SIGNIFICANCE OF PRETESTING PREPARATIONS IN EVALUATING INDEX PROPERTIES OF LATERITE MATERIALS

M. D. Gidigasu and S. L. Yeboa, Building and Road Research Institute, Ghana

This study assessed the implications of the different degrees of dessication of the dry savannah zone and wet forest zone laterite minerals in Ghana in terms of the effect of pretesting preparations on some laboratory index test results. The study shows that wet forest zone materials and the deep-layer, dry savannah zone soils are more sensitive to drying than highly dessicated top soils from the dry savannah zone. The conclusions reached in the study have emphasized the danger inherent in writing specifications for field-compaction contracts based only on the laboratory tests carried out on air-dried samples. The study has also emphasized the usefulness of a method in which the final contract specification for field compaction is based on actual field trial compaction tests at the equilibrium moisture contents likely to exist during the life of the structure.

•STUDIES on the engineering properties and experiences of field performance of laterite materials have revealed a wide range of properties and have corrected the earlier misconception that all laterite materials have similar properties and are generally troublesome and undesirable highway and foundation materials. It has been amply demonstrated that the varied properties of laterite materials are due to their genesis, mineralogy, and environmental conditions.

Decomposition under temperate conditions of low-chemical and soil-forming activity does not continue past the clay-mineral forming stage, whereas under tropical rain forest conditions of high temperature and rainfall the clay minerals tend to decompose into various forms of oxides in relation to the nature of the weathering system. The climate, topography, and vegetation influence the weathering through their control of the character and direction of movement of water through the alternation zone and determine whether the weathering system and drainage conditions are productive of kaolinite, halloysite, illite, or montmorillonite type of mineral or some less known secondary minerals (20).

The anomalous engineering behavior, including sensitivity to drying, of some laterite materials has been shown to depend on the predominant clay mineral composing the clay fraction and the unique granular structure of these materials (14, 22, 16, 13, 33).

It is now well known that the free iron oxide content and the state of alumino-ferruginous complexes in the soil seem to underlie the deviation of engineering behavior of laterite materials from the expectations of conventional soil mechanics as developed (in Europe and North America) for the temperate zone soils (34, 22, 30).

Grant and Aitchison (15) on the basis of their experiences in Australia have suggested a positive distinction between dehydrated laterite materials in which the iron has been fully immobilized to the ferric state and the hydrated ones in which at least some of the iron is still mobile. In the first case the soil is inert and should be subjected to standard soil index tests, and in the second case the material has a stabilization prop-

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erty and should be tested as such in order to reap the greatest benefit from this property. Serious engineering and construction problems may arise through failure to distinguish between hydrated and dehydrated laterite materials.

In Ghana the grading and plasticity limits as well as procedures for field compaction are based on the specifications (28) used for the selection and compaction of subbase, base, and special fill materials. These specifications have been used indiscriminately for both the highly dessicated dry savannah and the nondessicated wet forest soils. However, observations on the behavior of pavements with similar traffic patterns in the 2 climatic-vegetational zones have revealed different levels of performance. The use of uniform field-compaction procedures in the 2 zones could partly account for different pavement-behavior patterns.

In this study, an attempt has been made to assess the implications of different degrees of dessication of the dry savannah zone and wet forest zone soils in the laboratory evaluation of some index properties of those soils. It is hoped that this study will lead to a better appreciation of the effect of pretest preparations on the laboratory test results of some laterite materials and the field engineering implications of the sensitivity to pretreatment procedures.

SOME ENGINEERING SIGNIFICANCE OF TROPICAL SOIL GENESIS

Extensive literature available on the chemistry and mineralogy of the processes of primary and secondary (laterization) weathering has revealed that the genesis of residual laterite materials may be divided into 3 stages. The first stage (primary weathering) involves the partial or complete physical and chemical breakdown of the parent rock and the release of small primary particles and iron and alumina gels. The second stage (secondary weathering or laterization) involves partial or complete leaching of bases and combined silica and after that the coating or coagulation and impregnation or both of the residuals by iron and alumina gels. The level to which the second stage has been carried out depends to a large extent on the weathering system. Under certain conditions, the weathering processes may be so intense and may continue for so long that even the clay minerals, which are primary hydrous aluminum silicates, are destroyed in the continued weathering; the silica is leached, and the remainder consists merely of aluminum oxide, such as gibbsite, or of hydrous iron oxide, such as limonite or goethite derived from the iron.

