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EVALUATION OF A ONE-POINT COMPACTION TEST FOR MISSOURI SOILS

MISSOURI STATE HIGHWAY DEPARTMENT

FEDERAL HIGHWAY ADMINISTRATION

EVALUATION OF A ONE-POINT COMPACTION TEST FOR MISSOURI SOILS

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ABSTRACT

A family of curves for use with a one-point compaction test was developed from over 500 AASHTO T-99, Method C laboratory moisture-density relations tests. The family of curves is considered applicable to all Missouri soils, except those defined as coarse grained or organic, within a maximum dry density range of 88-120 pcf.

Accuracy of field test procedures and methods of compaction control were related to laboratory results. One-point results, computed by both oven dry and nuclear moistures, were found acceptable when limited to those points plotting within a range of minus 4 to plus 2 percentage points of optimum on the family of curves.

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INTRODUCTION

Compaction control of earthwork in Missouri has been based upon the visual-manual method. With this method, a moisture-density relations test or "standard" is performed on each identifiable soil of a project at the earliest possible time. Thereafter, the results of an in-place density test are compared to the results of the previously performed standard considered most appropriate based on visual-manual correlation. The reliability of this method is highly dependent upon the ability to match soils by eye and feel and upon the assumption that each identified soil has a consistent MDD (maximum dry density) and OM (optimum moisture). The principal advantage is that rapid decisions can be made except when a new soil is identified for which base values have not been established.

A method of compaction control which has the capability to largely eliminate the judgement factor in matching density tests to standards is the one-point method. With this method, average values of moisture-density relations tests are used to draw a family of curves, usually at about 2 pcf intervals, covering the range of MDD and OM likely to be encountered. The soil at the site of the in-place density test is compacted, generally at field moisture, in the same manner as for a single test point of a moisture-density relations test sequence. The results of this test point are then plotted on the family of curves and a new curve geometrically similar to adjacent curves is sketched through the point. The MDD and OM are determined from the apex of the sketched curve.

The one-point compaction test has been in use since the late 30's and is gaining increased acceptance. It was anticipated that a family of curves for Missouri soils would be similar to those developed by other agencies. However, because of the possiblity of differences in soil properties or conventional test procedures, it was considered necessary that Missouri develop its own curves and evaluate the test method and its application. To assess the relative accuracy of the one-point test and the one-point method of compaction control it was also necessary to establish comparative values for the conventional moisture-density relations test and the visual-manual method of compaction control.

Determination of moisture content by conventional drying is the most time consuming step in performing either a one-point or conventional moisture-density relations test. Since the one-point test is performed on the same soil which may be tested for in-place density and moisture by a nuclear gauge, it was decided to make a comparative evaluation of the one-point test results using moisture values determined by both nuclear and conventional methods.

CONCLUSIONS

1. The family of curves developed for a one-point compaction test seems applicable state wide for all except granular and organic soils as defined by ASTM D 2487.
2. Relative to duplicate laboratory tests, one-point test results (oven dry moisture) plotting within the range of OM-4 to OM+2 on the family of curves furnished results equal in accuracy to the complete laboratory moisture-density relations test.
3. Relative to duplicate laboratory tests, one-point tests used in conjunction with corrected nuclear moisture values from in-place density and moisture tests were slightly less accurate than the complete laboratory compaction test within the range of OM-4 to OM+2. The slight loss in accuracy is considered tolerable for field use in view of the speed of obtaining nuclear moisture results.
4. The relative errors for all one-point test results are about 3 times greater than those only within the range of OM-4 to OM+2. This large increase in relative error is justification for accepting only those one-point results that plot within the limiting moisture range.
5. Compaction control by the present visual-manual method was found to be considerably less accurate than control based upon use of a one-point test for each density test. Relative errors computed for the visual-manual method were about 5 times those of the one-point method (corrected nuclear moisture) when used within the range of OM-4 to OM+2.
6. After initial field use of the one-point test, additional research could be considered: (1) to extend the range of the family of curves above 120 pcf and below 88 pcf; (2) to evaluate the one-point test and family of curves for use with granular soils; (3) to determine if the limiting moisture range (OM-4 to OM+2) can be expanded below OM-4 without significant loss in accuracy; (4) to determine the cause of the significant t value found in the SM soil and (5) to resolve any other problems uncovered by trial field use.

IMPLEMENTATION

It is recommended that the one-point test and family of curves as developed be accepted for the determination of moisture-density relations for all except coarse-grained (sands and gravels) and organic soils as defined by ASTM D 2487. The one-point test should be performed in accordance with AASHTO T-99, Method C except that:

1. Only one point need be determined. This point must plot within the range of OM-4 to OM+2 on the family of curves. (While the one-point test can usually be performed at field moisture, the moisture content may be adjusted by wetting or air drying so that the results plot within the desired range.)
2. A portable mold support weighing no less than 75 pounds may be used.
3. Moisture content may be determined either by the drying procedures of AASHTO T-99 or, where no adjustment in moisture is required, by a nuclear gauge in accordance with Department test method MSHD T-35-3-75.

