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OBSERVATIONS OF MOISTURE CONTENTS AND DENSITIES OF SOIL TYPE BASES AND THEIR SUBGRADES

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SYNOPSIS

This paper is a report of a survey made in North Carolina during 1947 of the moisture contents and densities of soil type bases and their subgrades. The report describes the survey procedure and contains photographs showing the various operations. Charts are used to show the monthly fluctuations in moisture contents of the bases and subgrades expressed in terms of the standard optimum and plastic limit of the soils and in terms of the degree of saturation of the existing base and subgrade. The average relative densities of the bases are given and the influence the degree of relative density has upon the moisture absorbed is shown. The subgrades are divided into two types, granular type and silt-clay type, and their average relative densities given and the influence the degree of relative density has upon the moisture absorbed is also shown.

The data in this report reveal certain pertinent facts regarding the moisture soil bases and subgrades will contain under service conditions. Also, the relative densities the bases and the various types of subgrades develop under traffic is revealed. This information is very important to the designing engineer who must have or assume the moisture and density of a soil before determining its bearing value.

The amount of moisture a mass of soil contains is probably the most influential factor governing its stability. The use of soil type materials for base courses placed on soil subgrades has caused this fact to be of great concern to engineers engaged in pavement design. Many designing engineers assume that the soils composing the base courses and subgrades become saturated with moisture during service and base their designs on this assumption.

The degree of compaction required for base courses and subgrades, in order to prevent additional consolidation by traffic, is another problem with which engineers are concerned. Consolidation under traffic causes rough riding surfaces and often is the cause of failures in the surface courses. Also, it is believed by most engineers that since the degree of consolidation influences the amount of voids in soil masses, it also influences the amount of moisture these masses can absorb.

Realizing the importance of moisture content and degree of consolidation of soil type bases and subgrades, it was decided to conduct a survey in North Carolina to secure factual data on these factors. The survey was begun in January, 1947, and continued through December of that year. Twenty stations were selected representing some of the most common soils to be encountered in the Piedmont and upper Coastal Plain sections of the State. Monthly determinations of moisture content and field density were made of the base and subgrade at each station and samples were taken for the determination of:

(1) Mechanical Analysis
(2) Liquid Limit
(3) Plasticity Index
(4) Specific Gravity
(5) Standard AASHO Density and Optimum Moisture
(6) Modified AASHO Density and Optimum Moisture

Figure 1. Removing Thin Bituminous Surface Treatment Mat

The field work consisted of removing the thin bituminous surface treatment mat, which was from 1 to 2 in. thick, and making an in-place density test of the base. This was done by removing the base material for its full depth from a hole about 4 in. in diameter, and placing the material in an air-tight container. The volume of the hole was determined by the rubber balloon method. The moisture content and dry weight of the soil removed from the hole were determined in the laboratory. Also about 15 lb. of the base material adjacent to the hole was taken to the laboratory for tests. The base was then removed from the area, which was about 15 in. square, and the in-place density test was made of the subgrade to a depth of 6 in. A 15-lb. sample of the subgrade soil was taken for laboratory tests, and the hole carefully patched to prevent water from entering the adjacent base and subgrade.

Figure 2. Removing Base Material Containing Prime and Leveling the Area

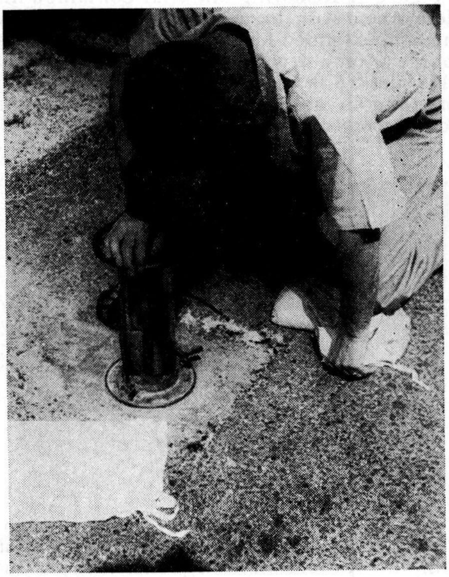


Figure 3. Taking "Zero" Reading with Rubber Balloon Density Apparatus

The openings were made on the right side of the pavement 24 to 30 in. from the edge, for the months of January, February, March, April, May, and June and on the left side at the same distance from the edge for the months of July, August, September, October, November, and December. This procedure allowed the whole road section to be included, and put the pavement openings in those portions of the pavement and subgrade subjected to the traffic wheel loads.

