Stabilization of Laterite Soils

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Introductory Remarks by the Chairman: Laterite soils are typical for the wet tropics and are widely distributed in such areas as India, Indonesia, Indochina, Malaya, Burma, Western Australia, Madagascar, Central Africa, the Guianas, Brazil, Cuba, and others. They normally possess good tilth, and with plenty of solar energy and water available, they are, if properly fertilized, capable of excellent crop yields and may well be destined to contribute in a major degree to the food supply of a rapidly growing world population. A great need exists for a suitable network of low-cost roads in these areas already in their present underdeveloped condition and even more so if their proper agricultural development is to proceed.

Laterite soils differ widely from the soils of the temperate regions with respect to their physical and chemical properties. It is in these soil areas that the greatest discrepencies have been observed when soil-stabilization methods developed for certain temperate climates have been unjudiciously applied. This is especially true for granular soil stabilization.

Remillion, who is director of the Brazzaville Branch of the Laboratories for Construction and Public Works of the French Government, has attacked the problem of stabilizing laterite soils from the point of view of the scientifically well-trained, responsible executive engineer. Significantly, he has gone to the heart of the problem. Instead of trying to adjust for his conditions standards developed for temperate climates and soils of such climates, he makes a fresh analysis based on the actual properties of his soil materials and on the classical work of Talbot in the design of concrete mixtures. The analytical conclusions are compared with actual road performance, and the resulting design recommendations are as scientific and as practical as one can wish for.

● LATERITE formations cover an important portion of the tropical and equatorial zones. They may be present in the form of red clays or of laterite proper.

The latter may or may not be covered with an iron-oxide carapace.

Laterites form natural soil-concretes that are utilized widely for the construction of runways and highways. In the following we shall consider only the laterites proper, excluding the indurated oxide shield or carapace and also the lateritic clays.

GENERAL CONSIDERATIONS

Mineralogic Composition of laterites

Microscopic examination of laterites derived from the alteration of rocks in place shows that these materials are composed of: pure silica (SiO_2) from eolian sands; and hydrous oxides of aluminum ($Al_2O_3 \times 3 H_2O$) and of iron ($2 Fe_2O_3 \times H_2O$ - Goethite).

Processes and factors of alteration

Mineralogic examination reveals that two distinct and independent alteration processes occur simultaneously in laterite formation. On one hand, the normal weathering of feldspars leads to the formation of clays; on the other hand, the specific lateritic alteration leads first to hydrates and then to oxides.

This lateritic alteration is a consequence of the hydrolysis of the feldspars and of the elutriation of the alkalis and of part of the iron in the form of the bicarbonate. This elimination is favored by the great purity of the waters (hydrotimetric degree generally lower than 3) and by an elevated temperature (about 86 F). The hydrates tend to transform into oxides under the effect of solar radiation (ultraviolet) and possibly also under the action of iron bacteria.

The concretions or pisoliths that constitute the skeleton of the laterites seem to have formed around hydrargillite crystals that served as crystallization nuclei.

These nodules always have a higher specific gravity than the average of the material.

Several examples of these are given in Table 1.

These results and the analyses made on the different fractions show that the nodules are almost exclusively composed of the oxides, while the fine particles are still in the form of the hydrates.

TEST METHODS AND PROPERTIES OF LATERITES

All laterites possess peculiar mechanical properties; this necessitates modifications in the test methods.

The nodules are always friable and of porous structure.

The fine particles are always flocculated.

Granulometric analyses and Atterberg limits

For the separation of the fine particles from the nodules wet sieving is necessary. In addition, for the hydrometer analysis deflocculation of the fine constituents is required.

