

Soil Stabilization by Coarse Sand for Different Soils and Pavement Cost Evaluation

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ABSTRACT: Soils exhibit highly plasticity characteristics, low strength properties and high swell-shrink characteristics. The alternative swell-shrink seasons causes distress to the structures and the pavements constructed on them. Maintenance and repair costs of the distressed structures and pavements are quite high. It is therefore necessary either to bring suitable soils from far off borrow areas or to stabilize locally available soils to improve their engineering properties. In the present study laboratory studies are carried out on four types of soils viz Black cotton soil, Sandy gravel soil, Sandy silty and Loamy soil stabilized with coarse sand.

Wet sieve analysis, Atterberg limits, modified compaction and California bearing ratio test were carried out on native soils and 10%, 20% and 30% coarse sand blended soils. It is found that in wet sieve analysis sand content has increased by increasing the percentage of coarse sand when compared to native soils. It is also seen from compaction test by increasing the percentage of coarse sand the dry density has increased and moisture content has reduced marginally when compared with native soil. From California bearing ratio test it is seen that the strength is gradually increased by increasing the percentage of coarse sand.

Finally the cost of construction has been evaluated and it can be reduced for locally available low bearing strength soil by stabilizing it with coarse sand.

KEYWORDS: Wet sieve analysis, Atterberg limits, modified compaction, California bearing ratio test, soil by stabilization and cost of construction

I. INTRODUCTION

A. GENERAL

Soil is the most abundantly available construction material; the term soil has different connotations for scientists belonging to different disciplines. The definition given to soil by civil engineer is different from the one used by an agriculturist or a geologist. For a civil engineer, soils mean all naturally occurring, relatively unconsolidated earth material- organic or inorganic in character which is found above the bed rock.

Soil is the cheapest and the most widely used material in a highway system, either in its natural form or processed form. All road pavement structures eventually rest on soil foundation, therefore a thorough study of the engineering properties of soil is of vital importance in working out an appropriate design of the under the given traffic and climatic conditions. In any road embankment, the bulk of the material used is soil and if properly designed, should possess stable slopes and should not settle to any appreciable extent. Also, the embankments require a stable foundation; if the foundation soil happens to be soft clay, unless properly designed; excessive settlement or even ultimate failure can take place

B. SOIL STABILIZATION

Soil stabilization is the permanent physical and chemical alteration of soil to enhance their physical properties. Stabilization can increase the shear strength of a soil there by controlling the shrink-swell properties of soil and, improving the load bearing capacity of a subgrade. Stabilization can be used to treat a wide range of subgrade materials from expansive clays to granular materials.

C. PROPERTIES OF STABILIZATION

1. Bonds soil particle together (increases strength and stiffness).
2. Reduces permeability (fills voids, forms membrane).
3. Improves compaction (lubrication, particle restructuring).

D. FEATURES AND BENEFITS:

1. Higher resistance values.
2. Reeducation in plasticity.
3. Lower permeability.
4. Reeducation of pavement thickness.
5. Elimination of excavation, material hauling and handling.
6. Aids compaction.
7. Provides "all weather" access on to and within project sites.

E. THE PRINCIPLES OF STABILIZATION

1. Evaluating the properties of given soil.
2. Deciding the method of supplementing the lacking property by the effective and economical method of stabilization.
3. Designing the stabilized soil mix for intended stability and durability values.

II. OBJECTIVE OF PRESENT STUDY

A. To study the use of coarse sand for stabilizing Black cotton soil, Sandy gravel soil, Sandy silty soil and Loamy soil and compare the properties for use in subgrade

B. To determine the strength of blended soil by CBR test.

C. Designing the flexible pavement for the native soils and blended soil, by that estimating cost of construction.

III. SCOPE OF PRESENT STUDY

A. The present study deals with the testing of soil samples. The following tests were done on the soil are

1. Grain size analysis
2. Atterberg limits
3. Compaction
4. California bearing ratio.
5. Pavement design and cost evaluation.

IV. LITERATURE REVIEW

A. LIME STABILIZATION FOR LATERITIC SOIL SAMPLES

Amu Olugbenga Oludolapo, et al, (2011) evaluated the suitability and lime stabilization requirement of some selected lateritic soil samples as pavement construction materials. Soil samples A, B, and C collected from a dam site and stabilized with 0, 2, 4, 6, 8, and 10% of lime were subjected to preliminary tests (natural moisture content, specific gravity, particle size analysis and Atterberg's limits) and strength tests (compaction, California bearing ratio (CBR), unconfined compression and undrained triaxial). Results of the preliminary tests classified the samples as fair to poor pavement construction materials. The suitability of samples A, B and C was improved by optimum lime stabilization at 8, 6, and 6% respectively. The addition of lime to the samples caused a reduction in the plasticity indices of the samples. The CBR of A increased from 10.6% at 0% to 29.0% at 8% lime, while that of C improved from 2.5% to 8.6% at 6% lime. The compressive and shear strengths were also improved; the uncured compressive strength of B improved from 119.13 kN/m² at 0% to 462.81 kN/m² at 6% lime. With optimum stabilization, samples A and B will be suitable as base materials while sample C will perform well as sub-grade material in pavement construction.