Figure 4. Removing Material Contained in a Hole About 4-in. in Diameter. The depth of the hole extended for the full depth of the base course or for a depth of 6 in. into the subgrade. This picture is of the subgrade. Material is placed in an air-tight container for determination of moisture in the laboratory.

Figure 5. Measuring Volume of the Hole with the Rubber Balloon Density Apparatus. This picture is of the subgrade.

This procedure was repeated during the first week in each month in 1947 at each of the 20 stations. Openings in the pavement were spaced 5 to 10 ft. apart in order to eliminate the possibility of moisture entering the patches made at previous openings.

Figures 1 through 10 are photographs showing the various steps of the field work. Figure 11 is a map of the State showing the location of the 20 stations where data were collected. The amount of traffic using the roads at the 20 stations is shown in Table 1.

Figure 6. Close-up of the Rubber Balloon Density Apparatus

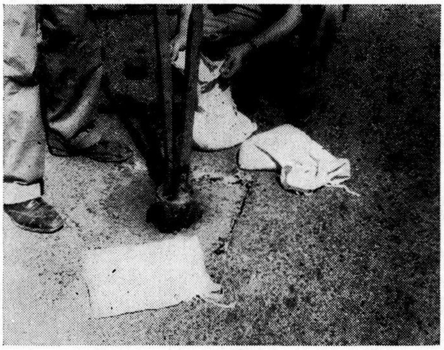


Figure 7. Taking 15-lb. Sample of Soil for Laboratory Tests. This picture shows sampling of the base material.

STUDY OF TEST DATA

Tables of the complete field and laboratory test data together with relations between road and laboratory densities, road and optimum moistures, road moistures and plastic limits of the soils, and road moistures and moistures for saturation of the bases and subgrades are available in the offices of the Highway Research Board and the North Carolina Highway and Public Works Commission.

Figure 8. Patching the Opening. This was carefully done to prevent infiltration of moisture. The top 4-in. of the patch consisted of cold-patch material.

Figure 9. Sealing the Patch with Cut-Back Asphalt

Base and Subgrade Soils

The soil type bases included in this survey are composed of well graded granular type soils belonging to the A-2-4 (O) and A-1-b (O) HRB Subgrade Groups. Their standard densities vary between 118.8 and 132.3 lb. per cu. ft., averaging 126.2 lb. per cu. ft.

Figure 10. Sand Spread Over Fresh Patch to Blot Any Excess of Bituminous Material

The subgrade soils encountered in the survey are quite varied; 70 percent of them are of the silt-clay type and 30 percent are of the granular type. They are listed in Table 2 which gives their occurrence expressed as a percentage of the total number, and their standard densities.

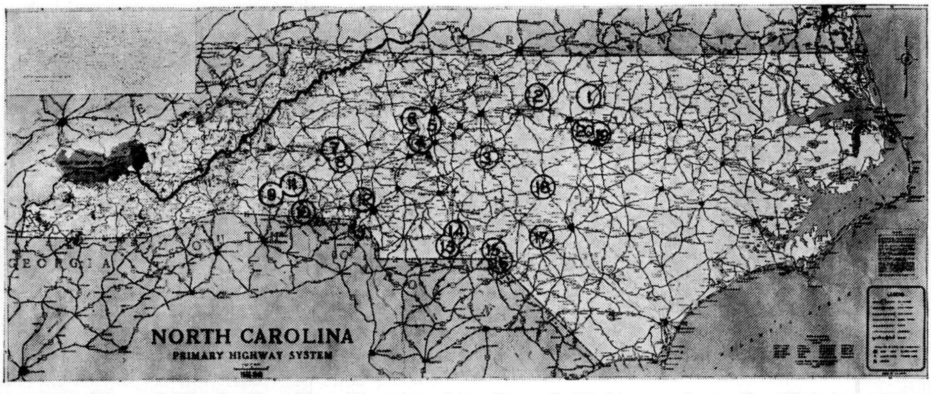


Figure 11. Map of North Carolina Showing Location of Stations where the Moisture-Density Observations were Made