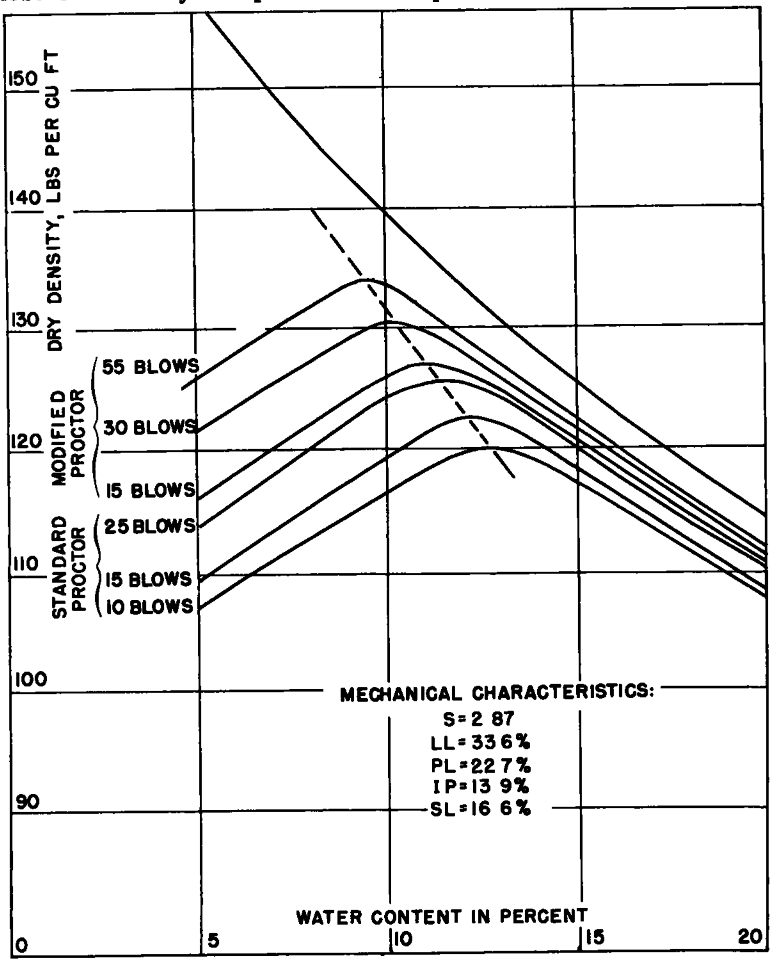

Figure 1. Proctor Test.

Although some laterites can be easily dispersed by means of ammonium or sodium phosphate, in many cases this is not successful.

Regarding the Atterberg limits, it must

TABLE 1

Values of specific gravities:	Ex 1	Ex 2	Ex 3
. Fraction			
>0.5 mm	2 76	3.13	3.13
0.5 - 0.1 mm	2 73	2.75	2 65
0.1 - 0 05 mm	2 71	2.64	2 63
<0.05 mm	2 65	2.63	2.60

be noted that the mixing of the particles during the determination of the liquid limit leads, on one hand, to a breaking up of the fines and, on the other hand, to a slight deflocculation.

These deflocculated fines absorb an additional amount of water. It is, therefore, difficult to give exact values for the Atterberg limits, since the limits obtained by experiment depend on the modifications which the material has undergone in the course of the determination[1].

All granulometric curves of laterites show a discontinuity between 2 and 0.5 mm. This discontinuity indicates that the nodules do not form in a continuous manner from the fines, but that they form around crystallization nuclei as has been indicated above.

In addition, the majority of granulometric curves show that laterites contain an appreciable quantity of fine windblown sand.

Proctor Test

The fragility of the laterite nodules is such that it is necessary to use new material for each point of the Proctor curve.

Figure 1 shows Proctor curves for different compactive efforts. Figure 2 shows that, if plotted on semilog paper, the variation of the dry density as a function of the compactive effort can be expressed by a straight line.

Classification of Laterite Soils

The majority of laterites generally possesses the following characteristics: (1) less than 35 percent passing the number 200 sieve; (2) liquid limit less than 40; and (3) plasticity index larger than 10.

The general types of laterites, therefore, fall into Class A 2-6 (AASHO Designation M 145-49). The fraction smaller than five microns usually has a liquid limit from 50 to 60 and a plasticity index from 15 to 30. These fines, therefore, correspond to an A-7 clay. Although classes as A 2-6 soils, laterites generally rank in road construction at least equal with soils of a Class A 1-b.

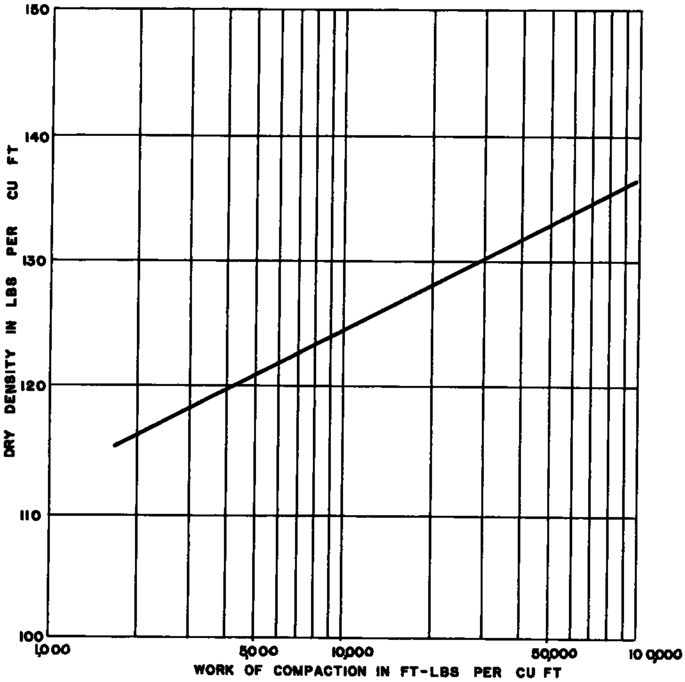

Figure 2. Variation of Maximum Dry Density as a Function of the Work of Compaction.