Consideration should also be given to changing acceptance testing procedures for compacted soil to include use of the one-point compaction test. There are essentially three approaches possible for implementation:

1. Maximum utilization of the one-point compaction test would require a one-point test be performed for each and every density test thereby eliminating all visual-manual correlations. This would involve more work than is now performed, possibly more time depending on the method of moisture determination, but would ensure much greater precision in determining degree of compaction.
2. The lowest level of use would involve acceptance only as a faster, more convenient substitute for the conventional multi-point moisture-density relations test while retaining the existing visual-manual method of compaction control.
3. The third approach, and perhaps the most practical, would fall between these extremes. The speed of the visual-manual method could be retained for homogeneous soils while requiring more detailed testing and greater precision in those heterogeneous soils where the visual-manual method is most imperfect.

SCOPE

This study was initiated to develop a family(ies) of typical AASHTO T-99, Method C moisture-density relations curves for use throughout the state of Missouri and to evaluate the relative accuracy of the visual-manual and one-point methods of compaction control.

Results from routine moisture-density relations tests performed on samples taken during soil surveys were used to develop typical curves. It was anticipated that this source would provide samples from all areas of the state, a wide variety of soil types and an adequate number of tests.

Field testing, to evaluate the family(ies) of curves and the one-point versus visual-manual methods of compaction control, consisted of a minimum of 20 tests on each of 4 construction projects.

Project inspectors were instructed to perform routine testing without regard to research personnel who obtained the data necessary for evaluating the one-point method. This consisted of one-point compaction test results computed by both oven dry and corrected nuclear moisture values and obtaining a soil sample for laboratory determination of moisture-density relations and specific gravity. The data necessary for evaluating the visual-manual method was obtained by recording the values reported by the compaction inspector for in-place density by nuclear method, the MDD and OM selected for use by visual-manual correlation and the computed percent compaction.

ACCURACY OF TEST METHODS

A. Repeatability of Laboratory Results

The complete AASHTO T 99, Method C test requires the determination of at least 3 points and is time consuming and rather complex. Consequently, it can be inferred that the results of duplicate, complete tests on a sample of soil would probably vary. It would be expected however, that duplicate tests results from a well equipped laboratory would have less variability than those from project laboratories which usually have a minimum of equipment. Repeatability values for AASHTO T 99, Method C results in the central laboratory were determined by duplicate testing. These laboratory repeatability values were the standards for evaluating the one-point and visual-manual results.

A total of 87 duplicate tests were made. Tests selected were divided about equally between ASTM soil classifications ML, CL and CH because these represent a wide range in plasticity and are the predominant classifications encountered in Missouri. An additional requirement was to select the duplicate samples from as many areas of the state as possible.

Samples selected for duplicate tests were from routine soil survey samples; consequently, the first test had to be performed and reported within a relatively short period of time. The portion of the sample to be used for the duplicate test was stored and tested at a convenient time. No effort was made to have both tests performed by the same technician using the same tamping device. The duplicate testing was performed by a total of five technicians using two tamping devices which probably influences the magnitude of the repeatability values reported.

Linear regression analysis was performed on the duplicate results to obtain the Se (standard error of estimate) which was used as the repeatability value.

The Se for the 87 tests was 2.6 pcf for MDD and 1.4 percentage points for OM. For comparable accuracy, the one-point and visual-manual Se values should be equal to these values and only slightly greater for acceptable accuracy.

B. Relative Error

The measure of accuracy is termed relative error and is the difference in Se values of a method under evaluation relative to the Se values established for an accepted method. The basis for such a comparison is that Se is similar to standard deviation in that, when a sufficient number of test results are analyzed, about 68 percent plot with ±Se, 95 percent within ±2 Se and 99+ percent within ±3 Se of the regression line.

The error that can be expected not to be exceeded by 95 percent of the results is a practical working value and can be obtained from the difference between the 2 Se ranges. The 2 Se values of the duplicate laboratory test results (AASHTO T 99, Method C) was the base for computing the relative errors for MDD and OM. The 2 Se value of the percent compaction correlation, computed from the complete laboratory moisture-density relations test vs. the one-point (oven dry moisture) test, was the base for computing the relative errors for percent compaction.

DEVELOPMENT OF THE FAMILY OF CURVES

The family of curves was developed only from the results obtained on samples submitted routinely to the laboratory for the determination of moisture-density relations. Test results of more than 500 samples from all 10 highway districts were available for study. Although complete laboratory tests were also performed on the soils obtained from the one-point test sites during the field evaluation phase, these results were not included in the family of curves data because it could have biased the relative error of the one-point results. Most of the major soil series found in Missouri and several shales were represented. The soil classifications represented were GC, SM, SC, ML, CL, MH and CH. The vast majority of the soils were classified CL and CH. No tests were obtained on granular or organic soils. Granular soils are frequently encountered in hydraulic fills and elsewhere and perhaps should be considered for evaluation in the future. Organic soils are of rare occurrence in Missouri and do not pose much of a problem.