The third stage involves partial or complete hardening either in situ or on exposure to air of the sesquioxide-impregnated materials due to dehydration of the hydroxides of the iron and aluminum. The free iron oxide is believed to play a major role in the hardening of the laterite materials. It is believed that the state of the sesquioxide gels, the free iron oxide, and the mineralogy considerably influence the engineering behavior of the laterite materials (34, 22, 12, 14, 32, 16, 31). One major result of the tropical weathering and laterization is the formation of a unique granular or concretionary (or both) structure of these materials. Alexander and Cady (2) have postulated that the development of the structure of laterite materials is due to the mechanism involving the migration and segregation of the major constituents, and they have identified several structure patterns. The gelatinous colloidal oxides of iron and alumina contribute to the formation of a concretionary soil structure by coating and coagulation or flocculation of the clay, silt, or sand particles and the subsequent dehydration of the coagulated material into clusters (modules) and stable aggregates (19). D'Hoore and Croegaert (9) have described "pseudosilt" and "pseudosand" formations in Congolese soils. Oxide-coated clay particles are bound by alumino-ferruginous binding agents or organic complexes or both to form stable aggregates of silt size, which in turn may be compounded to form particles of sand size. Millard (18) has also reported the structure of halloysitic red clays of central and east Africa and the engineering implications of this property during soil compaction.

Laboratory studies backed by field experience with laterite materials (13, 18) have revealed that with some soils the structure is persistent and with others it breaks down when the soil is worked. Such soils are difficult to classify by textural tests because their properties are changed by manipulation during testing.

Laterite materials formed over basic rocks and volcanic ash or in regions of continuously wet climate (rainfall of more than 60 in. per year) are characterized by high natural water content, high liquid limits, and high contents of gibbsite, halloysite, and allophane types of minerals that undergo irreversible changes on drying. Two factors that are related but different caused changes in the properties with drying: (a) the tendency to form aggregations on drying and (b) the loss of water in the hydrated minerals. The tendency to form aggregations was perhaps first described by Hirashima (16) and later, in more detail, by Terzaghi (32) for the red clays at the Sasumua Dam site in Kenya.

The aggregating effect of free iron oxide in the Sasumua clay was later demonstrated by Newill (22). Newill removed the iron chemically and found that the aggregations had been dispersed. This did not reform as had been the case after mechanical manipulation. The Atterberg limits were determined before and after chemically removing the free iron oxide, and the plasticity was found to increase considerably.

The unique structure of some laterite materials has led to difficulties in achieving adequate dispersion during grading and sedimentation tests. Consistent results of variations in the particle-size distribution with method of pretesting preparations have been widely reported. Drying causes the particle size to increase such that much of the clay-sized material becomes the size of silt (19).

Regarding the effect of pretreatment, it was found, for example, that using sodium oxalate as a dispersing agent on typical halloysite clay (in Kenya) gave 20 to 30 percent clay fraction and that using sodium hexametaphosphate gave 40 to 50 percent clay fraction with the same soil (23).

The liquid limit of a typical red clay from Kenya was found to vary with the mixing time required to break all the aggregations caused by free iron binding (30).

The effect of the iron oxide in binding smaller particles into larger ones is considered to account partly for the successful performance under tropical conditions of road bases having a silt and clay content considerably higher than that accepted by ASTM standards. Terzaghi (32) and Newill (22) attributed the properties of low compressibility, high permeability, and high angle of shearing resistance of the Sasumua clay (in Kenya) to the iron content that bound the clay minerals existing in the form of tube-shaped crystals into aggregations.

Millard (18) and Bhatia and Hammond (3) also showed that the strength of concretionary aggregates (hardness) correlates well with the amount of iron enrichment. The higher the iron content is, the higher the specific gravity is (21, 23). The low colloidal activities in laterite soils has also been attributed to the existence of considerable iron in these soils (10). Tateishi (31) and Brand et al. (5) have described variations in the values of maximum dry density tests, depending on whether the tests were performed after air-drying or without air-drying, by determining the points backward along the moisture-density curve as the soil dries. This was confirmed by Quinones (26) on a variety of materials from South America and laterized micaceous materials from Liberia. The clay minerals of tropical weathering profiles that are most susceptible to changes in properties with drying are allophane (12, 14), halloysite, especially hydrated halloysite (12, 29, 32, 22), and gibbsite (12). These minerals generally occur either over volcanic extrusives or at locations where the rainfall is more than 60 in. per year. In a recent lecture on the engineering implications of tropical weathering and laterization, Peck (25) emphasized that, when dealing with laterite soils sensitive to drying, the engineer may need to determine the index and engineering properties on the basis of tests run at natural moisture content and again at various degrees of air-drying in order to evaluate fully the range of properties associated with the physical conditions that may prevail on the job.

