Mechanical Stabilisation of Lateritic soil for Improving Subgrade

by

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Introduction

Soil compaction is the process whereby all the particles of soil are forced to pack close to each other by reducing the air voids. The air voids can be eliminated almost completely and the soil can be brought to a condition in which there will not be any tendency for further changes in moisture content. This is achieved by proportioning the various grains properly and fully compacting the same. The term mechanical stabilisation in fact gives particular importance in controlling the grading of various particles in the soil. Stabilisation in this connection implies nothing but increasing the stability of the material under a given condition of moisture.

This paper deals with the study of lateritic soil. The soil was modified using Rothfuch's (HMSO 1952) specifications for determining the proportions in which materials of known sizes to be mixed with one another produce a specified size distribution so as to get maximum density. A study was also made using cinder ash obtained from steam locomotives, as an additive. The resulting changes in California Bearing Ratio, permeability, compression strength and swelling were studied.

For this investigation lateritic soil was collected from the Calicut Regional Engineering College campus and allowed to dry at the room temperature. Soil was disintegrated gently so as not to crush the individual particles. The maximum size of the particles was 4.76 *mm* (IS 480) and it can be seen that about 80 per cent of the soil is coarse grained. The grain size analysis shows a distinct gap grading. (Figure 1)

The physical properties of the soil are given in Table 1.

TABLE 1 : Physical Properties

Liquid limit	39%
Plastic limit	15%
Plasticity index	24%

It is widely known that Atterberg limits of residual soils as oqtained by the usual test procedures are deceptive, since the mixing of particles

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during the determination of these limits leads to a breaking up of the fines and to slight defloculation. These defloculated fines absorb more water and consequently the values obtained depends upon the alteration that the soil has undergone. Thus the Atterberg limits obtained are not absolute. The values presented in Table I are the average values of repeated tests in accordance with IS procedures.

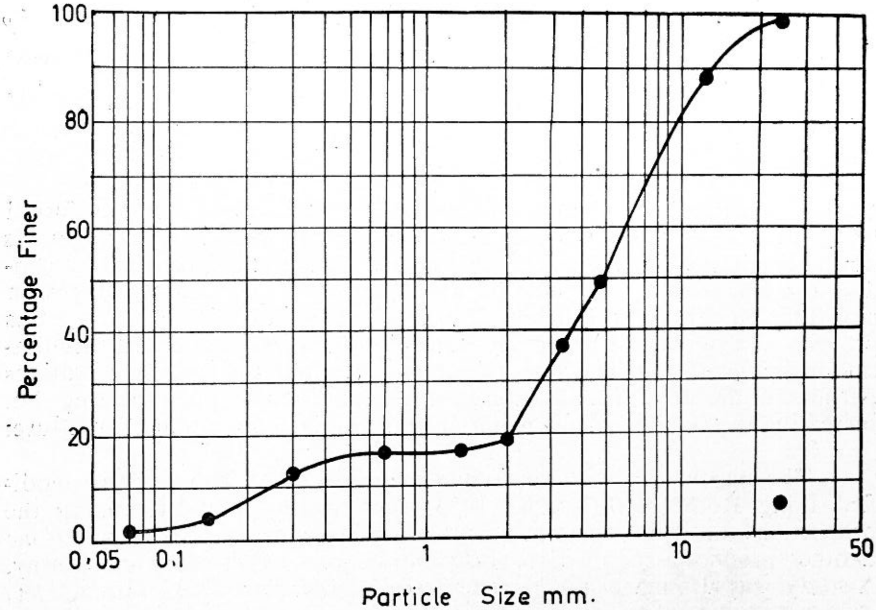

FIGURE 1. Sieve analysis of lateritic soil from Calicut

More often natural materials are deficient in one or more of the particle fractions and a mechanically stable mixture can be obtained by replenishing the deficient sizes.