UTILIZATION OF LATERITES FOR THE CONSTRUCTION OF UNPAVED ROADS

Many tests have been made on sections that during the dry season formed cor-

[1]See: "Laterite Soils and Their Stabilization" by Hans F Winterkorn and E. C. Chandrasckharan, Proc. 30th Ann Meeting, Highway Research Board (January 1951).

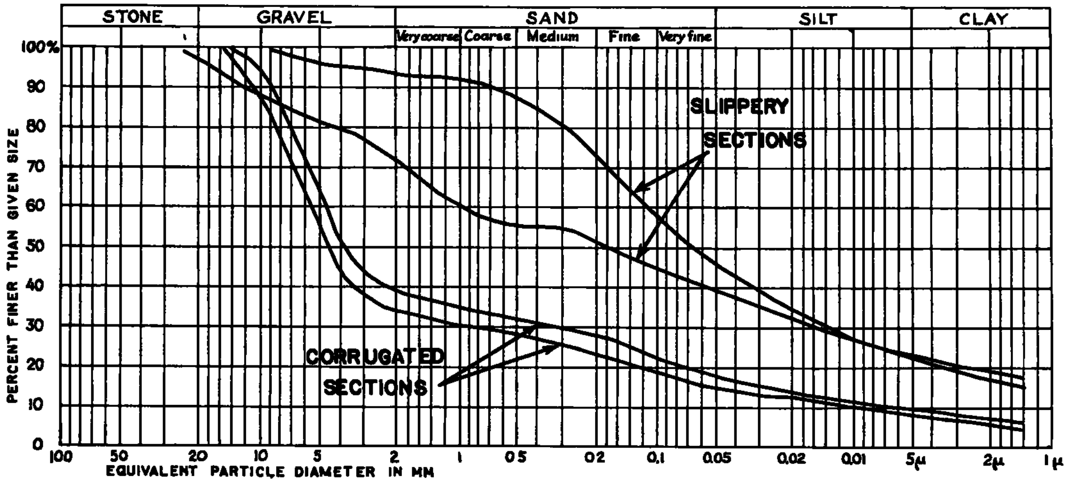

Figure 3. Granulometric analyses: Samples from unsatisfactory sections of unsurfaced roads.

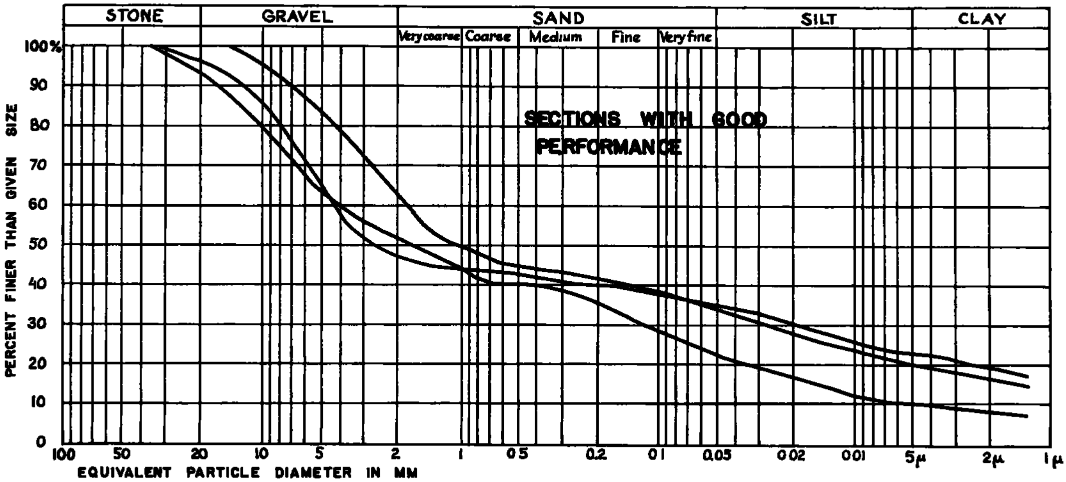

Figure 4. Samples from satisfactory sections of unsurfaced roads.