SCOPE OF STUDY AND GENERAL CHARACTERISTICS OF MATERIALS

The aim of the study reported here was to contribute to the standardization of laboratory test procedures for laterite materials. The object of a standardization study is to establish on the basis of existing standards and new tests a set of test procedures that take into account the inherently genetic characteristics resulting from the processes of tropical weathering and laterization and the different chemical and mineralogical contents formed in different environments. The application of such a system would involve the use of simple tests that yield reproducible results. Two approaches to this problem are readily obvious. The first one involves a long-term program of selection of physical properties indicative of engineering behavior of laterite materials and the establishment of suitable simple but reproducible tests for evaluating them. This approach seems more difficult and requires a lot of time. The second approach, which was adopted here, is to accept the standard laboratory tests as a basis for evaluating index properties and to select testing conditions that ensure reproducibility of the test results using these test procedures.

A major contribution to the study of laterite materials was perhaps an observation implying a reversible mobilization and immobilization of alumino-ferruginous complexes leading to the hardening and softening of laterite materials in oxidizing and reducing environments respectively (2). Moreover it seems that the state of the sesquioxides and in particular of the free iron oxide in laterite materials may underlie the anomalous engineering behavior of some laterite materials (32, 30, 22).

The study investigated the effects of drying, soaking, and kneading on the Atterberg limits of typical wet forest zone and dry savannah zone laterite materials; and the effect of drying and compaction procedures on the moisture-density curves of those materials. The nature and general characteristics based on pedological data of the soils studied are given in Table 1. The forest ochrosols (FO) and the savannah ochrosol-groundwater laterites (SO-GWL) cover more than 80 percent of the surface of Ghana and form the most important road-making materials in the wet forest and dry savannah zones of the country. A rough assessment of the degree of dessication (dehydration) in terms of average natural moisture contents (based on long laboratory experience) and field studies is suggested as follows:

1. Forest ochrosols are of low degree of dessication due mainly to the forest vegetation cover;
2. Surface (up to about 6 ft) materials in the savannah ochrosol and groundwater laterite areas are highly dessicated; and
3. Deeper (below 7 ft) materials in the savannah ochrosol-groundwater laterite areas are also of low degree of dessication.

SAMPLE PREPARATION AND TESTING PROCEDURES

The samples used in the Atterberg limit tests were subjected to the pretest treatment given in Table 2 .

The laboratory tests were carried out according to the specifications described in the British Standard 1377 of 1961. The British standard particle-size scale was adopted in the study. The samples were compacted according to the Ghana standard (samples are compacted in 5 layers in a CBR mold, each layer receiving 25 blows with a 10-lb hammer falling 18 in.). The soil types studied in the program are typical naturally occurring lateritic base (2FO, 1SO-GWL), subbase (1FO, 4FO, 2SO-GWL), and fill (3FO) materials in dry savannah and wet forest zones. The results of the identification, chemical composition, and loss-on-ignition tests on soil fractions (passing No. 200 British standard sieve) and the aggregate impact test results (British Standard 812) on gravel fraction are given in Table 3. The results of Atterberg limit tests on 24 samples from each site are given in Table 4; the data show that in terms of plasticity the wet forest zone soils as well as soils from a deeper layer in the dry savannah zone are similar. Materials from the shallow depth in the dry savannah zone (1SO-GWL) are less plastic than the rest probably because they have been highly dehydrated and dessicated in situ.

DISCUSSION OF TEST RESULTS

Effect of Preheating and Drying on Plasticity of Soils

The variation of Atterberg limits for the wet forest and dry savannah zone soils is given in Table 5 and shown in Figures 1 and 2. The wet forest zone soils (Fig. 1) are

Table 1. General characteristics of residual profiles studied.

Soil[a]	Climate[b]	Zone	Topography and Drainage	Parent Material	Nature of Weathering System	General Characteristics of Profiles
1FO 2FO 3FO 4FO	P = >50 in./year T = 70 to 89 F H = 83 percent E = P	Medium rain to semideciduous wet forest	Gentle undulating to strongly rolling; upland soils are well drained and highly leached	Intermediate to acidic rocks, peneplain drafts covering intermediate erosion surface and upland terrace alluvia	Acidic to neutral in residual profiles studied	High-level peneplain surfaces covered with aluminous (bauxitic) hardpans; clay fraction contains high proportion of sesquioxides and kaolinite; highly leached profiles; soils generally wet
1SO-GWL 2SO-GWL	P = 40 to 50 in./year T = 71 to 82 F H = 65 percent E > P	Deciduous woodland dry savanna	Undulating to very gently rolling; well drained over sandstones; drainage impeded over shales and mudstones	Sedimentary sandstones or sandstone-shale-mudstone deposits	Mainly acidic in residual profiles studied	Friable and porous materials over sandstone to clayey mottled materials over mudstone-shales; surface materials generally dry (dessicated); clay fraction rich in kaolinite and iron oxides

[a]FO = forest ochrosol, SO = savannah ochrosol, and GWL = groundwater laterite.
[b]P = precipitation, T = temperature, H = humidity, and E = evaporation.

Table 2. Pretest treatment of samples.