Moisture Contents

It is realized that when the moisture contents of soils are expressed as percentages of their dry weights, their physical condition is not indicated. For instance, a clay soil may require 25 to 30 percent of moisture (optimum) in order that it may be compacted to a satisfactory density using a standard compactive effort. A sandy soil, on the other hand, would be saturated with about one-half of this amount of moisture. It is therefore necessary to consider the moisture contents of soils in relation with other moisture contents that express some known condition, such as the optimum moisture, the plastic limit, and the amount of moisture necessary to saturate the soil mass when consolidated.

TABLE 1

Station Number	Traffic Count	Relative Density Base	Station Number	Traffic Count	Relative Density Base
1	380	100.0	11	294	97.9
2	538	101.3	12	325	99.4
3	580	100.2	13	665	101.1
4	460	102.3	14	360	100.3
5	445	98.3	15	490	100.6
6	420	98.2	16	368	100.3
7	380	100.6	17	502	100.2
8	1300	102.4	18	610	105.1
9	970	100.4	19	480	98.9
10	568	100.1	20	420	101.8

TABLE 2

H R.B Subgrade Group	Occurrence Percentage of Total	Standard Density		
		Max.	Min.	Ave.
			lb. per cu. ft.	
A-7-5	31.3	111.3	96.2	104.1
A-7-6	10.8	116.6	105.3	109.4
A-6	10.0	116.3	108 3	113.4
A-5	5.8	114.4	105 0	107.8
A-4	12.1	121.1	113.5	116 1
A-2-6	1 7	120.5	117.0	119.2
A-2-4	28.3	127.0	118 0	121.8

Figure 12 shows graphically the amounts of moisture found to be present in the soil bases each month in the year. Curve A shows the moisture content expressed as a percentage of the standard optimum. In Curve B the moisture content is shown as a percentage of the plastic limit (liquid limit for non plastic soils). Curve C shows the percentage the compacted base is saturated when it contains the moisture found in the soil. It will be noted that the average moisture content is 73.6 percent of the standard optimum, 41.4 percent of the plastic limit, and that the base is 60.9 percent saturated with this average moisture content. It will also be noted that the moisture content of the bases is highest during April when it is 82.9 percent of the standard optimum, 47.4 percent of the plastic limit, and 71.5 percent of saturation.