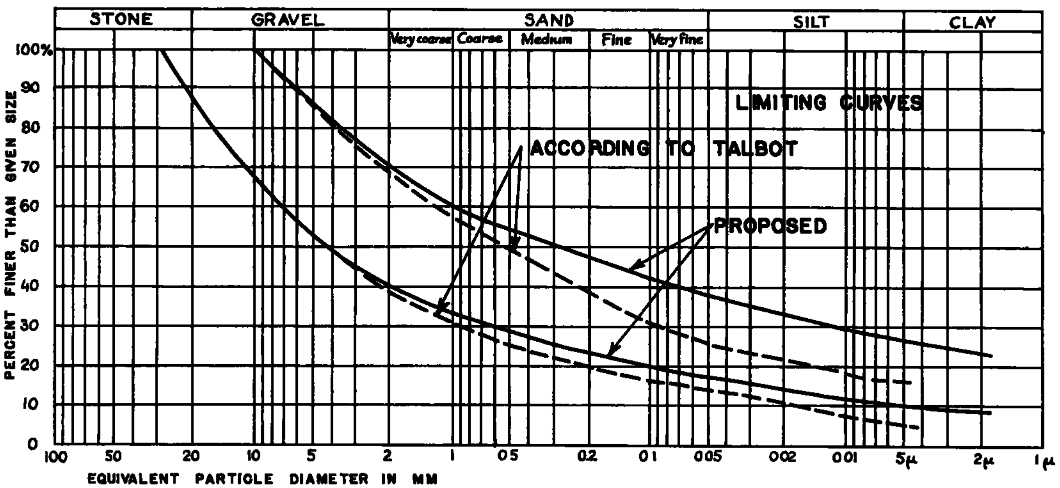

Figure 5. Granulometric analyses: Unsurfaced Roads.

rugations and also on sections that during the rainy season either showed lack of stability or excessive slipperiness. Typical curves for each of these conditions are reported in Figures 3 and 4. The curve envelopes of materials that give satisfactory performance have been derived from a number of granulometric analyses and are reported in Figure 5.

In the small-size range, these envelopes differ from the formerly accepted curves of Talbot. The mortar content must exceed the values indicated by the Talbot curves if the road surface is to retain a good riding quality. The clay content must lie between 10 and 25 percent.

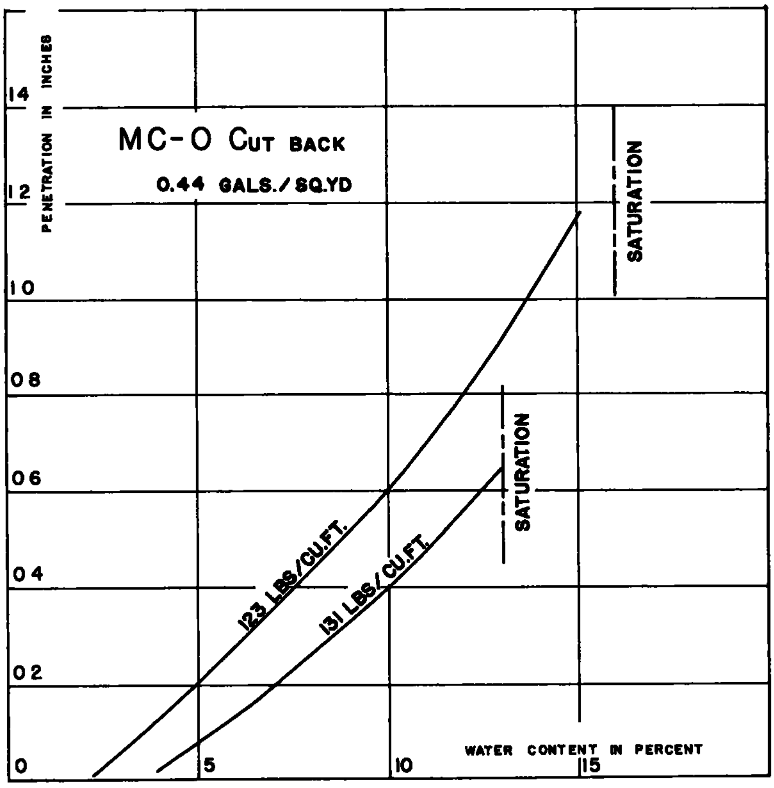

Figure 6. Influence of water content on the penetration of cut-back asphalt.