Test	Treatment	Code
Atterberg limit	Molded at natural moisture content	NMC
	Air dried, 4 days, 34 C	AD4
	Air dried, 4 days, and	
	Soaked 1 day	AD4 S1
	Soaked 2 days	AD4 S2
	Soaked 4 days	AD4 S4
	Soaked 7 days	AD4 S7
	Air dried, 4 days, and	
	Soaked 1 day and intermittently kneaded[a]	AD4 SK1
	Soaked 2 days and intermittently kneaded	AD4 SK2
	Soaked 4 days and intermittently kneaded	AD4 SK4
	Soaked 7 days and intermittently kneaded	AD4 SK7
	Air dried, 5 days	AD5
	Air dried, 5 days, and	
	Soaked 1 day	AD5 S1
	Soaked 2 days	AD5 S2
	Soaked 4 days	AD5 S4
	Soaked 7 days	AD5 S7
	Oven dried	
	6 hours, 50 C	OD6-50
	24 hours, 50 C	OD24-50
	6 hours, 100 C	OD6-100
	24 hours, 100 C	OD24-100
	Oven dried, 6 hours, 100 C and	
	Soaked 1 day and intermittently kneaded	OD6 SK1
	Soaked 2 days and intermittently kneaded	OD6 SK2
	Soaked 4 days and intermittently kneaded	OD6 SK4
	Soaked 7 days and intermittently kneaded	OD6 SK7
Compaction	Molded at natural moisture content with addition of water or subtraction by air drying	CT-NMC
	Air dried, 4 to 5 days, 30 C	CT-AD
	Oven dried, 24 hours, 105 to 110 C	CT-OD

[a]About 3-min with spatula.

Table 3. Index properties and chemical composition of soils.

Soil	Location of Profile	Grading: Gravel Size (percent)	Grading: Sand Size (percent)	Grading: Silt and Clay[a] (percent)	Plasticity[b] (percent): WL	Wp	Ip	Chem. Composition[a] (percent): SO_2	Al_2O_3	Fe_2O_3	Aggregate Impact Value[c] (percent)	Loss on Ignition[a] (percent)
1FO	Patasi Road	61	13	26	45	19	26	40.3	16	33.4	26.5	10
2FO	Barekese	70	9	21	31	15	16	56.2	7.7	19.4	27.9	7.0
3FO	Okodie Road	—	26.4	73.6	65	27	39	44.7	16.9	15.9	—	12.0
4FO	Kumasi-Bekwai Road	56	16	28	43	19	24	50.5	12.1	23.4	35	7.0
1SO-GWL	Tamale-Yapei Road	57	18	25	38	18	20	59	26.9	29.3	30 to 35	6.8
2SO-GWL	Tamale-Yapei Road	42	24	34	43	18	25	—	—	—	—	—

[a]Fraction passing No. 200 BS sieve. [b]Fraction passing No. 36 BS sieve. [c]British standard 812.

Table 4. Plasticity characteristics of soils.

Soil	Liquid Limit (percent)	Plastic Limit (percent)	Plasticity Index (percent)	Frequency (percent)
2FO	40 to 75	20 to 40	20 to 40	95
3FO	40 to 65	20 to 30	20 to 35	95
1SO-GWL[a]	40 to 50	20 to 30	20	95
2SO-GWL[b]	40 to 60	15 to 30	25 to 30	95

[a]0 to 6 ft. [b]7 to 9 ft.

Table 5. Effect of drying, soaking, and kneading on soil plasticity.