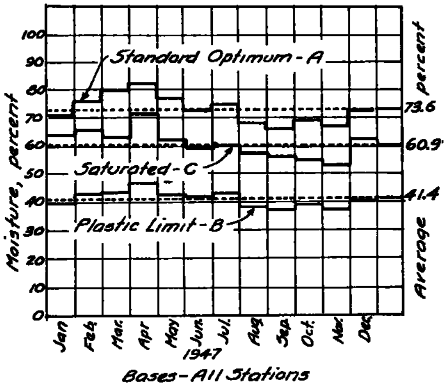


Figure 12

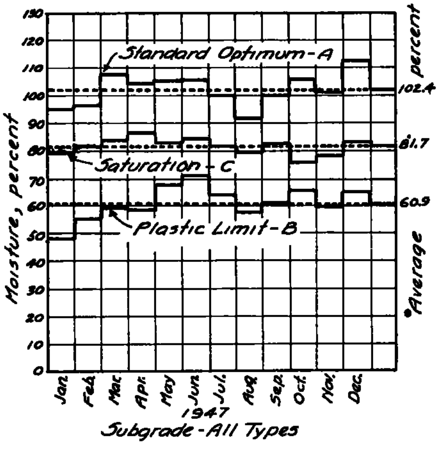
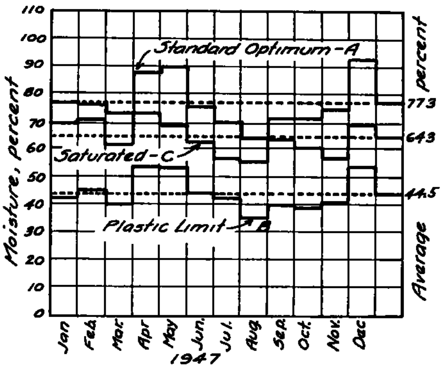


Figure 13

Figure 13 shows graphically the amounts of moisture found to be present in the subgrades at the 20 stations, which consist of 70 percent silt-clay soils and 30 percent granular soils. It will be noted that their average moisture content is 102.4 percent of the standard optimum, as shown in Curve A, 60.9 percent of the plastic limit as shown in Curve B, and 81.7 percent of saturation as shown in Curve C. High moisture contents are indicated for March, April, May, and June in Curve A, when they range from 104.4 to 107.9 percent of the standard optimum. A high moisture content of 113.1 percent of standard optimum was found to be present in December and a moisture content of 106.3 percent of standard optimum in October. In Curve B high moisture contents are indicated for May, June, and July when they reach 67.4, 71.0, and 64.0 percent of the plastic limit, respectively. As was shown in the standard optimum chart, high moisture contents are shown in Curve B for October and December when they reach 65.6 and 65.2 percent of the plastic limit, respectively. The average moisture content for the year is 60.9 percent of the plastic limit. Curve C shows the moisture contents expressed as percentages of the moisture necessary for saturation. It will be noted that the average moisture content for the year is 81.7 percent of saturation. Although the fluctuation in moisture content from month to month does not appear large as shown in this chart, high moisture contents are shown to exist during March, April, May, and June when they reach 84.0, 86.7, 82.9, and 84.4 percent of saturation, respectively.

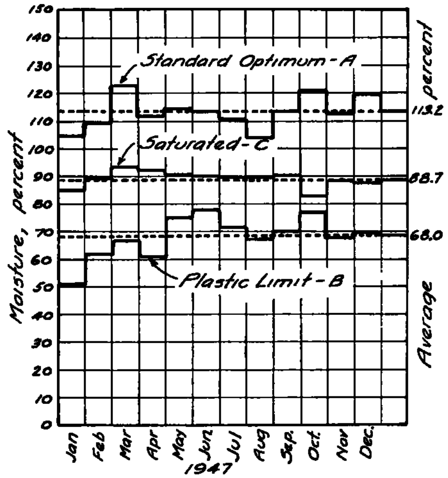


Granular Subgrade Materials

Figure 14

Figure 13 includes all of the subgrades of which 70 percent are of the silt-clay type and 30 percent of the granular type. Realizing that these charts show only a trend in moisture fluctuations and do not give quantitative data that could be used in design or stability determinations, the subgrades were separated into these two groups and charts made as before showing the moisture contents in terms of the standard optimum, the plastic limit, and amount of moisture necessary to saturate the mass in its existing condition. The separation was made in accordance with the HRB Subgrade Classification method in which soils below the A-4 group are classed as granular soils and soils including and above this group classed as silt-clay soils.

Figure 14 shows the monthly moisture contents found in the granular type subgrades expressed as percentages of the standard optimum, the plastic limit, and saturation moisture. It will be noted in Curve A that the average moisture content for the year is 77.3 percent of the standard optimum and that the highest moisture content was found to occur during April, May, and December when they reached 88.0, 90.0, and 93.2 percent of the standard optimum, respectively. Curve B shows the average moisture content for the year to be 44.5 percent of the plastic limit with the highest moisture contents occurring, also, in April, May, and December when they reach 53.4, 53.1, and 54.3 percent, respectively. The average moisture content for the year causes the granular type subgrades to become 64.3 percent saturated, according to Curve C. Greater saturation was reached January, February, April, May, and December when the subgrades were 69.2, 70.8, 73.3, 68.3, and 69.2 percent saturated.