B. SOIL STABILIZATION USING FINE AND COARSE GGBS

Takhelmayum Gyanen, et al (2013) carried out a study on use of fine and coarse ground granulated blast furnace slag (GGBS) for soil stabilization the investigation is to evaluate the compaction and unconfined compressive strength of stabilized black cotton soil using fine and coarse ground granulated blast furnace slag (GGBS). Characterization of black cotton soil is carried out for grain distribution and soil classification. A series of compaction test were carried out using mini compaction mould for different combination of soil along with fine and coarse ground granulated blast furnace slag (GGBS) mixtures. For stabilization of black cotton soil, the unconfined compressive strength test were carried out in accordance with the standard procedures for different combination of soil with ground granulated blast furnace slag (GGBS) mixtures. And they found that with the increase in water content the dry density also increases up to 20-30% moisture content and with further increase in water content the dry density increases gradually. The lowest dry density was observed to be about 1.42g/cc for 95% soil and 5% GGBS mixture and maximum density was about 1.72 g/cc for 70% soil and 30% GGBS mixture. This variation in density is primarily due to chemical composition, glass phase content, particle size distribution and surface morphology. The increase in the maximum dry unit weight with the increase of the percentage of GGBS mixture is mainly due to high specific gravity and immediate formation of cemented products by hydration which increases the density of soil. The increase in dry density with increase in fine and coarse GGBS mixture is due to enhanced C-S-H formation compared to using Soil alone. this enhanced C-S-H occupies pore spaces, normally occupied by calcium hydroxide in the hydration of pozzolanic reaction taking place in mixtures which uses the excess SiO₂ from the slag source, Ca (OH)₂ produced by the hydration of the silicates, and water to produces more of the desirable C-S-H making slag a beneficial mineral admixture to attain and increase in dry density.

C. SOIL STABILIZATION WITH FLYASH AND RICE HUSK ASH

Brooks robert M (2009) conducted a study and the objective of the author is to upgrade expansive soil as a construction material using rice husk ash (RHA) and flyash, which are waste materials. Remolded expansive clay was blended with RHA and flyash and strength tests were conducted. The potential of RHA-flyash blend as a swell reduction layer between the footing of a foundation and subgrade was studied. In order to examine the importance of the study, a cost comparison was made for the preparation of the sub-base of a highway project with and without the admixture stabilizations, and the findings are, Stress strain behavior of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the flyash content was increased from 0 to 25%. When the RHA content was increased from 0 to 12%, Unconfined Compressive Stress increased by 97%. When the RHA content was increased from 0 to 12%, CBR improved by 47%. The optimum RHA content was found at 12% for both UCS and CBR tests. The swelling potential of expansive soil decreases with increasing swell reduction layer thickness ratio. The vertical movement of clay soils with cushioning material stabilizes after 3 cycles of swelling and shrinkage. An RHA content of 12% and a flyash content of 25% are recommended for strengthening the expansive subgrade soil while a flyash content of 15% is recommended for blending into RHA to form a swell reduction layer.

D. SAND: AN ADDITIVE FOR STABILIZATION OF SWELLING CLAY SOILS

Bahia Louafi, et al, (2012) they carried out a study to understand the physical mechanisms of stabilization of an expansive soil by adding an inert material (sand) at various forms; mixing and intercalation layers of sand. The first aim of the study is to analyze the effect of stabilization on the variation of soil consistency. The results show a marked improvement in soil consistency. Then a study of the effect of the additives on the variation of the swelling in order to solve the lifting structures caused by this phenomenon is carried out. It can be seen that the addition of sand is capable of reducing the swelling action. They completed the study using an ultrasonic device, measuring the propagation velocities of ultrasonic pulse through the tested clay samples. This shows a change occurring in the porosity of the clay when sand is added to it. As a result some interesting conclusions concerning the expansive soil-material amendment are drawn and they are, The addition of sand reduces all parameters of consistency. The reduction is slightly affected by the granularity of the sand. Plasticity is relatively more important when the sand added is finer.

The results obtained showed the effectiveness of sand in the stabilization of expansive soils. The evolution of swelling with the sand content is similar for all samples tested regardless of the granularity of the sand fraction added or form of its addition.

Moreover, the introduction of sand as layers distributed into two different configurations (layer on top of sample and layer in the middle) showed the effectiveness of these layers in reducing swelling. It was found that the most efficient distribution in reducing swelling is that of layers of sand placed between two layers of clay compared to the sand layer placed on top of sample. The latter provides a single contact surface only between the two materials used.

The technique of mixing can provide a better distribution of clay particles in the voids created in the mixture and thus allows a reduction in the number of bonds between the clay particles by an increase in typical bonds between sand grains and clay particles. Consequently the volume changes are less important.

In addition to the effects of size and shape of the addition is not noticeable for low levels of sand, confirming that the reduction of swelling for these levels is the result of the decrease in the clay fraction.

