EFFECT OF RE-USING SOIL ON MOISTURE-DENSITY CURVES

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SYNOPSIS

The standard compaction test (AASHO Designation T 99-38) requires compaction of a sample of soil at different water contents to determine the moisture-density relationship. In order to do this the same portion of soil is re-used several times in one test. Comparison of the results of tests made by the standard procedure with the results of tests in which the procedure is modified by using a fresh sample of soil for each point on the curve shows that the standard procedure gives higher maximum densities.

The difference in maximum densities by the two procedures has been found to be from one to four lb. per cu. ft. This is significant, since densities specified for fill construction are often expressed as percentages of the "maximum" density obtained by using a specified number of blows with a particular type of hammer, without specifying whether or not the same portion of soil is to be used throughout the test. It is probable that the use of separate portions of soil for each point on the moisture density curve more closely represents field conditions, but this procedure in some cases is slower and requires a larger sample than the standard method. Where dependable moisture-density curves are required, the method of separate points is more reliable and possibly should be adopted.

Late in 1948 the authors were requested by a contractor to investigate his inability to secure the specified densities in a large earth fill. The fill was being placed at the optimum moisture, but in spite of rolling and rerolling, the densities were too low. The contractor suspected that the moisture-density curves that had been determined before the work began were not representative of the soil he was using, but the authors' tests confirmed the original tests. Samples were then taken of the fill as it was placed prior to rolling, and these samples were compacted in compaction cylinders using the same hammer and number of layers as were used in making the moisture-density curves. Although these samples were at the optimum moisture, their densities when compacted were about 4 pcf. less than the corresponding densities as shown by the curves.

New moisture-density curves were prepared using fresh portions of soil for each point on the curves instead of reusing the same portion as is specified by the standard method. The maximum densities of the new curves were about 4 pcf. lower than those of the original curves, and they were the same as the compacted densities of the samples made from the fill soil being placed.

It has long been suspected that there is a difference between moisture-density curves prepared by the standard procedure of re-using the same portion over and over again, and curves prepared by using separate fresh portions of soil for each point on the curve. In his lectures at the Graduate School of Engineering at Harvard, Dr. Casagrande has pointed out the desirability of using separate portions for each point, because the continual re-working of a soil can change its characteristics. The authors have encountered difficulties in compacting fresh portions of soil for studies of compacted shear strength so that the soil will meet specified requirements for moisture and density as shown by the moisture-density curves. Invariably, the densities of the fresh portions were less than those indicated by the curves. As a result, the authors prepare moisture density curves that are to be used for special purposes by using fresh portions of soil for each point on the curves.

LABORATORY INVESTIGATION

The investigation herein reported was undertaken at the suggestion of Mr. W. H. Mills, District Engineer for the Asphalt Institute, and Mr. L. D. Hicks, Chief Soils Engineer of the North Carolina State Highway and

Public Works Commission. The purpose was to determine the magnitude of the difference between the maximum density determined by the standard method and that determined by using fresh portions of soil for each point on the curve.

Sixty-pound samples of representative types of soils were secured especially for this project. Each sample was prepared as specified by the standard method (TM 99-38) by air drying, pulverizing all lumps, and passing through a No. 4 sieve. Each sample was divided into eight identical 6-lb. portions, and the remainder was used for determining the grain size and the liquid and plastic limits.

The first portion was compacted according

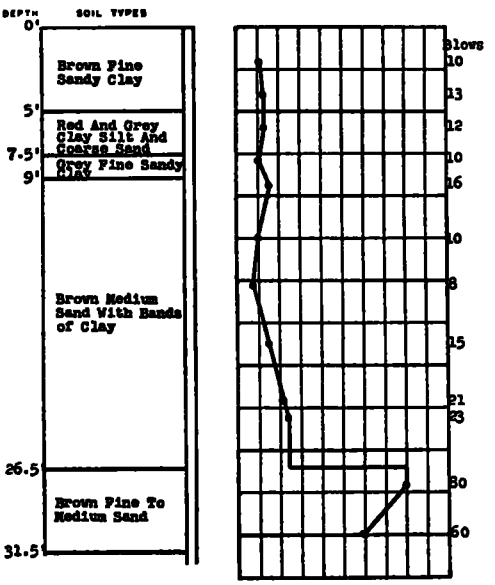

Figure 1. Test Boring Record—Boring A-4—The chart at the right shows the number of blows of the 140-lb. hammer falling 30 in. necessary to drive the 1.5-in. sample tube one ft.