Soil	Treatment	Liquid Limit X_M	Liquid Limit X	Liquid Limit X_m	Liquid Limit σ	Plastic Limit X_M	Plastic Limit X	Plastic Limit X_m	Plastic Limit σ	Plasticity Index X_M	Plasticity Index X	Plasticity Index X_m
3FO	NMC	72	65.0	56.8	5.94	28.0	27.2	26.2	0.76	44.8	38.8	30.1
	AD4	68.0	62.9	57.0	4.8	29.3	27.8	25.8	1.46	38.7	38.5	31.2
	OD6-50	62.5	58.3	54.8	3.7	31.0	29.4	27.9	1.48	31.5	28.9	26.9
	OD24-50	62.3	58.5	53.6	3.68	32.2	28.5	25.3	2.87	31.2	30.0	28.3
	OD6-100	52.0	49.4	46.8	2.33	25.5	24.4	23.8	0.77	26.5	25.0	23.0
	OD24-100	48.5	46.0	43.2	2.26	27.1	25.9	25.0	0.92	21.4	20.1	17.8
	AD4 S1	68.7	64.4	59.5	3.86	28.6	24.6	21.0	4.01	42.4	39.8	36.9
	AD4 S2	70.7	66.8	61.2	4.09	29.5	26.4	22.5	3.04	46.5	40.4	33.5
	AD4 S4	71.0	65.5	61.5	4.04	29.0	25.9	22.5	2.76	44.1	40.5	36.4
	AD4 S7	69.7	64.8	60.5	4.11	30.0	25.6	24.5	2.92	39.7	39.2	36.0
	OD6 SK1	63.5	59.4	55.0	3.70	31.0	28.4	20.5	2.0	32.5	31.0	25.5
	OD6 SK2	69.7	65.0	62.8	3.24	32.5	29.2	26.2	3.03	37.5	36.4	34.3
	OD6 SK4	67.8	63.3	60.3	3.21	20.5	26.4	23.3	2.62	38.3	36.9	36.0
	OD6 SK7	72.2	67.5	62.9	4.28	30.0	27.2	25.0	2.14	42.2	40.3	36.7
	AD4 SK1	69.5	65.0	61.2	3.88	29.5	26.8	24.2	2.39	40.0	38.2	37.0
	AD4 SK2	70.7	65.5	62.5	3.48	31.3	28.8	26.1	2.36	39.4	36.7	34.7
	AD4 SK4	69.6	65.8	61.2	3.56	32.2	29.2	16.6	2.47	37.4	36.6	34.6
	AD4 SK7	70.5	66.5	63.0	3.24	33.0	30.2	26.6	2.7	37.5	36.3	35.1
4FO	NMC	64.7	61.6	56.4	3.75	31.4	28.2	25.3	2.51	35.5	33.4	31.1
	AD4	50.0	53.4	49.7	2.67	29.3	25.5	22.5	2.87	30.0	27.9	26.7
	OD6-50	56.4	54.4	51.9	1.89	31.3	26.2	23.0	3.55	29.4	28.2	25.1
	OD24-50	56.5	53.9	52.5	1.84	28.6	24.8	20.0	3.84	32.5	29.1	27.2
	OD6-100	47.5	44.4	40.5	2.9	27.2	23.6	19.3	3.32	25.3	20.8	15.7
	OD24-100	44.5	42.7	40.7	1.60	27.5	23.8	20.2	3.97	24.0	18.9	13.2
1SO-GWL	NMC	60.4	56.1	52.8	3.18	26.8	23.8	21.3	2.41	33.6	32.3	31.5
	AD5	53.0	49.1	43.5	4.0	22.5	20.2	16.3	2.7	30.5	28.9	27.2
	OD6-50	52.5	48.5	45.0	3.3	22.3	21.1	17.8	2.1	30.5	27.4	27.0
	OD6-24	50.0	47.5	45.6	2.24	22.2	20.6	18.0	2.27	27.8	26.9	25.4
	OD6-100	46.2	44.1	41.5	1.99	20.5	19.3	17.5	2.86	25.7	24.9	24.0
	OD24-100	46.2	44.2	42.5	1.86	20.8	19.2	17.5	1.65	25.4	25.0	24.7
	AD5 S1	59.9	57.7	55.6	1.81	24.9	24.0	22.8	0.95	37.1	33.7	31.9
	AD5 S2	61.7	60.0	58.8	1.36	22.6	21.3	20.9	1.04	41.6	38.7	37.4
	AD5 S4	62.3	60.5	59.2	1.31	23.4	22.1	20.6	1.15	40.0	38.4	37.9
	AD5 S7	62.4	61.2	59.9	1.08	32.2	22.2	21.0	1.0	39.8	39.0	38.2
2SO-GWL	NMC	48.5	45.7	42.5	2.49	25.7	23.2	18.5	3.24	24.0	22.5	21.5
	AD5	47.3	44.2	40.0	3.08	26.2	23.5	20.5	2.42	23.6	21.4	19.5
	OD6-50	47.3	44.4	42.5	2.0	28.0	25.9	21.8	1.9	20.1	18.5	19.8
	OD24-50	47.3	44.4	42.0	2.4	28.0	25.9	23.2	2.08	20.1	18.5	16.1
	OD6-100	45.3	43.4	41.9	1.45	28.2	26.2	24.8	1.48	18.8	17.2	17.1
	OD24-100	47.0	44.4	41.3	2.34	27.5	26.1	24.5	1.34	19.5	18.3	16.8

Note: X_M = maximum value; X_m = minimum value; X = mean value; and σ = standard deviation.

more sensitive to drying and heating than the highly dessicated dry savannah zone materials from shallow depths. Materials from a deeper layer in the dry savannah zone (Fig. 2) are also more sensitive to drying than those from shallow depths. Oven drying at 100 C for 6 hours or more reduces the dispersion of the test results considerably. The plastic limit seems to vary little with preheating and drying methods. Figure 3 shows the variation of average values of liquid and plastic limits for some of the samples. The variation of liquid limit is almost nil for the highly dessicated material.