Finally, the overall analysis of the porosity by ultrasonic pulse propagation showed an increase in the volume of voids with increasing sand content. This modification in the structure of bentonite treated by sand, made it possible to find a response to the appeal of the reduction in the swelling of clay by sand addition. It is come out from this study that the reduction of swelling is the result also of the reduction in the clean density of clay in the mixture.

E. INFLUENCE OF SAND AND FLY ASH ON CLAYEY SOIL STABILIZATION

Rama Chavali, et al, (2014) in their study an attempt was made to assess the effectiveness of clayey soil blended with Beas sand and fly ash for soil stabilization by studying the subgrade characteristics. It gives solution for proper disposal of fly ash and also provides good subgrade material for pavement construction. The results show substantial improvement in compaction and California bearing ratio of composite containing clay, sand and fly ash (70: 30: 10). The swelling nature of the clay also reduced up to 60% after stabilization. Thus the stabilized composite can be used for construction of flexible pavements in rural areas with low traffic, and their conclusions are, The maximum dry density of clay-sand mix improved with the addition of sand up to 30% thereafter it decreased and the optimum moisture content decreased up to 30% sand content thereafter it increased slightly. The maximum dry density of clay-sand-fly ash mix decreased with the addition of fly ash and optimum moisture content increased. The California bearing ratio of the stabilized clay increased from 2.47% to 4.56% for soaked CBR and 5.59% to 7.36% for un-soaked CBR. The expansion ratio of the stabilized clay decreased from 8% to 3.2% i.e., 60% of swelling was decreased with stabilization which can be used as a sub-grade material for construction of flexible pavements in rural roads with low traffic volume.

V. ANALYSIS OF LABTEST RESULTS

A. GRAIN SIZE ANALYSIS

The following analysis graphs are plotted between sieve size verses percentage fines passing and the percentage of gravel, sand and fines are tabulated in the following tables.

Table 1. Wet sieve analysis results for Black cotton soil + coarse sand

Black cotton soil	Gravel (%)	Sand (%)	Fines (%)
Native	0.82	26.06	73.1
10%	1.7	26.18	72.12
20%	2.24	32.66	65.1
30%	3.66	39.56	56.78

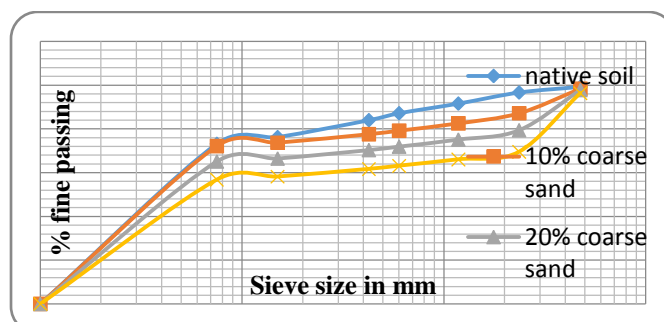


Fig 1. Grain size distribution curve for Black cotton soil + coarse sand

Table 2. Wet sieve analysis results for Sandy gravel soil + coarse sand

Sandy gravel soil	Gravel (%)	Sand (%)	Fines (%)
Native	21.14	51.76	27.10
10%	15.78	54.1	30.12
20%	12.64	59.44	27.92
30%	13.42	61.42	25.16

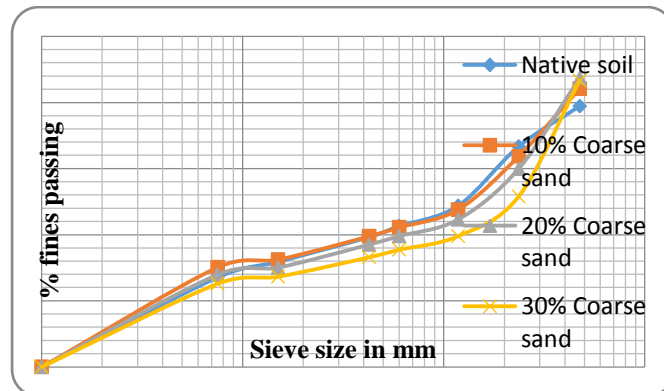


Fig 2. Grain size distribution curve for Sandy gravel soil + coarse sand

Table 3. Wet sieve analysis results for Sandy silty soil + coarse sand

Sandy silty soil	Gravel (%)	Sand (%)	Fines (%)
Native	0.44	60.36	39.2
10%	2.16	63.46	34.38
20%	2.44	67.24	30.32
30%	9.2	60.7	30.1