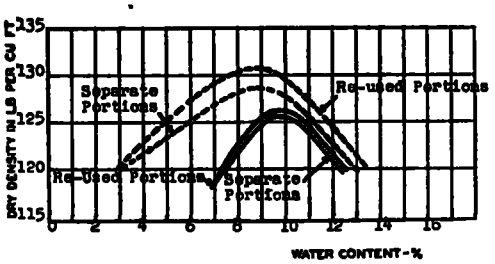

Figure 2. Sample 1

Solid lines—Standard AASHO Method (5.5-lb. hammer, 3 layers).
Dashed lines—Modified AASHO Method (10-lb. hammer, 5 layers).
Classification A-2-4 (1).

Percentage Passing No. 40 Sieve—72
Percentage Passing No. 200 Sieve—35
Liquid Limit —19
Plasticity Index — 0

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	126	9.7
Std. Meth.—Separate	125	9.7
Mod. Meth.—Re-used	131	8.8
Mod. Meth.—Separate	128	8.8

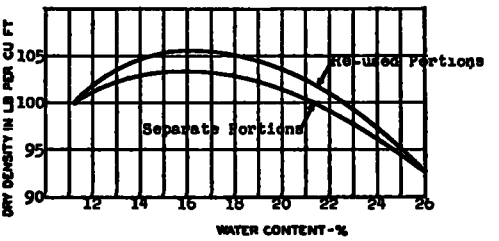

Figure 3. Sample 5

Standard AASHO Method (5.5-lb. hammer, 3 layers).
Classification A-5 (1).

Percentage Passing No. 40 Sieve—85
Percentage Passing No. 200 Sieve—41
Liquid Limit —44
Plasticity Index — 0

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	106	16
Std. Meth.—Separate	103	16

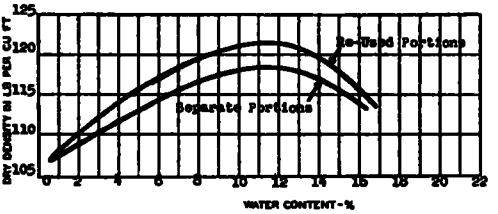

Figure 4. Sample 6

Standard AASHO Method (5.5-lb. hammer, 3 layers).
Class A-4-(1).

Percentage Passing No. 40 Sieve—78
Percentage Passing No. 200 Sieve—41
Liquid Limit —30
Plasticity Index — 0

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	122	11.5
Std. Meth.—Separate	118	11.5

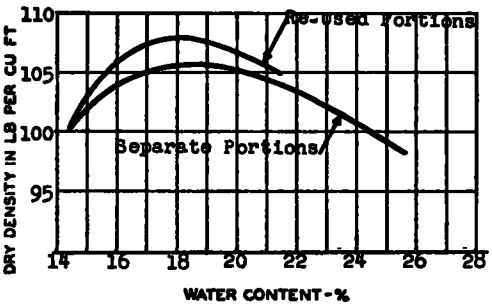

Figure 5. Sample 7

Standard AASHO Method (5.5-lb. hammer, 3 layers).
Classification A-6 (16).