In this soil the gap in the finer side of the soil could have been made good and a well graded mixture would have resulted. But in the present investigation the authors treated the naturally available soil as made up of two fractions. One is a fraction of very coarse material having a gradation as in Figure 2 and forming the major portion of the soil. The other is of very fine particles having its own gradation (Figure 2). These are combined to get a dense combination. This method of stabilising a soil without the addition of foreign fine material has definite advantage in field also. The naturally available lateritic soil is therefore divided into two groups, one as all the material retained and the other as all the material passing sieve IS 1.18*mm* (IS 120).

Some of the particles finer than 1.18*mm* though appear to be coarser grains, they are really not so since they can be easily powdered between fingers. However, the grains retained on IS 120 are found to be stable. This was the reason for selecting sieve IS 120 as the dividing grain size.

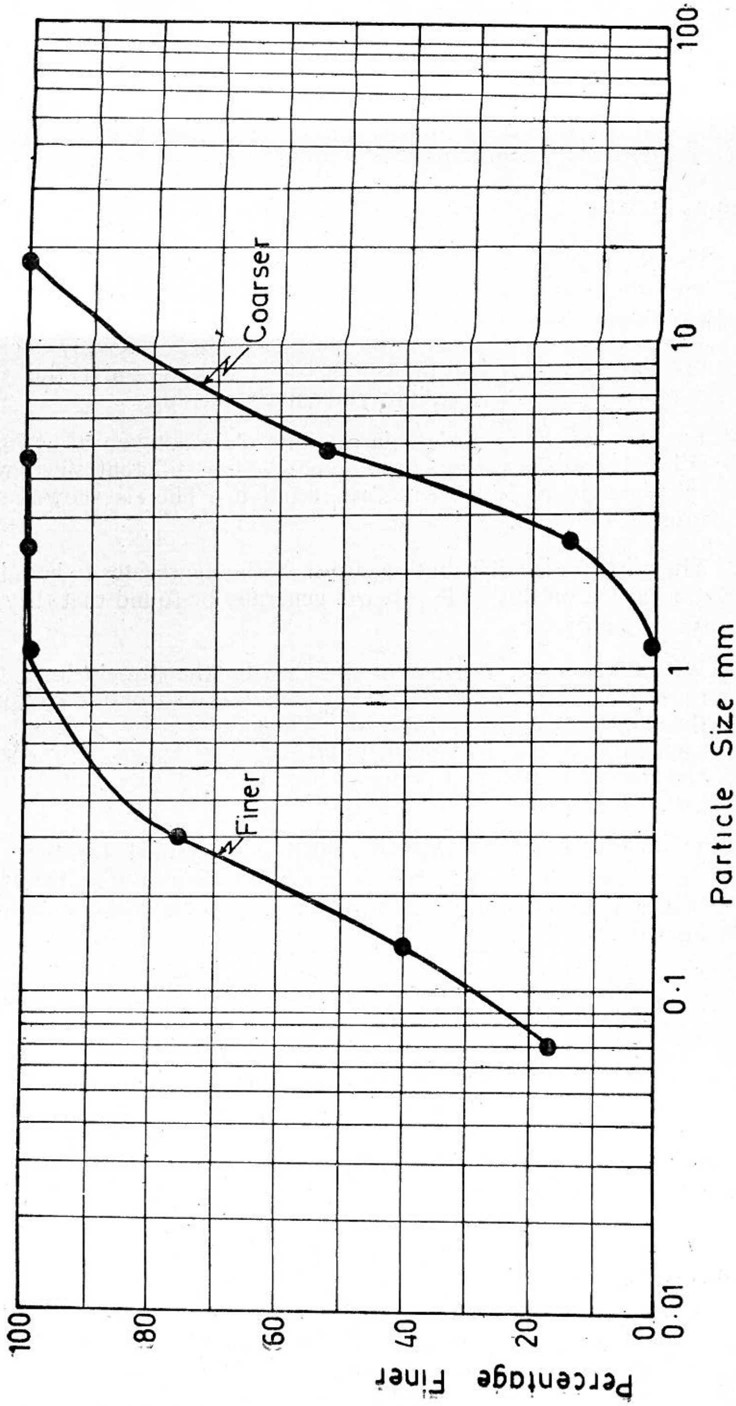

FIGURE 2. Individual gradation curves of the coarser and finer fractions of lateritic soil

Stabilization Using Rothfuch's Methods

Several methods are available for determining the proportions in which any two categories of materials to be mixed to get a mechanically stable mixture. The method suggested by Rothfuch (HMSO 1952) in his graphical determination of the proportioning of various aggregates necessary to produce a mix of a given grading was used.

