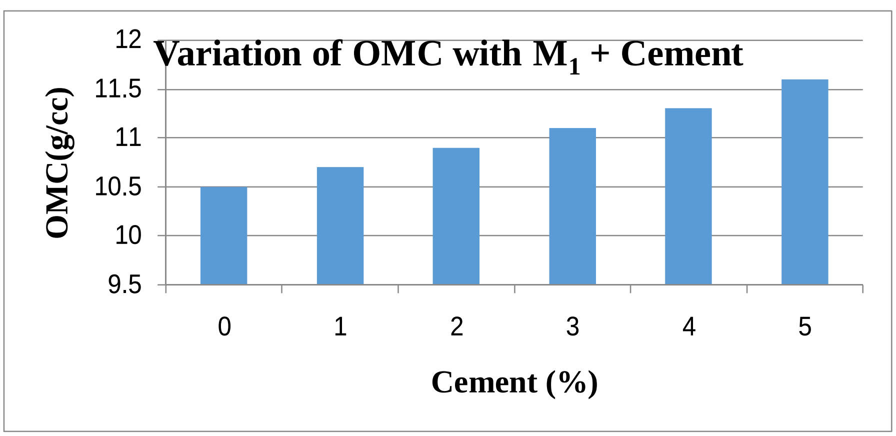


Fig11 Variation of MDD with M_1 + cement

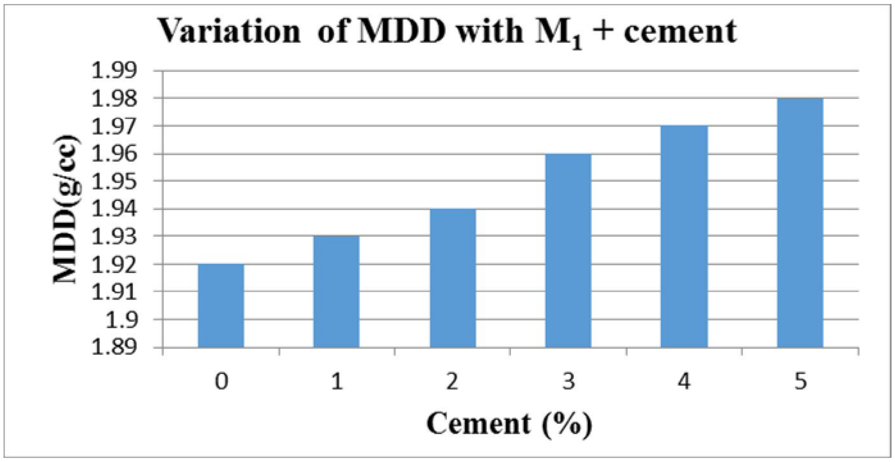
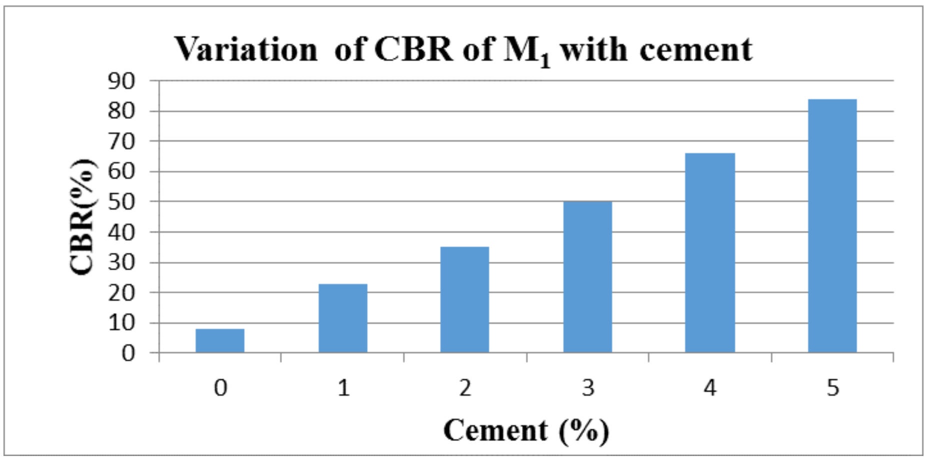


Fig 12 Variation of CBR of M_1 with cement



From the test results it is identified that as the percentage of cement is increasing OMC and MDD values are increasing. OMC increased from 10.5 to 11.6% and MDD from 1.92 g/cc to 1.98 g/cc. More water is needed to roll the particle and more solids in a given volume under effective rolling are responsible for attaining the above values. At lower dosages that are 2%, 3% etc, less amount of cement is participated in generation of these strength values where as at high percentage 4%,5% high amount of cement is contributed for generation of high CBR values. Hence addition 2 % of cement to red soil + 20% pond ash achieves a CBR of 35% can be used as Sub –Base material has addition of 4 % cement achieves a CBR of 66% can be used as Base-course material.