Percentage Passing No. 40 Sieve—94
Percentage Passing No. 200 Sieve—76
Liquid Limit —40
Plasticity Index —12

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	108	18
Std. Meth.—Separate	106	18.8

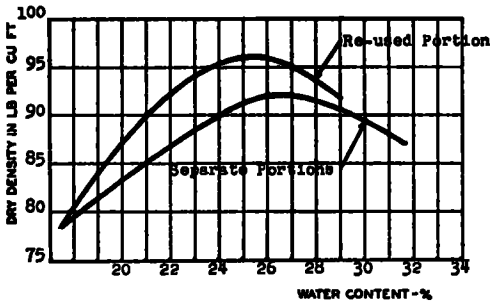

Figure 6. Sample 9

Standard AASHO Method (5.5-lb. hammer, 3 layers).
Classification A-7-5 (19).

Percentage Passing No. 40 Sieve—95
Percentage Passing No. 200 Sieve—83
Liquid Limit —67
Plasticity Index —27

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	96	25.5
Std. Meth.—Separate	92	26.7

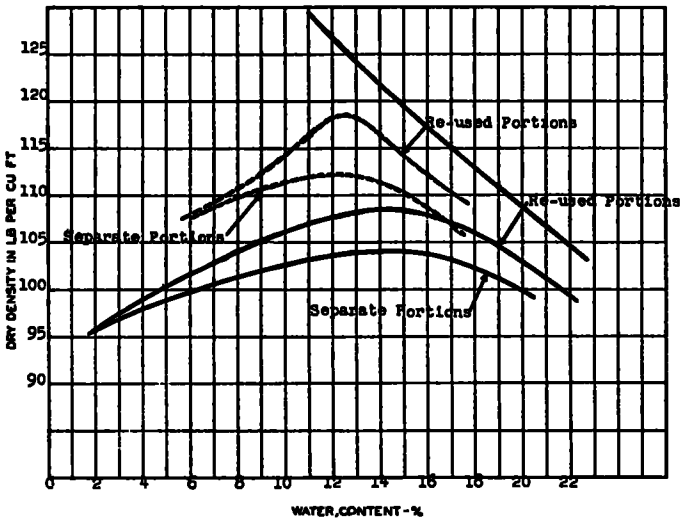

Figure 7. Sample 11

Solid line—Standard AASHO Method (5.5-lb. hammer, 3 layers)
Dashed line—Modified AASHO Method (10-lb. hammer, 5 layers)
Classification A-3 (0)

Percentage Passing No. 40 Sieve—86
Percentage Passing No. 200 Sieve—12
Non plastic

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	108	14.5
Std. Meth.—Separate	104	14.5
Mod. Meth.—Re-used	118	12.5
Mod. Meth.—Separate	112	12.3

to the standard AASHO procedure (TM 99-38). The sample was thoroughly mixed with a small amount of water and compacted in a $\frac{1}{30}$-cu. ft. cylinder in three layers using 25

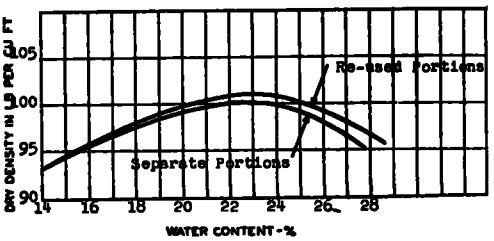

Figure 8. Sample 12

Standard AASHO Method (5.5-lb. hammer, 3 layers).
Classification A-7-6 (15).

Percentage Passing No. 40 Sieve	—100
Percentage Passing No. 200 Sieve	— 97
Liquid Limit	— 48
Plasticity Index	— 26

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	101	23
Std. Meth.—Separate	100	23

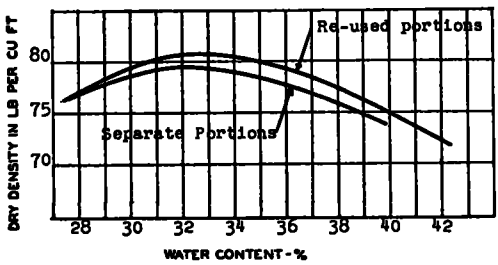

Figure 9. Sample 13

Standard AASHO Method (5.5-lb. hammer, 3 layers).
Classification A-7-5 (18).