Effect of Soaking of Samples on Atterberg Limits

Table 5 also gives typical results of statistical analyses of data on the effect of soaking on the plasticity of typical wet forest and dry savannah zone soils. The maximum and minimum plasticity values and also the means and standard deviation values of the effect of soaking on the air-dried samples are not significant for wet forest zone soils. The Atterberg limits vary between the same range, and the standard deviation values are almost the same for different periods of soaking. There is a definite increase for the dry savannah zone soil when soaked for the different periods.

Effect of Soaking and Kneading on Atterberg Limits

Air-dried soils from the wet forest zone are not affected much by soaking and kneading. Samples preheated to 100 C and then soaked and kneaded showed appreciable variation. The soaking and kneading led to the breakdown of the artificial aggregation produced during heating, and this increased plasticity. Table 5 gives the results of statistical analysis of test data for typical wet forest zone samples. The wet forest and dry savannah zone soils react differently to preheating and drying methods as revealed by the results of Atterberg limit tests.

Wet forest zone soils are fairly sensitive to preheating and drying probably because there is very little dehydration of these soils in the wet environment. Dry savannah zone materials from shallow depths are not affected much by the preheating and drying probably because these materials are highly dessicated in the field and, hence, most of the dehydration has already taken place in situ.

Soaking and kneading have very little effect on the air-dried materials but affect preheated materials considerably, for some degree of dehydration and aggregation has occurred during heating.

Effect of Preheating and Drying on Compaction Characteristics

The oven drying consistently gave highest maximum dry densities and lowest optimum moisture contents for both the wet forest and dry savannah zone soils. Figures 4 and 5 show the effect of using fresh and reused samples. Figure 5 shows that materials from the deeper layer in the dry savannah zone vary widely among compaction characteristics with different pretreatment methods. Soils from the shallow depth in the dry savannah zone (highly dessicated materials) show practically no difference in compaction test results obtained on oven-dried and undried soils. Failure to recognize the effective depth of highly dessicated topsoil may lead to serious disparities between specified and obtained field compaction results.

Effect of Compaction on Particle Breakdown

The effect of the level of compaction on the degree of breakdown of concretionary laterite gravel fractions was also investigated. This was to explain why reuse of samples during compaction gave in some cases lower and in other cases higher maximum dry densities with corresponding optimum moisture contents. When the breakdown of particles led to improvement in grading, higher maximum dry densities were noted; and when the breakdown of particles led to poorer grading, lower maximum dry densities were noted. It was also found that the weak concretionary gravels do break down considerably, and that confirmed the need for a criterion for selecting laterite gravels based not only on the grading and plasticity characteristics but also on the strength of the coarse aggregates (7).

Figure 1. Effect of drying on Atterberg limits of 3FO soils.

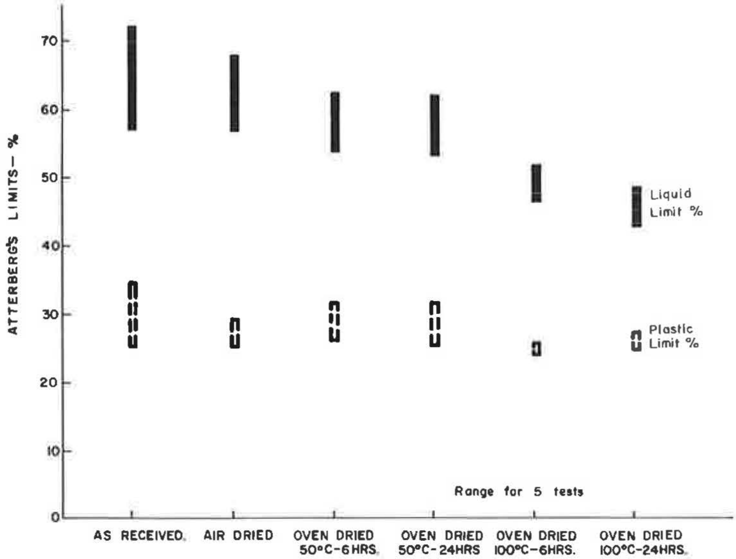


Figure 2. Effect of drying on Atterberg limits of 1SO-GWL and 2SO-GWL soils.

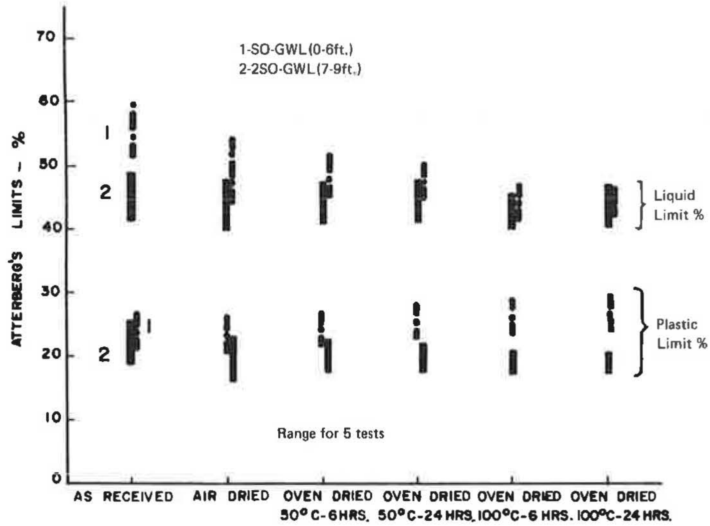


Figure 3. Effect of drying on mean Atterberg limits of 3FO, 4FO, 1SO-GWL, and 2SO-GWL soils.