Rothfuch's method consists of the following stages.

1. The cumulative curve of the required aggregate particle size distribution is plotted using the usual linear ordinates for the percentage passing but choosing a scale of sieve size such that a particle size distribution plots as a straight line. This is readily done by drawing an inclined straight line and marking on it the sizes corresponding to the various percentages passing.

   For this test the size of the largest particle was taken as 4.76*mm* (IS 480) and the various percentages passing different sieves were calculated using Fuller-Rothfuch relation. This is shown as an inset in Figure 3.

2. The particle size distribution curves of the aggregates to be mixed are plotted on this scale. It will generally be found that they are not straight lines.

3. With the aid of a transparent straight edge the straight lines that most nearly approximate to the particle size distribution curves of the single aggregates are drawn. This is done by selecting for each curve a straight line such that the areas enclosed between it and the curve are a minimum and are balanced about this straight line.

4. The opposite ends of these straight lines are joined together and the proportions for mixing can be read off from the points where these joining lines cross the straight line representing the required mixture.

It is found that a mixture of 65 per cent of the material retained on sieve IS 1.18*mm* (IS 120) and 35 percent of the fines passing sieve IS *1.18mm (IS 120)* are to be mixed for a stable combination.

In order to study and compare the natural soil and the soil obtained after modification (hereafter referred to as modified soil) by using Rothfuch's method, Proctor's compaction tests were done. Further studies on permeability, compressive strength, California Bearing ratio and swelling characteristics were done on natural and modified soils. The tests were done on soils remoulded at the corresponding optimum moisture contents.

Stabilisation with Cinder Ash

The cinder ash, the reject of the locomotive engine, is available in abundance and costs almost nothing. The authors feel that making use of this material if found effective would be advantageous.

The cinder ash collected from Calicut Railway Station premises was analysed chemically (Table 2) and it was found that it contains about