Percentage Passing No. 40 Sieve	—100
Percentage Passing No. 200 Sieve	—100
Liquid Limit	— 67
Plasticity Index	— 25

	Max. Density lb. per cu. ft	Opt. Moisture percent
Std. Meth.—Re-used	81	33
Std. Meth.—Separated	79	32

blows of a 5.5-lb. hammer falling 12 in. on each layer. This was repeated for successively larger water contents, re-using the same portion of soil each time. The moisture and density of each point were used to plot a moisture-density curve.

The remaining seven portions were used to develop a second moisture-density curve The standard method was followed except that a separate portion of fresh soil was used for each different water content.

For two of the soil types the entire procedure outlined above was repeated by compacting a second set of eight portions of soil according to the Modified AASHO procedure with 25 blows of a 10-lb hammer falling 18 in on each of 5 layers of soil in a $\frac{1}{30}$-cu. ft. cylinder The first portion was re-used at different water contents, and the remaining

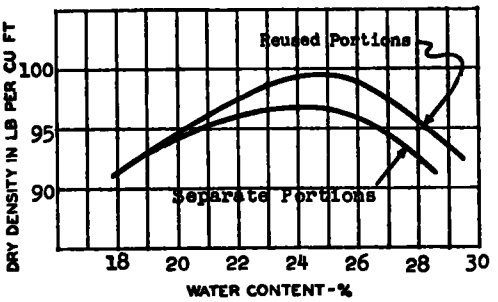

Figure 10. Sample 14

Standard AASHO Method (5.5-lb. hammer, 3 layers).
Classification A-7-5 (13).

Percentage Passing No. 40 Sieve	—99
Percentage Passing No. 200 Sieve	—92
Liquid Limit	—52
Plasticity Index	—17

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	99	25
Std. Meth.—Separate	97	24

seven used separately, one for each different water content

The moisture-density curves resulting from the tests are plotted on Figures 1 to 10 The soils are classified according to the revised Bureau of Public Roads system described in the 1945 *Proceedings* of the Highway Research Board.

DISCUSSION OF RESULTS

A comparison between the maximum densities obtained by re-using the same portion of soil for the entire test and the maximum densities obtained by using separate portions of soil is made in Table 1. The difference varies from 1 to 4 pcf. or from 1 to 4 percent The soil type apparently does not reflect the magnitude of the difference since the difference is

great in both A-3 soils composed of fine silty sand, and also A-7 types that are plastic clays. In the case of the modified method the difference between the maximum densities is more pronounced.

In a few cases there is a difference in the optimum moistures, but that difference is erratic. For two of the A-7-5 soils the separate sample curves had lower optimum moistures while for the A-6, and one A-7-5 the separate sample curves had higher optimum moistures.

The sample of fly ash, while not soil, was tested as an example of a material whose grains fractured under the impact of the compaction hammer. Here the differences in both maximum densities and optimum moistures were great. Similar great differences have been observed in natural sandy soils whose grains are partly decomposed rock fragments

The cause of the differences in maximum densities is probably two-fold. First, the re-used portion is subjected to much greater total compactive effort, for it is compacted many more times than each corresponding fresh separate portion Of course after each determination the re-used soil is partially pulverized and passed through a No. 4 sieve, and more water is added to it. However it is unlikely that its voids which have been freed of air during the previous compaction will refill with air to any extent. The result is that each time a portion of soil is re-used, the test is really beginning with a partially-compacted soil.

Re-using a soil possibly results in a better mixing of the water and soil grains, and consequently easier compaction. However, this should not be true if the laboratory work has been conducted carefully.