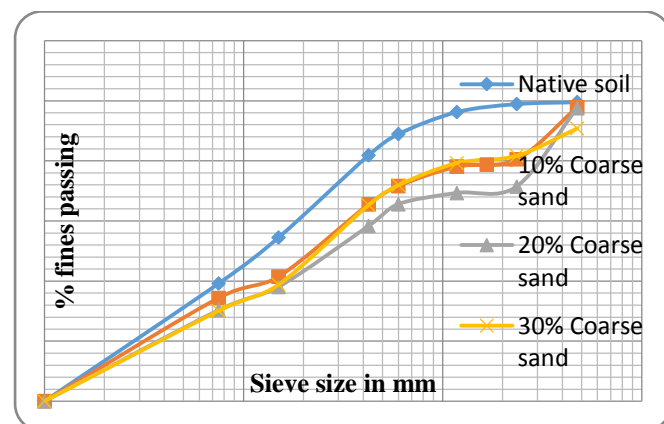


Fig 3. Grain size distribution curve for Sandy silty soil + coarse sand

Table 4. Wet sieve analysis results for Loamy soil + coarse sand

Loamy soil	Gravel (%)	Sand (%)	Fines (%)
Native	5.1	32.94	61.96
10%	3.82	35.88	60.3
20%	2.74	36.96	53.24

30%	4.82	56.54	38.64
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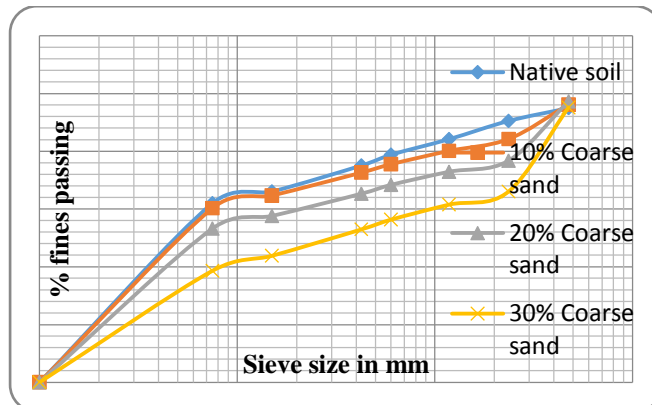


Fig 4. Grain size distribution curve for Loamy soil + coarse sand

B. ATTERBERG LIMITS

The following graph is plotted for plastic limit of four soils between number of blows verses moisture content, and the Liquid limit, Plastic limit and plasticity index values are tabulated in the table 5.

Table 5. Atterberg limits test results for native soils

Type of soil	Liquid limit	Plastic limit	Plasticity index
Black cotton soil	63.15	28.42	34.73
Sandy gravel soil	54	25.86	28.14
Sandy silty soil	29	13.99	15.01
Loamy soil	51	29.24	21.76

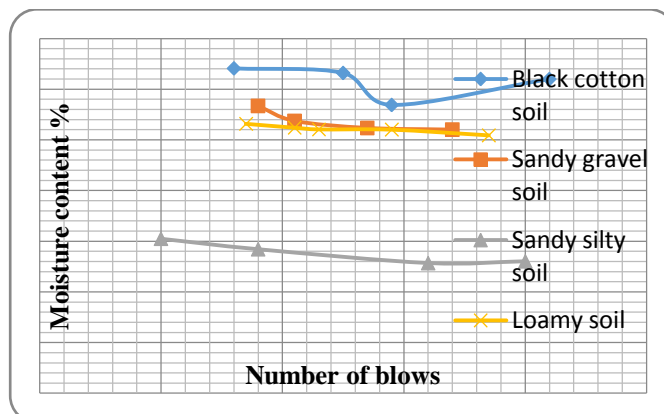


Fig 5. Number of blows Vs water content for four soils

C. COMPACTION TEST

In the following analysis the maximum dry density and optimum moisture content results has been tabulated in the table 6, and the graph is plotted between optimum moisture content verses maximum dry density as shown in fig 6 to 9.

Table 6. Results of OMC and MDD for four type soils

Soil type	Moisture density relation	Percentage stabilizer			
		Native soil	10%	20%	30%
Black cotton soil	OMC	17.8	15.4	13.1	10.89
	MDD	1.7	1.86	1.95	1.98
Sandy gravel soil	OMC	10.85	11.19	10.39	8.84
	MDD	2.01	2.04	2.07	2.11
Sandy silty soil	OMC	11.2	10.21	8.7	8.25
	MDD	2.02	2.05	2.12	2.16
Loamy soil	OMC	14	11.6	9.4	8.5
	MDD	1.9	1.92	1.94	1.99