The plasticity indices of satisfactory materials have all been found to lie between 15 and 25 percent. One must notice, however, that this plasticity condition is not sufficient by itself, since materials showing formation of corrugations possessed correct plasticities. As a matter of fact, the two conditions of granulometry and plasticity cannot be separated.

Maintenance of Nonpaved Highways

The maintenance of nonpaved highways is generally done by motor grader. This treatment leads to a disintegration of the upper portion of the highway. If the respective materials are in too advanced a stage of alteration, it is no longer possible to shape the affected portion without incorporation of clay.

This phenomenon is due to the fact that the laterite placed on the road surface loses part of the fines in the form of dust and also to the fact that certain laterites placed on roads age and lose their plasticity by formation of oxides. One says then that the laterite has gone dead.

Generally speaking, unpaved highways that are expected to be maintained by motor grader must be constituted of "live" laterites, that means of such whose fines are still rich in hydrates. Before placing materials on the highway one should check the state of evolution of the fines by determination of their specific gravities and their chemical composition.

UTILIZATION OF LATERITES FOR PAVED HIGHWAYS

Impregnation of Laterites

Numerous tests have been performed over a number of years on roads made of compacted, impregnated, and paved laterites. The principal difficulty encountered in the course of construction was in the impregnation of the laterite. As a matter of fact, impregnation is only possible after thorough moistening of the surfaces. Figure 6 shows the influence of moisture content on the penetration of the binder. Experience has proved that even in the case of laterites having a high plastic index, penetration is satisfactory if the surface is thoroughly moistened.

Trafficability of Paved Highways

Simply impregnated and paved laterite roads have been constructed only within the last few years, and data on their permanence and performance under heavy traffic are still insufficient for complete evaluation. However, some investigations have already been performed on highways that have deteriorated under traffic. Particularly the intrinsic curves for compacted laterites have been determined, and have been employed for working out standards regarding the quality of laterite highways.

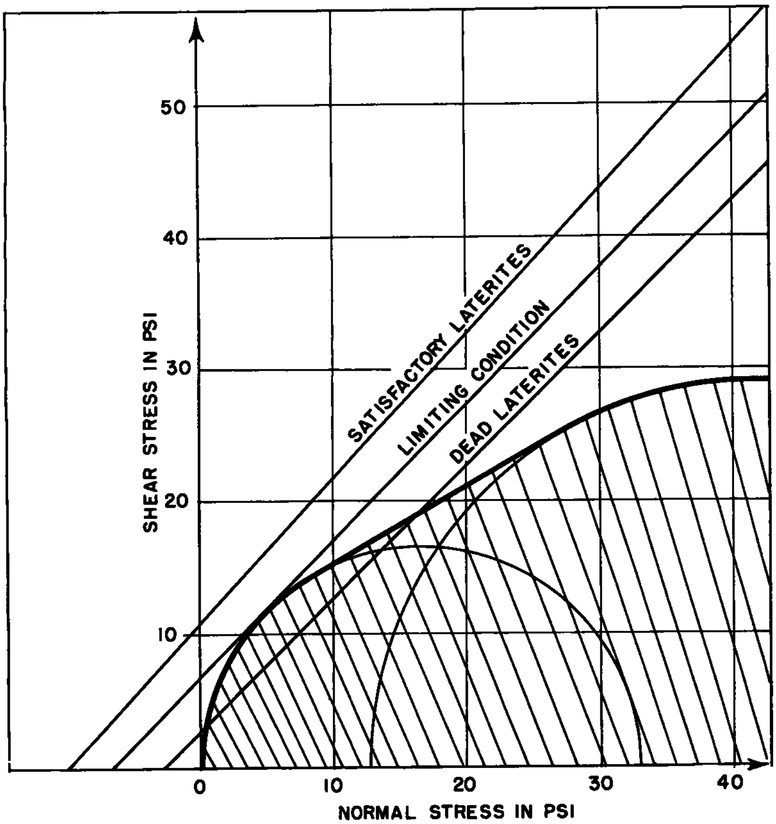

Figure 7. Stress envelope for 5-ton load.

In Figure 7 is shown the stress envelope corresponding to the effect of a 5-ton wheel load on the road surface. For a satisfactory strength of the road bed, it is sufficient if the intrinsic curve of the material does not cut the stress envelope. Since the majority of laterites have angles of friction of at least 40 deg., it is sufficient if the cohesion is at least equal to 7.1 psi. Before constructing paved highways on laterites, one must make certain that at least this amount of cohesion is obtained.

ACKNOWLEDGMENT

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