Silt-Clay Subgrade Materials

Figure 15

Charts showing the moisture contents found in subgrades composed of silt-clay materials are designated as Curves A, B and C in Figure 15 with the moisture contents expressed in terms of the standard optimum the plastic limit, and saturation moisture. The average moisture content for the year is 113.2 percent of the standard optimum, 68.0 percent of the plastic limit, and 88.7 percent of saturation. High percentages of the standard optimum are shown for March, October, and December by Curve A. During these months, the moisture content reached 122.7, 121.0, and 119.8 percent of the standard optimum, respectively. When expressed in terms of the plastic limit, according to Curve B, high percentages of the plastic limit occur during May, June, July, September, and October with values of 75.1, 77.5, 71.1, 69.9, and 76.9 percent, respectively. Curve C shows the moisture contents found in the silt-clay type soils expressed in terms of the amount of moisture sufficient to cause saturation of the subgrade, and gives percentage values above the average from March through September, ranging from 89.8 percent for August to a peak of 93.5 percent for March.

Densities of Bases and Subgrades

Soil type bases and subgrades are compacted under the action of traffic until a definite degree of consolidation is reached to suit the compactive effort exerted, unless they have been compacted to at least this degree of consolidation during their construction. Heavy vehicles will cause higher degrees of consolidation than light vehicles, and a large volume of traffic will cause consolidation equilibrium quicker than a small volume of traffic. Table 3 shows the average relative road densities found in this survey of the bases and the two types of subgrades. The average relative densities are shown as percentages of the standard density and modified density of the soils. Table 1 shows the traffic count at each of the 20 stations and the relative densities of their bases. The relative densities shown in this table are percentages of the standard densities of the soils.

It will be noted in Table 3 that the average relative density of the bases included in the survey is 100.5 percent of the standard density and 96.5 percent of the modified density. In Table 1 the relative density (standard) of the base at each station is given, and it will be noted that the minimum relative density is 97.9 and the maximum is 105.1. Either of these two values is close to the average relative density of 100.5 given in Table 3, which indicates that traffic of the weight and volume using this type of road will produce neglegible consolidation of bases that are compacted to 100 percent of their standard densities.

Table 3 also shows the average relative standard density and modified density of granular type subgrades to be 101.2 and 96.7, respectively, which are practically the same values as shown for the bases. Since the base materials are granular, it is reasonable that this should be the case. These values also indicate that granular type subgrades, compacted to 100 percent of their standard densities, will receive little or no consolidation by traffic of the weight using this type of road.

TABLE 3

AVERAGE RELATIVE ROAD DENSITIES

	Standard Density	Modified Density
	%	%
Bases	100.5	96.5
Granular Subgrades	101.2	96.7
Silt-Clay Subgrades	96.8	88.8

TABLE 4

BASES

INFLUENCE OF COMPACTION ON ROAD MOISTURE

Relative Densities Under 100 Percent

Average Relative Density	Standard Optimum	Plastic Limit	Saturated
%	%	%	%
98.5	75.0	43.8	60.3

Relative Densities 100 Percent and Above

Average Relative Density	Standard Optimum	Plastic Limit	Saturated
%	%	%	%
101.1	73.1	40.6	61.1

The average relative standard density and modified density of silt-clay type subgrades are 96.8 and 88.8, respectively, as shown in Table 3. These lower values are to be expected since silt-clay type soils are more difficult to compact to high relative densities than granular type soils. Also, it is probable that silt-clay type subgrades swell slightly due to the moisture they absorb in service. The relative standard density of 96.8 indicates that silt-clay type subgrades should be compacted to at least 97 percent of their standard densities in order not to be appreciably consolidated by traffic.