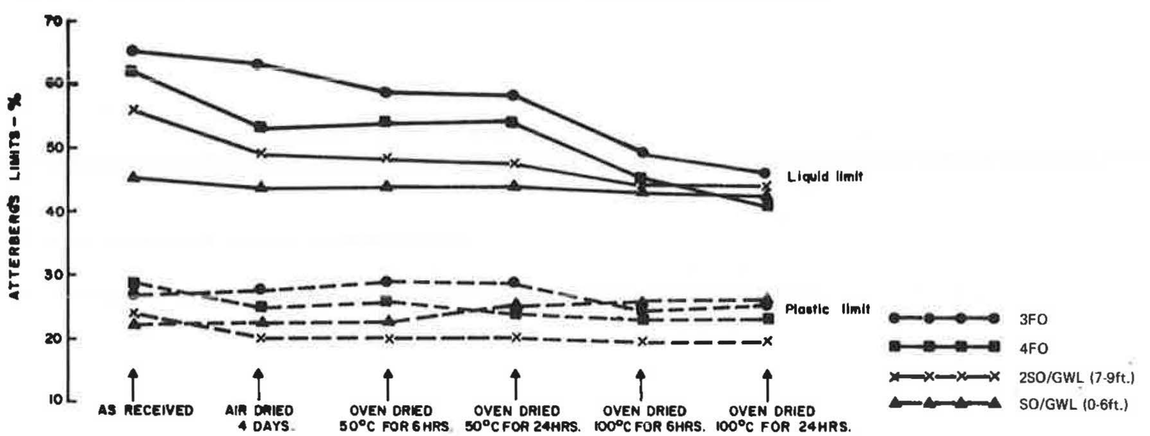


Figure 4. Moisture-density curves for 1FO, 2FO, and 3FO soils.