Table 13 variation of OMC when 30% sand is added to red soil with varying percentages of cement

	Cement (%)	Optimum Moisture (%)	Maximum Dry Density (g/cc)	CBR (%)
MIX (M_2) Red Soil+ 30% sand	0	10.2	1.91	10
	1.0	10.4	1.92	25
	2.0	10.6	1.94	38
	3.0	10.9	1.96	54
	4.0	11.1	1.98	70
	5.0	11.3	1.99	88

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Fig 13 Variation of OMC with M_2+Cement

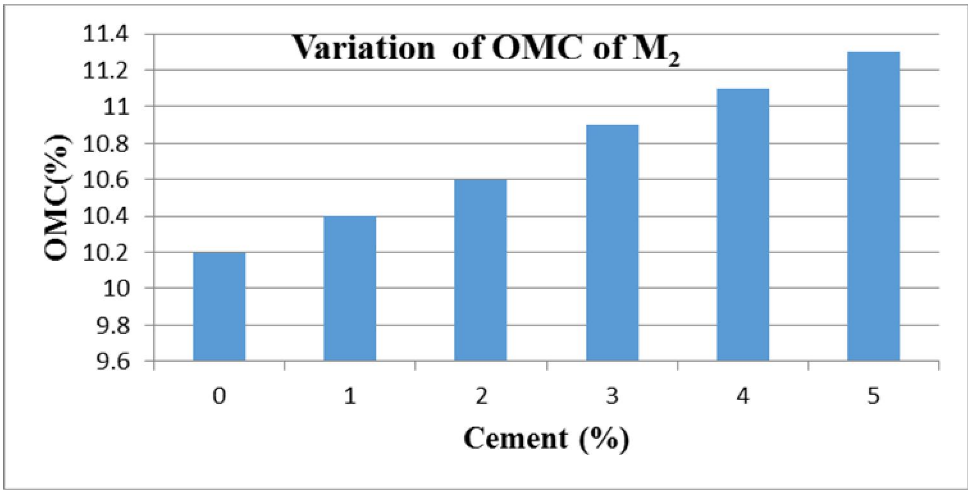


Fig14Variation of MDD with M_2+Cement

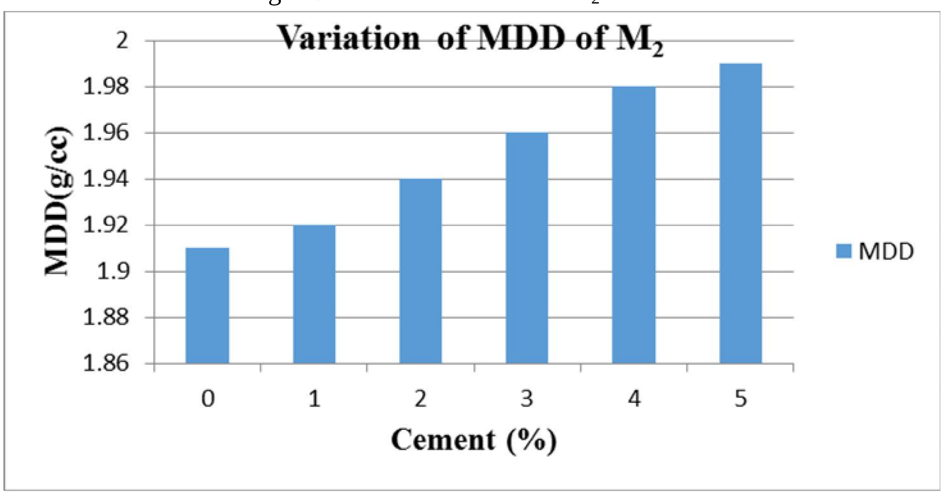
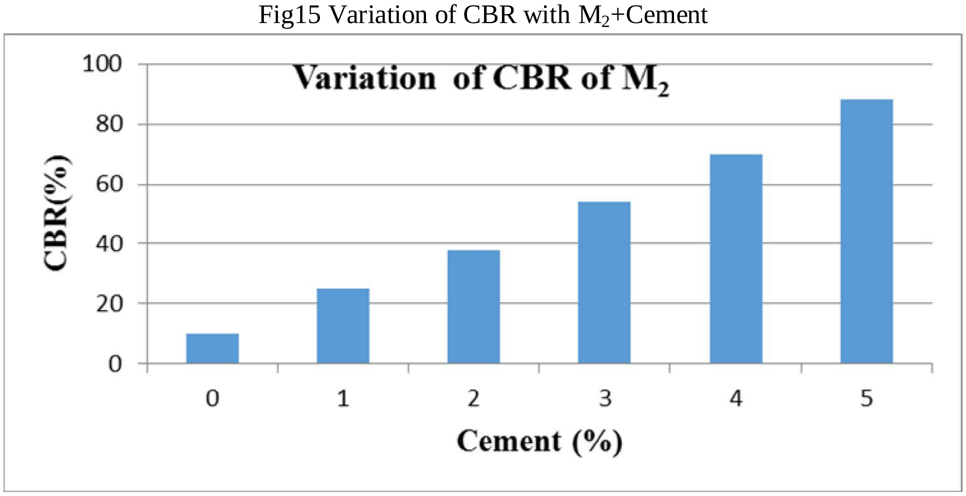