It is logical that the fewer voids a soil mass has, the less moisture it will absorb when exposed to a sufficient amount of moisture to saturate the mass. It is assumed that complete inundation of the mass is required for saturation. But, does the degree of compaction of a soil mass affect the amount of moisture the mass will absorb when exposed to less moisture than required to saturate it? In an attempt to answer this question, Tables 4, 5, and 6 were compiled. In these the average road moistures of the bases and the two types of subgrades are given as percentages of the standard optimum, plastic limit, and saturation for relative densities under 100 percent and for relative densities 100 percent and above. It will be noted in Table 4, for bases, that the relative density does have some affect on the moisture contents when expressed as percentages of the standard optimum and plastic limit, but not when expressed in terms of the saturation moisture. In Table 5, covering granular type subgrades, the affect is more pronounced, even when the moisture contents are expressed as percentages of saturation. Table 6, covering silt-clay subgrades, also shows the same affect when the moisture contents are expressed as percentages of the standard optimum and plastic limit, but as in the case of the bases, no appreciable affect is shown when the moisture contents are expressed as percentages of saturation.

TABLE 5
SUBGRADE
(Granular Material)
INFLUENCE OF COMPACTION ON ROAD MOISTURE

Relative Densities Under 100 Percent

Average Relative Density	Standard Optimum	Plastic Limit	Saturated
%	%	%	%
98.1	85.1	46.9	67.2

Relative Densities 100 Percent and Above

Average Relative Density	Standard Optimum	Plastic Limit	Saturated
%	%	%	%
103.9	70.5	42.3	61.8

TABLE 6
SUBGRADE
(Silt-Clay Material)
INFLUENCE OF COMPACTION ON ROAD MOISTURE

Relative Densities Under 100 Percent

Average Relative Density	Standard Optimum	Plastic Limit	Saturated
%	%	%	%
95.7	117.0	68.9	89.2

Relative Densities 100 Percent and Above

Average Relative Density	Standard Optimum	Plastic Limit	Saturated
%	%	%	%
100.9	99.4	64.4	89.0

CONCLUSIONS AND RECOMMENDATIONS

The data obtained in this survey reveal several important facts, knowledge of which should be of benefit to maintenance, construction, and designing engineers in North Carolina. The time of the year when the moisture contents of soil bases and subgrades are high or low is revealed in the moisture—month charts. This information is important in that it informs the engineers when to restrict traffic loads and when to reinforce detour roads. Information on the average amount of moisture various types of soils will absorb in service is available and the relative densities of the bases and the two types of subgrades assume under traffic are given. This information is desired by the designing engineer who must know or assume the moisture contents of bases and subgrades when he prepares sections of them for load tests or other strength tests. The relative densities assumed by bases and subgrades is important information for the construction engineer who must decide the amount of compaction to require in the construction of them.

Fluctuations in Moisture Content—Bases

It will be noted in Figure 12 that, in general, high moisture contents are to be expected in bases from January through May. During June, July, and December they are at about average, while during August, September, October, and November they are below the average. The maximum moisture content occurs in the month of April when it reaches 82.9 percent of the standard optimum, 47.4 percent of the plastic limit, and 71.5 percent of saturation. The average moisture content for the year is 73.6 percent of the standard optimum, 41.4 percent of the plastic limit, and 60.9 percent of saturation. The writer favors the use of the moisture-standard optimum relationship and recommends that bases be tested with moisture contents equal to 75 percent of their standard optimum. This figure is slightly below the maximum and slightly above the average found to be present in bases in service in North Carolina.