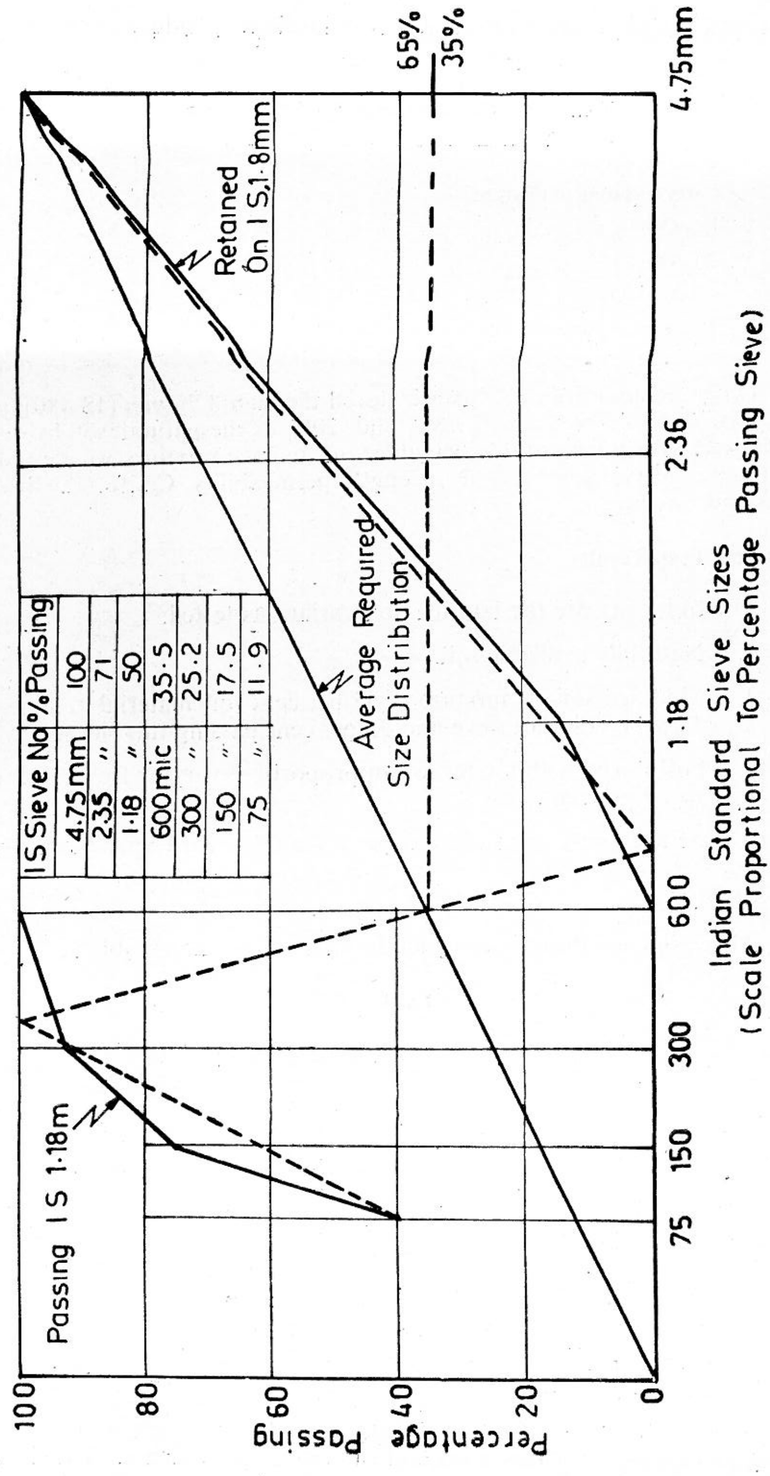

FIGURE 3. Determination of mixture for stable combination

4 per cent of oxides. Most of this ash is as insoluble residue. The unburnt carbon comes to about 8.3 per cent.

TABLE 2. Chemical analysis of cinder ash

Volatile matter	1.2 %
Carbon (unburnt charcoal)	8.3 %
Fe_2O_3	2.5 %
Al_2O_3	1.0 %
CaO, MgO	0.24%
Insoluble residue	86.76%

Different quantities of this ash sieved through 4.76 *mm* (IS 480), such as 8%, 10%, 12%, 14%, 16%, 18% and 20% of the natural soil by weight were mixed with the naturally available soil and the mixture was tested for maximum density, compressive strength, permeability, California Bearing Ratio and Swelling.

Tests and Test Results

The following are the lateritic soil variations tested.

1. Naturally available soil.
2. Modified soil—a mixture of 65 per cent of material retained on 1.18*mm* (IS 120) sieve and 35 per cent passing this sieve.
3. Soil mixed with cinder ash in proportions varying from 8 per cent to 20 per cent.

All the tests were conducted as per Indian Standard Specifications.

Dry Density

The results of Proctor compaction tests are given in Table 3.

TABLE 3

Description of the soil	*Maximum dry density* gm./c.c.	*Optimum moisture* content percentage
Natural soil	1.85	17.5
Modified soil	1.966	17.0
Natural soil + 8% ash	1.810	18.2
Natural soil + 10% ash	1.850	17.5
Natural soil + 12% ash	1.765	18.2
Natural soil + 14% ash	1.720	19.5
Natural soil + 18% ash	1.750	18.5
Natural soil + 20% ash	1.660	21.1

The results show that the naturally available soil when modified by Rothfuch's procedure enables the soil to become more dense. This increase in density is only due to the proper arrangement and grading of the material. The increase in dry density is 7 per cent. Though this is a small increase it is commendable since the increase is brought about by merely readjusting the soil.