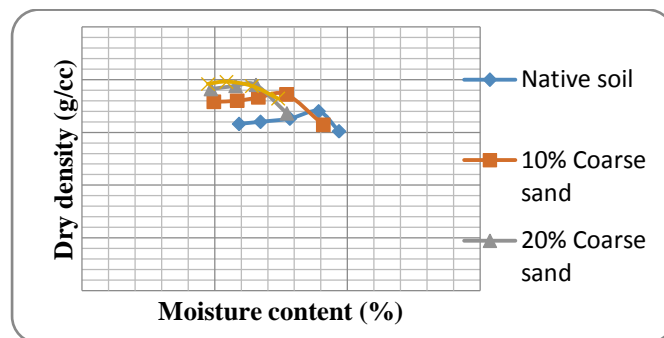


Fig 6. Graph of OMC verses MDD for Black cotton soil + coarse sand

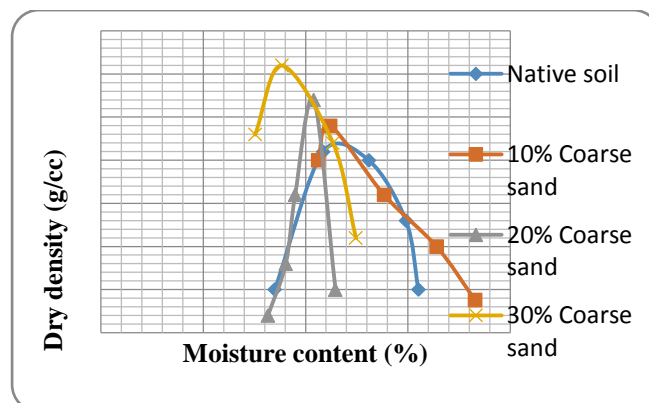


Fig 7. Graph of OMC verses MDD for Sandy gravel soil + coarse sand

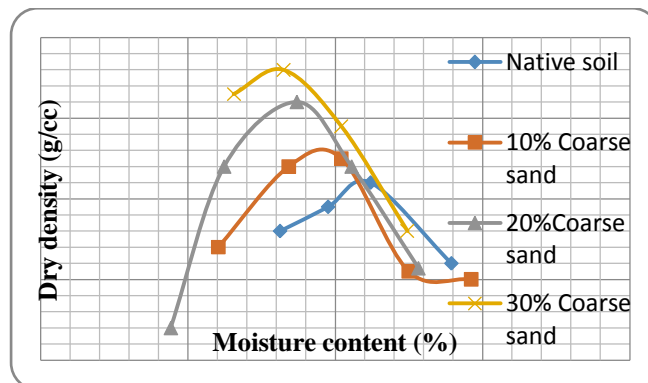


Fig 8. Graph of OMC versus MDD for Sandy silty soil + coarse sand

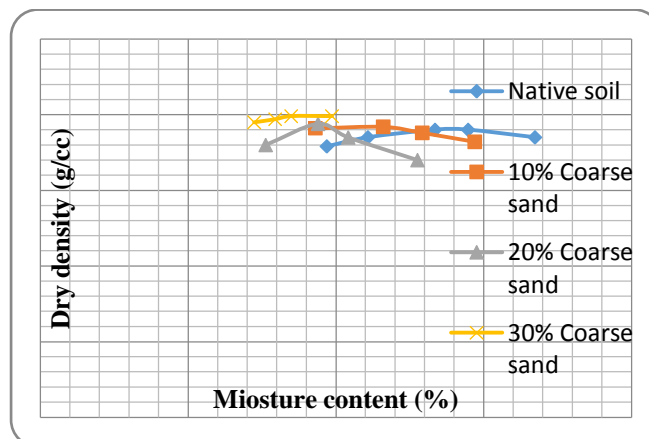


Fig 9. Graph of OMC versus MDD for Loamy soil + coarse sand

D. CALIFORNIA BEARING RATIO

The California Bearing Ratio test result analysis has been carried out and the final CBR values are tabulated in table 7, the graph will be plotted between load verses penetration in fig 10.

Table 7. CBR values for four types of soil with varying percentage of coarse sand

Type of soil	California Bearing Ratio (%)			
	Native soil	10%	20%	30%
Black cotton soil	1.64	2.05	2.79	4.02
Sandy gravel soil	7.99	9.47	14.45	21.6
Sandy silty soil	4.47	5.14	7.88	8.64
Loamy soil	3.5	4.16	4.92	6.24