TABLE 7
AVERAGE MOISTURE CONTENTS FOUND IN THE SUBGRADE GROUPS

H.R.B. Subgrade Group	Standard Optimum	Plastic Limit	Saturated
	%	%	%
A-1-b	82.5	36.4	69.0
A-2-4	75.5	43.7	62.9
A-2-6	104.3	62.3	85.3
A-4	106.1	65.0	82.6
A-5	114.7	54.0	89.8
A-6	109.1	75.2	85.4
A-7-5	118.9	68.2	91.2
A-7-6	109.4	70.9	90.9

Fluctuations in Moisture Content—Granular Type Subgrades

According to Figure 14, high moisture contents, in general, may be expected in granular type subgrades from January through May. While there are some fluctuations shown on the charts, the trend is for high moisture contents during this period. High moisture contents are to be expected, also, during December, according to the charts. The average moisture content for the year is 77.3 percent of the standard optimum, 44.5 percent of the plastic limit, and 64.3 percent of saturation. It will be noted that these values are slightly higher than those for the bases, which is probably due to the fact that the base materials are better graded. When the moisture contents are expressed in terms of the standard optimum, the highest value, 93.2 percent, is obtained for December; when expressed in terms of the plastic limit, the highest value, 54.3 percent, is obtained for December also; but when expressed in terms of saturation the highest value, 73.3 percent is obtained for April. On the strength of these data, the writer recommends a moisture content equal to 85 percent of the standard optimum of the soil when preparing granular type subgrade materials for load tests. It will be noted that this value is an average of the average moisture for the year and the highest for December shown on the standard optimum chart.

Fluctuations in Moisture Content—Silt-Clay Subgrades

The fluctuation of moisture in silt-clay type subgrades seems to follow a slightly different pattern from bases and granular type subgrades according to Figure 15. When the moisture contents are expressed in terms of the standard optimum, the highest values are obtained for March, October, and December. For April, May, June, September, and November, the values are about the same as the average for the year. The highest value, 122.7 percent of the standard optimum, is obtained for March, and the average for the year is 113.2 percent of the standard optimum. When the moisture contents are expressed as percentages of the plastic limit, the highest values are obtained for May, June, and October with the highest being 77.5 percent for June. The average for the year expressed in terms of the plastic limit is 68.0 percent. When expressed in terms of saturation, the moisture contents give high values for a period from March through September, the highest value, 93.5 percent, is obtained for March. The average for the year is 88.7 percent of saturation.

TABLE 8

H.R.B. Subgrade Group	Standard Optimum %
A-4	110
A-5	115
A-6	110
A-7-5	120
A-7-6	110

In Table 7 all subgrade soils are separated into the subgrade groups and the average moisture contents found in each group are expressed as percentages of the standard optimum, plastic limit, and saturation. Since the silt-clay subgrade soils embrace five of the groups and their characteristics are quite diversified, it is reasonable to expect that the moisture contents they would carry in service would be different. Such is the case, as is seen in this table. Therefore, the moisture contents recommended for these soils when they are prepared for load testing differ. The recommended moisture contents are given in Table 8.

Recommended Relative Densities for Bases and Subgrades

As stated in the discussion of Table 3, bases and granular type subgrades should be compacted to 100 percent of their standard densities. In this same discussion it was stated that silt-clay subgrades should be compacted to 97 percent of their standard densities. These same relative densities should be used when bases and subgrades are prepared for load testing.

OTHER SURVEYS ARE RECOMMENDED

While one survey of this type is of great value, other surveys will enhance this value as they will increase the data and cover more area. The more data available for study, the more accurate and dependable the results, and the greater the area covered, the more useful the data will be. It is believed that surveys of this type will solve two of the major problems confronting engineers today, the relative densities to which soils should be compacted and the moistures they will absorb in service.

DISCUSSION

Dr. Miles S. Kersten, *University of Minnesota:* It is enlightening to compare some of the North Carolina results with those of other investigations, namely a survey of subgrade moisture conditions in highway subgrades, largely in the Midwest[1]; a study of moisture conditions beneath airport pavements[2]; and an extensive study of conditions beneath flexible pavements in Minnesota[3].

The results reported by Mr. Hicks are of particular value because they were obtained in a well-planned systematic program; such results merit more consideration than averages of spasmodic sampling by a variety of methods and variable completeness of accompanying soils test data. The method of presentation of moisture contents used, i.e., percentage of plastic limit, percentage of optimum moisture content, and percentage of saturation are those suggested in the study sponsored by the Highway Research Board in 1944 and it seems these are the most logical available.