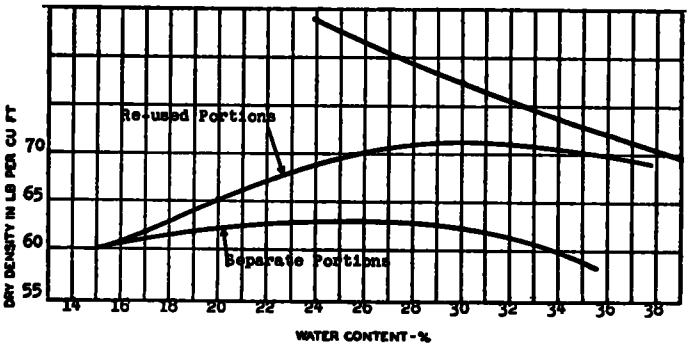

Figure 11. Sample 15
Standard AASHO Method (5.5-lb. hammer, 3 layers)
Classification A-2(0) Fly Ash from ash disposal area near large steam power plant
Percentage Passing No. 40 Sieve—61
Percentage Passing No. 200 Sieve—14
Non Plastic

	Max. Density lb. per cu. ft.	Opt. Moisture percent
Std. Meth.—Re-used	71	30
Std. Meth.—Separate	63	26

TABLE 1

COMPARISON OF MAXIMUM DENSITY OBTAINED BY USING SEPARATE SAMPLES OF SOIL FOR EACH POINT TO DENSITY OBTAINED BY USING SAME PORTION FOR EACH POINT

Soil Type (Revised PRA)	Maximum Density		Difference	
	Re-Used	Separate		Percent of Re-Used Max.
	Pcf.	*Pcf*	*Pcf.*	
	(Compaction in 3 layers with 5 5-lb hammer)			
A-1				
A-2-4	126	125	1	0.8
A-3	108	104	4	3.7
A-4	122	118	4	3 3
A-5	106	103	3	2.8
A-6	108	106	2	1.9
A-7-5 (13)	99	97	2	2 0
A-7-5 (18)	81	79	2	2 5
A-7-5 (19)	96	92	4	4 2
A-7-6 (15)	101	100	1	1 0
Fly Ash	71	63	8	11.3
	(Compaction in 5 layers with 10-lb. hammer)			
A-2-4	131	128	3	2.3
A-3	118	112	6	5 1

When the soil grains are easily fractured by the impact of the compaction hammer, the soil's gradation changes and higher densities result. In one case compaction of a soil composed largely of fragments of weathered schist resulted in a curve whose density increased with the number of times the soil was re-used.

CONCLUSIONS

There is a significant difference in the maximum density obtained by re-using the same soil throughout the compaction test and the density obtained by using fresh separate samples for each point on the curve. Since in actual construction work, soil is compacted but once and at one water content, it is probable that the method using separate points would give results that are more representative of field conditions. This is emphasized by the fact that contractors on occasion have been required to obtain impossible densities.

Unfortunately, using separate samples for each point on the density curve involves extra trouble in sample preparation and requires a sample weighing 50 lb. For most purposes the standard method is satisfactory. For special studies involving the relation of compactive effort in the field to the effort in the laboratory, and studies of the soil's shear strength and compressibility, the authors believe that separate fresh portions of soil should be used for each point on the curves.

DISCUSSION

C. M. YEOMANS, *Bureau of Yards and Docks, Department of the Navy*—The effect of re-using soil in the Standard Compaction Test, as prescribed by the AASHO Designation T99-38, has long been recognized as being of great importance especially when the soils of a fracturable nature are compacted, such as coral, limestone, etc.

In the discussion of results by the authors, it is stated that a higher density will result when the soil grains are fractured This writer takes exception with this supposition. Such increase in densities would be obtained only if the soil used is poorly graded, in which case the fracturing of the grains could possibly change the material to one of better gradation which on compaction gives a higher density than the poorly graded soil.

In performing the Standard Compaction Test and the test described by the author, the curve representing the Standard Method (Re-used) should intersect the curve representing the separate method at the first point obtained by the re-used (Standard) method, since by both methods the soil undergoes only one compaction at this point. However, on inspection of the graph submitted with the paper, the two curves obtained by the Standard AASHO Method and the separate method do not intersect at any point. Assuming that the two tests started a 7 percent moisture the divergence at the peak should be corrected by the divergence at the beginning of the tests In this case the inexplainable difference at 7 percent, of 3 lb., would decrease the divergence at the peak of the curves to only 1 lb. Certainly if the first compaction in both methods is made at the same moisture content, the same density should be realized in both cases since all conditions of tests for this initial point are identical.