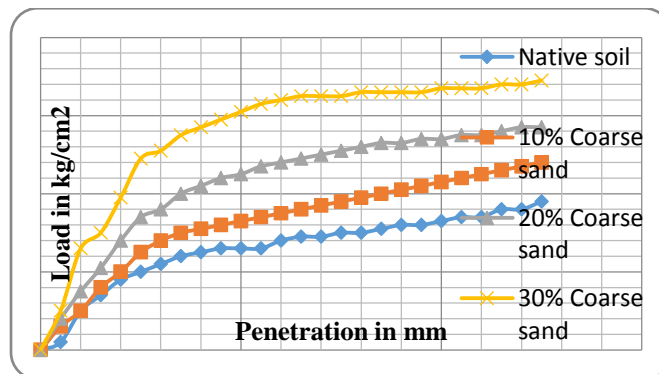


Fig 10. CBR curve for different percentage of Black cotton soil + coarse sand

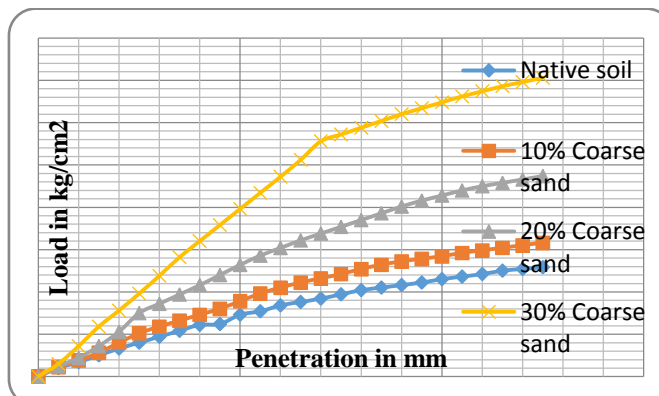


Fig 11. CBR curve for different percentage of Sandy gravel soil + coarse sand

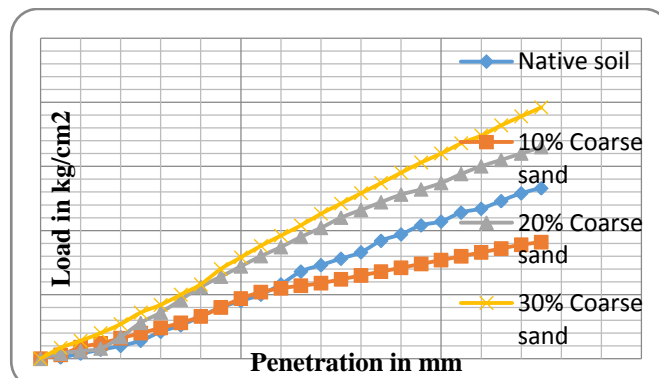


Fig 12. CBR curve for different percentage of Sandy silty soil + coarse sand

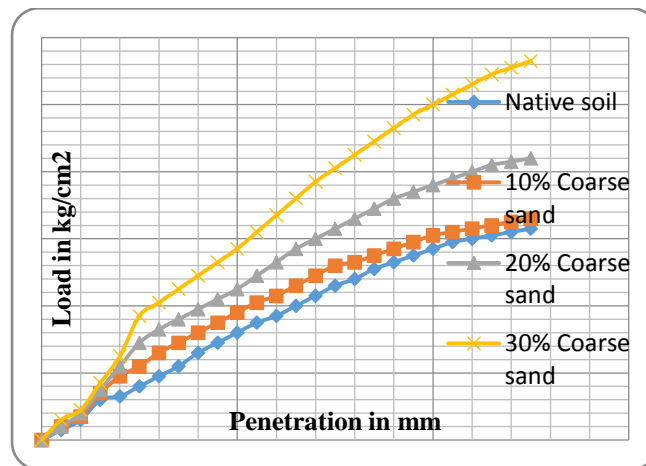


Fig 13. CBR curve for different percentage of Loamy soil + coarse sand

VI. PAVEMENT DESIGN AND COST EVALUATION

A. PAVEMENT DESIGN FOR BLACK COTTON SOIL

Considering a lane from National Highway of 3.5 m width and 1 km length and cumulative traffic of 10 million standard axels.

Pavement design has carried out according to IRC: 37-2012, Guidelines for the design of flexible pavements.

Table 8. Pavement design for different dosage of Black cotton soil + coarse sand

% of dosage		Native soil	10%	20%	30%
CBR (%)		1.64	2.05	2.8	4.02
Cumulative traffic		10 msa	10 msa	10 msa	10 msa
Pavement composition	Granular Sub Base (mm)	500	460	330	330
	Granular Base (mm)	270	250	250	250
	Dense Bituminous Macadam (mm)	105	100	80	80
	Bituminous Concrete (mm)	40	40	40	40
Total Pavement thickness (mm)		915	850	780	700

Table 9. Details of Quantities and Rate abstract for native Black cotton soil.

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
For Native soil	Granular Sub Base	1000	3.5	0.5	1750	818	14,31,500
	Granular Base	1000	3.5	0.27	945	981	9,27,045
	Dense Bituminous Macadam	1000	3.5	0.105	367.5	7836	28,79,730
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 10. Details of Quantities and Rate abstract for Black cotton soil + 10% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Black cotton soil + 10% coarse sand	Granular Sub Base	1000	3.5	0.46	1610	818	13,16,980
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.10	350	7836	27,42,600
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 11. Details of Quantities and Rate abstract for Black cotton soil + 20% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Black cotton soil + 20% coarse sand	Granular Sub Base	1000	3.5	0.395	1382.5	818	11,30,885
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.095	332.5	7836	26,05,470
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 12. Details of Quantities and Rate abstract for Black cotton soil + 30% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Black cotton soil + 30% coarse sand	Granular Sub Base	1000	3.5	0.33	1155	818	9,44,790
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.08	280	7836	21,94,080
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

B.PAVEMENT DESIGN FOR SANDY GRAVEL SOIL

Table 13. Pavement design for different dosage of Sandy gravel soil + coarse sand

% of dosage		Native soil	10%	20%	30%
CBR (%)		8	9.5	14.5	21.15
Cumulative traffic		10 msa	10 msa	10 msa	10 msa
Pavement composition	Granular Sub Base (mm)	200	200	200	200
	Granular Base (mm)	250	250	250	250
	Dense Bituminous Macadam (mm)	60	50	40	40
	Bituminous Concrete (mm)	40	40	40	40
Total Pavement thickness (mm)		550	540	530	530