The seasonal variations shown by the North Carolina data indicate in general a high point in the late winter or spring, or from January to May, and ordinarily the low point in late summer or fall. A study by the discusser of data from Illinois and Texas indicated the highest moistures in March and the lowest in October. Moisture conditions are apparently highly dependent upon the temperature cycle as well as the distribution of precipitation.

Mr. Hicks reports that many subgrade soils exist at moisture contents greater than their optimum. This fact has apparently led to a change in their condition for design since in 1947[4] it was reported that tests for design of flexible pavements were made at the optimum moisture content. The findings are in agreement with the 1944[1] report of the discusser wherein it was stated "The optimum moisture contents of the soils were exceeded by the field moisture in about a third of the determinations reported. Clay soils exceeded the constant most commonly but soils of all textures, including the sandy loams, have moistures greater than this value in a substantial proportion of tests." There may be some question, however, of the refinement which Mr. Hicks has introduced into his table of recommended moisture contents, wherein values of 110, 115, and 120 percent of the standard optimum are suggested. I believe only one value, perhaps 115 percent, would suffice for all soil groups from A-4 to A-7.

The findings in regard to density compare very closely with those reported by Swanberg and Hansen[3]. In Minnesota subgrade soil densities at a large number of test points averaged slightly over 97 percent of the standard maximum. This compares favorably with

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[1] Miles S. Kersten, "Survey of Subgrade Conditions," *Proceedings*, Highway Research Board, Vol. 24, p. 497 (1944).

[2] Miles S. Kersten, "Subgrade Moisture Conditions Beneath Airport Pavements," *Proceedings*, Highway Research Board, Vol. 25, p. 450 (1945).

[3] J. H. Swanberg and C. C. Hansen, "Development of a Procedure for the Design of Flexible Bases," *Proceedings*, Highway Research Board, Vol. 26, p. 44 (1946).

[4] L. D. Hicks, "Current Base Design Practices in North Carolina," *Proceedings*, Highway Research Board, Vol. 26, p. 58 (1946).

Mr. Hicks values of 96.7 and 101.2 percent for the silt and clay and granular type subgrades, respectively. With regards to bases, Swanberg and Hansen state "Densities of stabilized gravel bases in general were about at AASHO maximum . . ." which agrees with Hicks' value of close to 100 percent.

Table 26, which shows the progressive increase of the moisture content of subgrades with a change to soil groups of finer texture is very significant. Similar trends were shown for airfield subgrade data in Table 3 of an aforementioned paper[2], as well as for highway subgrades in Tables 4, 6, and 8 of the 1944 report[1]. This fairly well established variation of moisture content according to soil textural classes or classification groups should be of particular use in establishing conditions for pavement design tests.

It is hoped that Mr. Hicks' report does not signify the end of this investigation. A series of continued tests, separated by greater time intervals than those of the intensive program, would undoubtedly yield further valuable findings.

Mr. W. H. Campen, *Omaha Testing Laboratories:* The results reported by Mr. Hicks are very encouraging and confirm the contention of some of us who have been claiming for years that highly densified soils or mixtures will not take up any more water than their voids content predetermine. According to Mr. Hicks the densities of the bases and subgrades, at the time of construction, are not known. However, judging from the present values, they must have been high.

On the average the bases have a density of about 100 percent of the maximum and a moisture content of about 75 percent of the optimum. He therefore suggests that laboratory load bearing tests be made at these conditions. I cannot agree with him because in my opinion the results will be too optimistic.

While it is true, from his data, that the base samples contained only 75 percent of their optimum water contents, there is no fundamental reason why this should be so. The ultimate moisture content, assuming no swelling, is governed by the voids content and is almost equal to that required for saturation. For this reason we had better assume that the moisture content may reach optimum and design accordingly.

In the near future the committee on Flexible Design, A. C. Benkelman, Chairman, is going to send out an outline of needed research in which the participants will be asked to obtain data on a number of factors pertaining to design of flexible pavements. One of the factors deals with the stability of densified layers and will include data obtained during construction as well as thereafter.