W. H. MILLS, *Civil Aeronautics Administration*—The brevity of the paper presented by Professor Sowers is not, in my opinion, commensurate with its importance. Many of us have suspected that the differences shown here did exist but Mr. Nelson and Professor Sowers should be complimented on this investigation showing so clearly that there is an appreciable difference between weights of compacted soil obtained when re-using the same portion for all moisture contents compared with using a new portion for each point on the curve.

One of the practical applications of this fact is in field control. Many specifications require that the contractor compact soil to 90 or 95 percent maximum density by the Standard AASHO Method or by the Modified Method.

In my experience there have been many instances of difficulty in using this type of specification because it seemed impractical and almost impossible for the contractor to obtain the density. This data presented here show one reason for our trouble—following normal procedure with a typical soil having 104 pcf. weight at maximum density, 90 percent would require a field weight of 93 6 pcf. Using a new sample the weight at maximum density might be 100 pcf. and 90 per cent would be 90.0 pcf. Contractors have been forced to great expense at times in trying to attain the differ-

ence in these two figures. Certainly, soil compacted in regular construction in the field is closer kin to a laboratory sample where a new portion is used each time than to one which is re-used several times.

One of the serious objections to using a new portion for each point is the size of the main sample required. This paper shows little variation in optimum moisture content and a practical solution in the laboratory might be to use present procedure to establish the curve, then check a point a little below and a little above with new portions to get the correct weight. Certainly, the procedure for determining maximum density should receive careful study by those responsible for establishing the standard test procedures.

W. H. CAMPEN, *Omaha Testing Laboratories*—I concur with the findings of Messrs Nelson and Sowers. We have been following the practice of using separate samples for over ten years. Using the same sample for a number of trials has the effects of activating the binder and degrading the coarse aggregate.

We have found that the use of separate samples expedites rather than retards the speed with which the moisture-density test is made.

J. D. GRADY, *Civil Engineer, Physical Research Branch, Bureau of Public Roads*—This paper illustrates the differences in the moisture-density relation data obtained when a single soil sample is re-used to determine all of the points on the curve and when a new sample of soil is used for each increment of moisture. The standard AASHO compactive effort was used to compact the soils in both methods.

The maximum density and optimum moisture content obtained by these two methods vary significantly for certain types of soils and the data may be interpreted to mean that the standard AASHO method of compaction should be modified to minimize differences that may occur when laboratory compaction data are applied to the control of soil compaction on construction projects.

Table 1 of the Nelson and Sowers paper shows that 10 different soils were tested using both methods for developing the compaction curves The differences in maximum dry density between these two methods, with the exception of the sample of "fly ash" are from 1 to 4 lb. per cu. ft., five of the soils with differences of 2 lb. or less, and four of the soils with differences of 3 or 4 lb.

Variations of ±2 lb. or less in compaction test data are not significant since experimental errors of this magnitude are often found in the in-place density test methods used for the field control of earth work compaction However, the variations greater than ±2 lb. in compaction test data appear to be significant and may be justification for suggesting a modification of the standard AASHO compaction method.

It is reasonable to expect that differences in compaction test data are likely to occur for certain types of soils tested by these two compaction procedures. Soils with appreciable amounts of soil particles with either elongated or thin platey shapes or cellular structure or low-crushing strength, or with a combination of these characteristics, are likely to break down progressively under the repeated impact of the compaction hammer when the soil is re-used to obtain the moisture-density curve. This same soil will be less affected by impact of the hammer if separate samples are used to establish each point on the compactive curve.

Volcanic ash, cinders, micaceous soils, red dog, granulated slag screenings, and soils containing weakly cemented sandstone or shale particles are some of the subgrade and embankment materials likely to be significantly affected by the repeated impact of the compaction hammer when they are re-used to determine their compaction characteristics.