Table 14. Details of Quantities and Rate abstract for native Sandy gravel soil

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
native Sandy gravel soil	Granular Sub Base	1000	3.5	0.2	700	818	5,72,600
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.06	210	7836	16,45,560
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 15. Details of Quantities and Rate abstract for Sandy gravel soil + 10% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Sandy gravel soil + 10% coarse sand	Granular Sub Base	1000	3.5	0.2	700	818	5,72,600
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.05	175	7836	13,71,300
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 16. Details of Quantities and Rate abstract for Sandy gravel soil + 20% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Sandy gravel soil + 20% coarse sand	Granular Sub Base	1000	3.5	0.2	700	818	5,72,600
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.4	140	7836	10,97,040
	Bituminous Concrete	1000	3.5	0.4	140	9523	13,33,220
	Grand total						

Table 17. Details of Quantities and Rate abstract for Sandy gravel soil + 30% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Sandy silty soil + 30% coarse sand	Granular Sub Base	1000	3.5	0.2	700	818	5,72,600
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.055	192.5	7836	15,08,430
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

C.PAVEMENT DESIGN FOR LOAMY SOIL

Table 5.16 Pavement design for different dosage of Loamy soil + coarse sand

% of dosage		Native soil	10%	20%	30%
CBR (%)		3.5	4.2	4.9	6.2
Cumulative traffic		10 msa	10 msa	10 msa	10 msa
Pavement composition	Granular Sub Base (mm)	355	325	305	255
	Granular Base (mm)	250	250	250	250
	Dense Bituminous Macadam (mm)	85	75	70	65
	Bituminous Concrete (mm)	40	40	40	40
Total Pavement thickness (mm)		730	690	665	610

Table 5.17 Details of Quantities and Rate abstract for native Loamy soil

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
native Loamy soil	Granular Sub Base	1000	3.5	0.355	1242.5	818	10,16,365
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.085	297.5	7836	23,31,210
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 5.18 Details of Quantities and Rate abstract for Loamy soil + 10% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Loamy soil + 10% coarse sand	Granular Sub Base	1000	3.5	0.325	1137.5	818	9,30,475
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.075	262.5	7836	20,56,950
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 5.19 Details of Quantities and Rate abstract for Loamy soil + 20% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Loamy soil + 20% coarse sand	Granular Sub Base	1000	3.5	0.305	1067.5	818	8,73,215
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.07	245	7836	19,19,820
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 5.20 Details of Quantities and Rate abstract for Loamy soil + 30% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Loamy soil + 30% coarse sand	Granular Sub Base	1000	3.5	0.255	892.5	818	7,30,065
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.065	227.5	7836	17,82,690
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

D.PAVEMENT DESIGN FOR SANDY SILTY SOIL

Table 21 Pavement design for different dosage of Sandy silty soil + coarse sand

% of dosage		Native soil	10%	20%	30%
CBR (%)		4.5	5.1	7.9	8.6
Cumulative traffic		10 msa	10 msa	10 msa	10 msa
Pavement composition	Granular Sub Base (mm)	315	305	210	200
	Granular Base (mm)	250	250	250	250
	Dense Bituminous Macadam (mm)	75	70	60	55
	Bituminous Concrete (mm)	40	40	40	40
Total Pavement thickness (mm)		680	665	560	545

Table 22 Details of Quantities and Rate abstract for native Sandy silty soil

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
native Sand y silty soil	Granular Sub Base	1000	3.5	0.315	1102.5	818	9,01,845
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.075	262.5	7836	20,56,950
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 23 Details of Quantities and Rate abstract for Sandy silty soil + 10% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Sandy silty soil + 10% coarse sand	Granular Sub Base	1000	3.5	0.305	1067.5	818	8,73,215
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.07	245	7836	19,19,820
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 24 Details of Quantities and Rate abstract for Sandy silty soil + 20% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Sandy silty soil + 20% coarse sand	Granular Sub Base	1000	3.5	0.21	735	818	6,01,230
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.06	210	7836	16,45,560
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

Table 25 Details of Quantities and Rate abstract for Sandy silty soil + 30% coarse sand

	Items of work	Length (m)	Width (m)	Depth (m)	Quantity (m ³)	Rate (Rs/m ³)	Amount (Rs)
Sandy silty soil + 30% coarse sand	Granular Sub Base	1000	3.5	0.2	700	818	5,72,600
	Granular Base	1000	3.5	0.25	875	981	8,58,375
	Dense Bituminous Macadam	1000	3.5	0.055	192.5	7836	15,08,430
	Bituminous Concrete	1000	3.5	0.04	140	9523	13,33,220
	Grand total						

VII. DISCUSSIONS AND CONCLUSIONS

E. NOTE ON STABILIZER

In the present study coarse sand is used as stabilizer, which can be obtained by natural river or lake beds and for using this as stabilizer only cost is for transportation.

Traditionally river sand used as building construction material. The finer particles passing 2.36 mm sieve is used for building construction and that off coarser particles retained on 2.36 mm sieve will be discarded and dumped as a waste material, that waste material can be effectively used in subgrade construction for low bearing capacity soils in pavement construction.