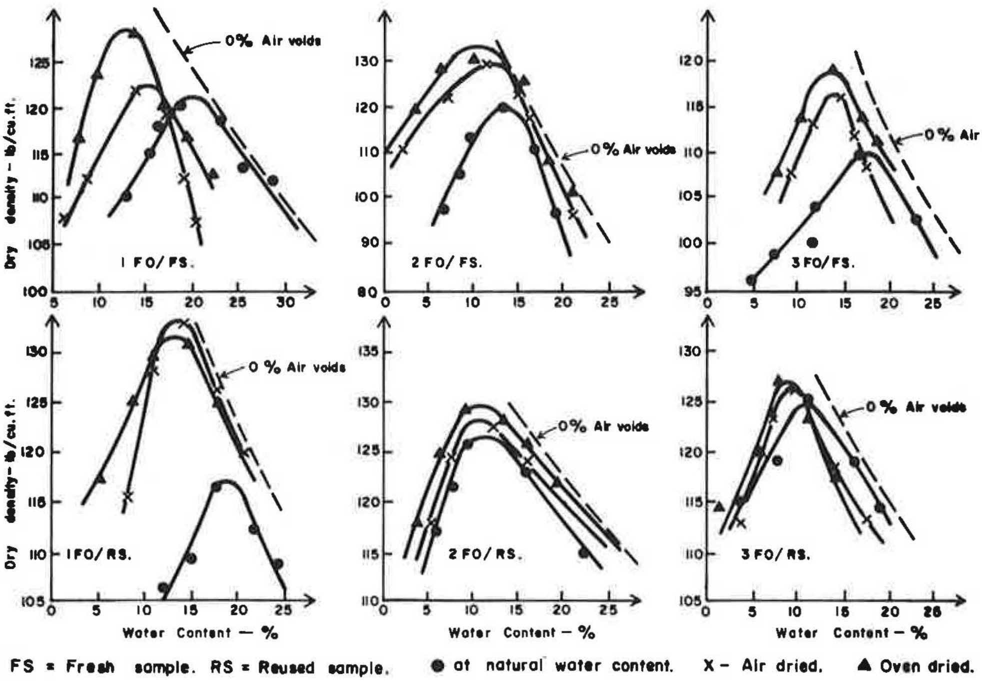
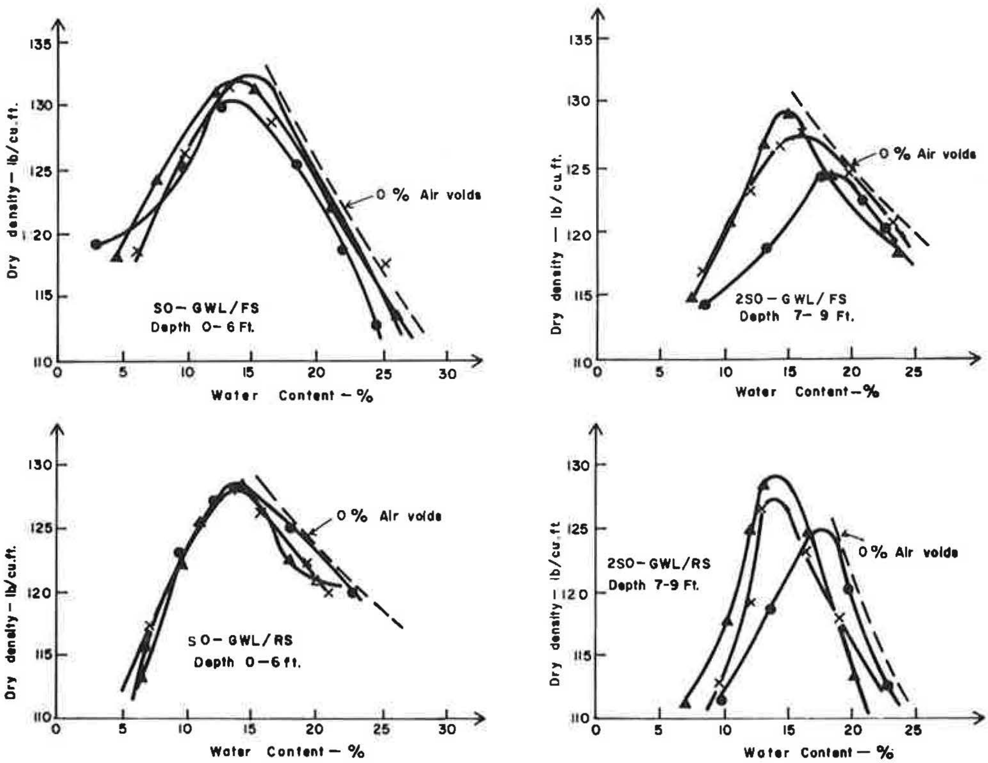


Figure 5. Moisture-density curves for 1SO-GWL and 2SO-GWL soils.



CONCLUSIONS

1. Highly dessicated shallow soils from the dry savannah zone react quite differently to heating and drying as well as to other pretesting preparation procedures than the less dessicated wet forest zone and deep dry savannah zone soils.

2. Although the less dessicated soils are highly affected by drying, the dessicated soils are not very much affected, as revealed by the variation of Atterberg limits with the preheating and drying methods.

3. The effect of soaking and kneading on Atterberg limits is very small in the case of air-dried wet forest soils and deep savannah zone soils. The difference in the effect of drying or preheating, soaking, and kneading on the Atterberg limits for the different soil types is attributed to the degree of in situ dehydration or dessication. The poorly dessicated soils are very sensitive to drying because of the relatively small in situ dehydration of the soils, and the highly dessicated (or dehydrated) soils are not very sensitive to drying. Because the dehydration (dessication) process seems to be associated with some degree of aggregation, the conclusions reached follow logically from the implications of the relation between dispersion and increase in liquid limit values.

4. With respect to moisture-density relations, it was found (as might be expected) that the oven-dried samples generally registered the highest maximum dry densities and corresponding lowest optimum moisture contents and that the soils compacted at natural moisture contents registered the lowest maximum dry densities and corresponding highest optimum moisture contents. The oven drying of samples before compaction is only of academic significance, but the relation between the oven-dried and natural moisture content compaction characteristics may be indicative of the degree of sensitivity to drying of a particular soil. Information like this will be useful for deciding the best laboratory test procedures to be adopted to simulate field moisture conditions likely to prevail on a job.

5. The reusing of samples during compaction led to either higher or lower maximum dry density with corresponding optimum moisture content depending on whether the breakdown of particles improved or worsened the grading curves. The degree of breakdown of gravel particles during compaction is a function of the strength of the aggregates, which may be assessed in terms of aggregate impact value or Los Angeles abrasion value.

6. The generalized approach to the evaluation and utilization of all laterite materials based on standard procedures can hardly be commendable. Each laterite material must be considered on its own merit. The degree of dessication or sensitivity or both to drying should be assessed vertically in the soil profile; and, after due consideration of genesis, mineralogical composition, and physicochemical processes that may occur when these materials are used in construction, tests should be designed that are appropriate to their nature.

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