In addition to differences in compaction test data likely to be attributed to degradation of soil particles under the impact of the compaction hammer, there are other factors which should be given consideration

Certain types of cohesive soils are slow to absorb soil moisture during the manipulation of the soil and water especially if the soils are allowed to become quite dry before starting the compaction test In some instances, the physical properties of the soil in the wet state are significantly changed if the soil is allowed to dry out prior to making physical soil tests. Rewetting the soil prior to making the physical tests apparently will not reverse the change occurring in the soil colloids, and the optimum compaction moisture content will be lower than found for the soil tested without allowing

the soil to dry before making the laboratory compaction test.

A discussion of lateritic soils by E. A. Willis[1] indicates that a marked difference can be obtained in the determination of physical properties of two Hawaiian soils, depending upon whether the soils were tested in their original state or allowed to dry out prior to testing

A recent program of compaction tests in the Bureau of Public Roads Soils laboratory has furnished a limited amount of data which indicates the range in maximum density and optimum moisture content found for samples of the same soil taken at different times between March 1949 and February 1950 at identical elevations from the same test pit.

The physical characteristics of two of these samples when tested after air-drying to hygroscopic moisture contents of 3.5 and 15.6 percent, respectively, are shown in Table A. Sample No. 1 was taken from the test pit in March 1949, stored in bags in the laboratory, and tested in October 1949. Sample No. 2 was taken from the pit in October 1949 and tested immediately. The compaction test data for this soil are shown in Table B. Prior to starting the compaction tests, the samples were air-dried to the initial moisture contents shown in this table. For the very dry samples, it was necessary to add water to obtain the first point on the moisture-density curve.

All compaction tests were performed in accordance with the standard AASHO Compaction Procedure T 99–38, or by the modified AASHO Compaction Method (using the 10-lb. hammer, 18-inch drop, 25 blows per layer and five layers in the 4-in. mold).

The effect of time that the soil was allowed to air-dry during storage in the laboratory is not known for all of the samples. However, examination of the data in Table B indicates that significant variations can be obtained for the same soil and that these variations appear to be related to the amount of the original natural soil water that the sample contained before the start of the compaction tests. The optimum moisture content varies directly and the maximum dry density varies inversely with the initial moisture content at the start of the compaction test. A similar relationship is found in the study of the compaction data obtained by the modified AASHO method.

The range of 12 lb. per cu ft. in density and 7 percent in moisture content in the compaction data for the standard AASHO method, and the range in density of 8 lb. per cu ft. in the test data for the modified AASHO method

TABLE A
TABULATION OF PHYSICAL TEST DATA FOR TWO SOIL SAMPLES TAKEN FROM THE SAME TEST PIT

Sample No	1	2
Percent moisture at start of test (air-dry)	3 5	15 6
Cumulative percent passing		
No 10 sieve	100	100
No 40 sieve	95	96
No 200 sieve	80	84
No 270 sieve (clay and silt)	75	80
Smaller than .005 mm. (clay)	50	57
Plasticity test constants		
Liquid limit	59	66
Plastic limit	30	33
HRB Classification	A-7-6 (20)	A-7-6 (20)

TABLE B
TABULATION OF COMPACTION TEST DATA FOR SOIL SAMPLES FROM SAME TEST PIT

Initial Moisture Content	Maximum Dry Density	Optimum Moisture Content
Standard AASHO Method[a]		
Percent	*lb per cu ft.*	*Percent*
0 (oven-dry at 105 C)	108	17
2 3 (air-dry)	106	15
2 6 "	105	15
4 4 "	105	18
6 7 "	98	21
15 5 "	97	24
16.0 "	96	22
18 7 "	96	24
Modified AASHO Method[b]		
2 3 (air-dry)	120	13
3 0 "	118	13
4 7 "	117	14
6.8 "	113	15
8 3 "	112	16
8 3 "	112	17

[a] 5 5-lb. hammer, 12-in drop, 25-in. drop, 25 blows per layer, and 3 layers

[b] 10-lb hammer, 18-in. drop, 25 blows per layer and 5 layers.

appear to be significant and suggest that further studies should be made with other types of cohesive soils. If similar changes are found, it would appear that modification in the compaction test methods should be given consideration.