We can use the coarse sand as a stabilizer for subgrade by taking care of grain size i.e. passing 6 mm and retained on 2.36mm sieve.

F. WET SIEVE ANALYSIS

The gradation obtained for all the four soils after adding stabilizer for different percentages viz 10%, 20% and 30% of coarse sand, the gradation varied compared to gradation of native soil, as we increased percentage of coarse sand the content of gravel, sand and fines varied significantly.

For 30% coarse sand blended in Black cotton soil, the percentage of fines has reduced to 23%, and sand content increased by 34%

For Sandy gravel and Sandy silty soil not much difference in gradation

For 30% coarse sand blended in Loamy soil, the percentage of fines has reduced to 38%, and sand content increased by 42%

It is concluded that for Black cotton soil and Loamy soil the coarse sand is an effective stabilizer to improve the density and to reduce water content, it is not as important to treat Sandy gravel soil, and for Sandy silty soil if conditions warrants treatment then we can think off coarse sand as a stabilizer if it is available locally.

G.ATTERBERG LIMITS

The Liquid limit and Plastic limit found only for native soils. For blended soil it is not possible to conduct LL & PL test, because as we used the coarse sand as stabilizer and for consistency test soil should be sieved through 425micron sieve there is no significance of the test for blended soil.

As granular material is used as stabilizer there is no significance of the liquid limit and plastic limit test, if we used any fines material viz cement, lime or any chemicals then it has significance with consistency limits.

H. MOISTURE DENSITY RELATION

It clearly shows that from compaction test results there is significant change in MDD and OMC for blended soil with coarse sand compared to native soil, as we are blending coarse sand to the native soil it densifies the soil and reduces the water content to achieve maximum dry density.

From table 6, test results for MDD and OMC we can make out the increase in density and reduction in moisture content.

For native Black cotton soil MDD is 1.7 g/cc, OMC is 17.8% and for 30% coarse sand blending MDD is 1.98 g/cc, OMC is 10.8%

For native Sandy gravel soil MDD is 2.01 g/cc, OMC is 10.85% and for 30% coarse sand blending MDD is 2.11 g/cc, OMC is 8.8%

For native Sandy silty soil MDD is 2.02 g/cc, OMC is 11.2% and for 30% coarse sand blending MDD is 2.16 g/cc, OMC is 8.25%

For native Loamy soil MDD is 1.9 g/cc, OMC is 14% and for 30% coarse sand blending MDD is 1.99 g/cc, OMC is 8.5%

From test results it is concluded that coarse sand is an effective stabilizer for Black cotton soil and for Loamy soil. It doesn't have much influence on Sandy gravel and Sandy silty soil

I. CALIFORNIA BEARING RATIO

From table 7.it is clear that by adding coarse sand to the selected soils the CBR values has increased significantly.

For native Black cotton soil CBR is 1.64% and for 30% blending of coarse sand CBR is 4.02%, it is increased by 59%

For native Sandy gravel soil CBR is 7.99% and it is enough for good pavement design, even though if we want to increase CBR value, by blending 20% coarse sand we can achieve CBR of 14.5%

For native Sandy silty soil CBR was 4.5% and by blending 30% coarse sand we can achieve 8.6% CBR

For native Loamy soil CBR was 3.5% and for the same soil if we blend 30% coarse sand we can achieve a CBR of 6.3% and it is a significant increase in CBR value so that we can reduce our pavement thickness.

From test results for CBR, it can be concluded that coarse sand is an significant stabilizer for Black cotton soil and for Loamy soil if it is available in economic haulage then it proves to be effective in economic considerations. The Sandy silty soil has also influenced by blending coarse sand and increased in strength. Finally the Sandy gravel soil has not much influenced by coarse sand.

J. COST EVALUATION

From table 9. it is seen that for native Black cotton soil total cost of construction will be around 65.7 lakh/lane/km, and that of 30% coarse sand blended soil the cost of construction is 53.3 lakh/lane/km, it can be saved up to 12.4 lakh/lane/km.

From table 14, for native Sandy gravel soil the cost of construction is 44.1 lakh/lane/km and for soil treated with 20% coarse sand the construction cost is 38.6 lakh/lane/km, we can save around 5.5 lakh/lane/km.

From table 22, for native Sandy silty soil the cost of construction is 51.5 lakh/lane/km and for soil treated with 30% coarse sand the construction cost is 42.7 lakh/lane/km, we can save around 8.8 lakh/lane/km.

From table 17, for native Loamy soil the cost of construction is 55.4 lakh/lane/km and for soil treated with 30% coarse sand the construction cost is around 47.04 lakh/lane/km, by that we can save around 8.36 lakh/lane/km.

ACKNOWLEDGMENT

We are very grateful to all authors in reference section. Their methods, conceptual techniques are very helpful for our research. AGM of planning department, site engineer, everyone at project shared information and knowledge helped us to complete our proposed work, and we are very grateful to them.

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