Fig15 Variation of CBR with M_2+Cement

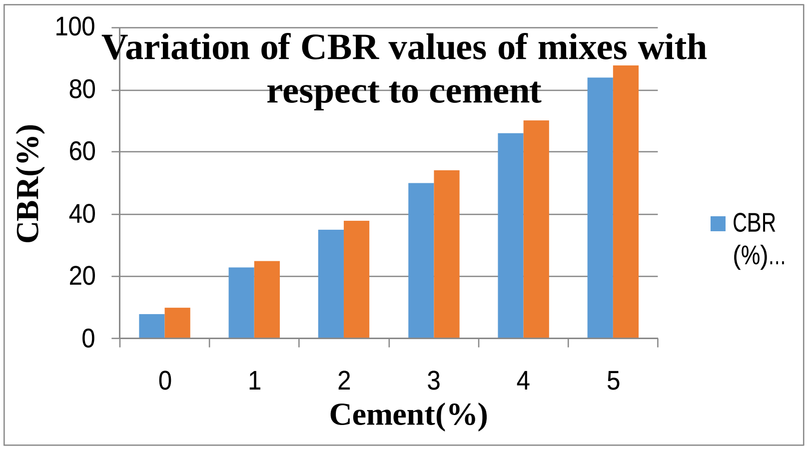


From the test results it is identified that as the percentage of cement is increasing OMC and MDD values are increasing. OMC increased from 10.2 to 11.3% and MDD from 1.91g/cc to 1.99 g/cc. More water is needed to roll the particle and more solids in a given volume under effective rolling are responsible for attaining the above values. At lower dosages that are 2%, 3% etc, less amount of cement is participated in generation of these strength values where as at high percentages 4%,5% high amount of cement is contributed for generation of high CBR values. Hence addition 2 % of cement to red soil + 30% pond ash achieves a CBR of 38% can be used as Sub –Base material has addition of 4 % cement achieves a CBR of 70% can be used as Base-course material.

Table 14 Variation of CBR value Red Soil sand mixes with respect to cement

Cement (%)	CBR value for M_1	CBR value for M_2
0	8	10
1.0	23	25
2.0	35	38
3.0	50	54
4.0	66	70
5.0	84	88

Fig 16 Variation of CBR values of mixes with respect to cement



From the test results it is identified that as the percentage of cement is increasing OMC values are increasing and maximum dry density values also increasing .This is due to that quantity of cement requires more water to from the paste and coat the coarse grained particles. High maximum dry densities are due to occupation of more solids of Red Soil and sand with respect to cement in a given volume resulting effective interlocking of Red Soil particles with sand and cement particles make strong bond and increases weight of solids in a given volume. At these maximum dry densities high CBR values are due to development of strength against penetrtion due to development of hard surface.

Addition of percentage of cement increases CBR value with respect to a given sand-Red Soil mix. At 20% of sand addition of 4% cement yields CBR value 66 and at 30% of sand, addition of 4% cement yields CBR value 70. Addition of percentage of sand that is 20% to 30% requires low percentage of cement (2%) to achieve CBR values (>30) to suit as Sub base course. Addition of 20% to 30% percentage of sand requires high percentage of cement (>4%) to achieve high CBR values (>60) to suit as base course. Hence for medium plastic Red Soils (I_p in between 7 to 15) addition of greater than 2% of cement and 20% to 30% of sand yields CBR values greater than 30 are used for Sub base course material and also by addition of greater than 4% of cement and 20% to 30% of sand yields CBR values greater than 60 are used for base course material.

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IV. CONCLUSIONS

From the study of the performance of cement on red soil the following conclusions have drawn.

As percentage of cement is increasing optimum moisture content increasing from 11.0 to 12.5%, maximum dry densities increasing from 1.94 to 2.02g/cc, strength increasing from 8.9 to 32.8 kg/cm^2 for 28 days curing period and CBR values increasing from 7 to 100 %.

The percentage of Sand is increasing OMC values are decreasing from 11.0 to 10.2% and MDD values are decreasing from 1.94 to 1.91g/cc.

The percentage of cement is increasing optimum moisture content, maximum dry densities and CBR values are increasingfor red soil-Sand mixes.

If the Sand is increasing the quantity of cement required to achieve high CBR values is decreasing.

Addition of 20-30% Sand and 2% cement gave CBR values greater than 30% to suit as Sub Base course material.

Addition of 20-30% of Sand and 4% of cement to the medium plastic red soils attained CBR values greater than 60 can be used as Base course material.

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