Other investigators[2, 3] call attention to

[1] Discussion of B Fruhauf's Paper "A Study of Lateritic Soils," by E. A. Willis, Vol. 26, *Proceedings* of the Highway Research Board.

[2] R. M. Hardy, "Compaction of Soils as Applied to Road Construction," *Roads & Bridges*, October 1949.

[3] D. J. Maclean & F. H. P. Williams, Re-

another factor which should be given additional study It is reported that when soils which have appreciable material retained on the No. 4 sieve are compacted in the laboratory by the standard AASHO method, the corrections applied to compensate for the plus No. 4 material do not always check with the maximum densities found in the road after it has been compacted with the construction equipment Variations as much as 10 percent have been reported between the standard AA SHO compaction data and laboratory compaction data obtained by using the total sample to establish the moisture-density curve. It has been reported that the compaction data obtained by using the total sample is in substantial agreement with the density developed in the field by the construction compaction equipment.

It would appear that there is a need for a comprehensive study of the compaction test both from the field and laboratory viewpoint so that the effect of factors apt to influence the maximum density of soils can be determined.

Until the effects of these factors are known, the engineer responsible for the control of earthwork compaction should compare the laboratory data with those obtained by experimental rolling in the field before selecting the maximum density to be used for field control purposes, especially so, if the field compaction characteristics of the soil have not been established for the roller equipment to be used for the compaction work.

A comparison of maximum densities obtained from compaction curves developed for the soil at different air-dry moisture contents should assist the engineer in determining whether air-drying is apt to change the compaction characteristics of the soil.

The examination of the texture and type of soil particles prior to starting the compaction tests should enable the engineer to determine if the soil is likely to break down and progressively change its compaction characteristics under the impact of the hammer. In case it appears that this factor alone may influence the compaction characteristics, a separate soil sample may be required for each point on the compaction curve.

If changes in the compaction method appear necessary because of air-drying or degradation of soil particles under impact of the hammer, it may be desirable to determine the moisture-density relationship developed by the roller equipment for the soil used on the construction project before selecting the maximum density required for the control of the compaction work.

G. H. Nelson and G. F. Sowers, *Closure*— Mr. Mills' suggestion to use the standard procedure to establish the approximate optimum moisture and then to use the new portions of soil to establish the maximum density is a practical method of obtaining the results of the separate-portions method without requiring unduly large samples. Before any such suggestion is adopted, the effects of re-using the soil on the optimum moisture should be clearly established.

Mr. Yoemans' comment that the higher densities will result from grain fracture only when the soil is poorly graded is not necessarily true. It is probable that grain fracture in well-graded soils composed of dense homogenous particles would not result in higher densities. However, if the grains are very irregular in shape or if the grains themselves contain voids (such as in fly ash, cinders, or decomposed rock) they may be compacted to greater densities after grain fracture.

Mr. Yoemans is correct in stating that the curve representing the Standard Method (re-used portions) and the curve representing the separate-portions method should intersect at the first point obtained by the re-used method. In all the tests where both curves were commenced at the same water content this was true. However, in drawing the curves Mr Yoemans questions, (Sample 11-Classification A-3), only the central portions of the curves were shown. If these curves were extended they would intersect at a water content of 4 percent.

The writers appreciate the comments of the discussers. The study was not intended to be a complete evaluation of the Standard Compaction Test. It was made for the sole purpose of determining whether the maximum densities secured by the Standard Method were appreciably different from those secured by using separate portions of soil for each point on the curve. The tests show that the difference in the results may be considerable in some cases.

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search on Soil Compaction at the Road Research Laboratory (Great Britain), Vol. IV, *Proc* of Second International Conference on Soil Mechanics, Rotterdam, June 1948