The density values (Table 3) obtained from Proctor compaction tests on mixtures of soil with ash mixed in proportions varying from 8 per cent to 20 per cent showed no appreciable increase in the value of dry density. In fact there is a reduction in the value of dry density for an increasing percentage of ash content. This may be probably due to the absence of any ingredient in the cinder ash which can contribute to the increase of density.

California bearing ratio and Permeability

The California bearing ratio value, obtained by the conventional procedure are for 10*mm* penetration. The permeability was determined by variable head method in each case.

The values are tabulated (Table 4). There is a gradual increase in the value of CBR for soil-ash mixtures upto 10 per cent, addition of ash. The moderated soil and the soil mixed with 10 per cent ash, both show increased CBR values compared to natural soil. The addition of ash at rates higher than 10 per cent does not increase the CBR.

TABLE 4

Description of soil	CBR values percentage	Permeability cm./sec.
Natural soil	12.2	0.365×10^{-5}
Modified soil	14.3	0.071×10^{-5}
Natural soil+ 8% ash	13.6	0.251×10^{-5}
Natural soil+10% ash	15.3	0.0175×10^{-5}
Natural soil+12% ash	15.2	0.0503×10^{-5}
Natural soil+14% ash	12.9	0.370×10^{-5}

The permeability decreases both for the moderated soil and for the soil ash mixture. Here again 10 per cent seems to be the optimum percentage of ash and any further additions, only increase the permeability. The change of permeability discussed here is with respect to that of natural soil. For the permeability tests the samples were moulded at a moisture content slightly on the wet side of the optimum. Due to this there may be a slight difference in the value of the permeability (Leonards 1962) compared to the value which would have resulted, if the samples were moulded at the exact value of the optimum moisture content.

The decrease in permeability may be attributed to Taylor (1948) the viscous or plastic expansion characteristics in the adsorption zones in the vicinity of points of contact or near contact of fine grained particles of colloidal nature. The rate of decrease upto 10 per cent is rather small when compared to the rate of increase of permeability after 10 per cent addition of cinder ash.

Unconfined Compression Test

The unconfined compression strength of 5 cm. diameter and 7.5 cm. high samples for the soil variations are given in Table 5.

TABLE 5 : Unconfined compression strength

Description of soil	q_u kg/cm^2
Natural soil	1.696
Modified soil	0.708
Natural soil+ 8% ash	0.642
Natural soil+10% ash	1.056
Natural soil+12% ash	1.608
Natural soil+14% ash	2.086
Natural soil+16% ash	1.056
Natural soil+20% ash	0.882

The unconfined compression strength as noticed in Table 5 for the modified soil is less compared to the U.C.C. value of natural soil. This reduction is in contrast to the increase in dry density. Therefore it was inferred that this reduction should be associated with an increase in the angle of internal friction. When tested for its angle of internal friction in a direct shear tests it was noticed that there is considerable increase in the angle of internal friction (Table 6).

The soil ash mixture also shows an increase in the U.C.C. value upto 14 per cent and any further addition of ash only reduces the U.C.C. value due to the development of a loose structure.

TABLE 6 : Angle of internal friction from direct shear tests

Description of soil	Angle of internal friction in degrees
Natural Soil	35
Moderated soil	48
Natural soil+10% ash	42

Swelling Tests

Swelling tests were conducted on samples of (1) natural soil (*ii*) Moderated soil (*iii*) Natural soil mixed with 10 per cent ash. The tests were conducted in the manner specified by Palit (1953). It was noticed that the moderated soil undergoes least swelling. The swelling of natural soil is 2.25 times that of moderated soil. The soil mixed with 10 per cent ash swells as much as 3.75 times that of moderated soil.

Conclusions

The investigations lead to the following conclusions.

1. The modification of the lateritic soil based on Rothfuch's graphical method results in 7 per cent increase in the value of maximum

dry density. There is 16 per cent increase in the CBR value and considerable reduction in permeability. There is commendable reduction in swelling.

2. The use of cinder ash as a stabilising additive to lateritic soil is not very promising since it does not contribute to the increase of maximum dry density. The optimum percentage appears to be 10 per cent.

Acknowledgements

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