Laboratory data was tabulated by the reported MDD. The initial step in obtaining the average curve points for a particular MDD was to test the data for outlying observations in accordance with ASTM E 178-75. Each curve point and OM were so tested. When the data was free of outlying observations, the curve points were averaged. The next step was to compute the best fit curve for OM vs. MDD. This curve and the average curve for each MDD were plotted. These average curves did not completely fit the OM vs. MDD curve, spacing was not uniform and the shapes varied slightly. The final step was to shift the average curves to conform to the OM vs. MDD curve and the desired spacing. The final MDD curves are of the shapes that were most prevalent, becoming flatter as MDD decreases and OM increases.

The MDD of the developed family of curves, as shown in Figure 1, ranges from 88 to 120 pcf. Curves could not be expanded beyond these limits due to insufficient data.

ANALYSIS OF MDD AND OM DATA

To evaluate the useable range of the family of curves, correlation data was developed for all one-point results and for those one-point results plotting only in the range of OM-4 to OM+2 on the family of curves. A planned analysis of one-point results plotting in the range of OM-6 to OM+2 was omitted because only a few points were available within the range of OM-6 to OM-4. Correlation data was determined for each project and then for all projects combined for the two sets of data used. For the visual-manual method, correlation data was developed only for all projects combined.

A. One-Point Test Data Within the Range of OM-4 to OM+2

It was anticipated that the one-point test results would correlate better when the soil at the test site was near optimum. The first moisture range evaluated was OM-4 to OM+2 because this is the narrowest range considered feasible for field use. Correlation data was developed first by project for laboratory MDD and OM results vs. one-point MDD and OM results determined both by oven dry moistures and corrected nuclear moistures. (Corrected nuclear moisture means that the amount of water indicated by the manufacturer's calibration curve was adjusted by a water correction factor(4) which was determined for each identifiable soil.) Laboratory results were used as the base data since a complete moisture-density relations test should give the best estimate of the MDD and OM of a soil. This data is shown in Section 1 of Tables 1 and 2.

The primary reason for examining these comparisons by project was to determine if there was a significant difference between the means of the test results. The t value was found to be significant at the 95 percent confidence level for both the MDD and OM (laboratory vs. one-point, oven dry moisture) correlations for the Route I-155 project. This is an indication that one of the tests gave an erroneous estimate of the MDD and OM. The problem seems limited to the I-155 project since the t values for the other projects do not approach the limiting value.

The I-155 soil was a silty sand while the soils of the other projects were mostly CL and CH. This suggests that the problem is limited to coarse-grained soils.

Examination of the individual results for the I-155 project revealed that each one-point MDD was lower than the corresponding laboratory MDD and that each one-point OM was equal to or greater than the corresponding laboratory OM. The laboratory results vs. the one-point results (corrected nuclear moisture) were not significant. However, these results had the same trend and the t value would probably have been significant if more tests had been available for analysis. The soils at many of the test sites on this project were wet and had to be dried which voided the corrected nuclear moisture results.

The Se values were 2.5 pcf for MDD and 1.2 percentage points for OM for the I-155 project. These Se values are in good agreement with those of the duplicate tests (2.6 pcf and 1.4 percentage points) and indicate that the difference between results was relatively constant.

The constant difference between the results suggests that the cause lies with either the laboratory results or the field results. To evaluate the laboratory results, the laboratory MDD was compared to the one-point MDD for each point of the laboratory curve for the 20 tests from the I-155 project and also for 20 tests in the same MDD range from other projects. Correlation values are tabulated below:

Curve Points	1	2	3	4	5
Se, pcf (I-155)	1.5	1.4	1.1	0.7	1.3
Se, pcf (All other projects)	2.1	1.7	0.8	1.2	1.3
t (I-155)	8.76**	5.58**	1.78	1.25	5.68**
t (All other projects)	4.86**	2.39*	0.58	1.46	4.80**

*significant at the 95 percent confidence level.
**significant at the 99 percent confidence level.

Correlation results of the two sets of data are quite similar. Only curve points 3 and 4 yielded acceptable MDD values. This indicates that the laboratory results for the I-155 project were normal and that the field results were the cause of the significant t value.

More field testing would have to be performed in silty sands, and possibly ML soils, to determine the cause of the low value for the one-point MDD and high value for OM. Reuse of the sample in the laboratory, but not in the field, is a possible cause.

Because of the significant t value, results from the I-155 project were eliminated from the remainder of the analysis. The data from all other projects were combined since increasing the number of observations improves the reliability of correlation values.

The combined data for laboratory MDD vs. one-point MDD, (calculated using oven dry moisture) included 59 observations. The Se value was 2.5 pcf compared to 2.6 pcf for the duplicate tests. For this comparison, the difference between the 2 Se values is so small that the one-point test (oven dry moisture) is considered equal in accuracy to the complete laboratory test for determining MDD when the one-point results plot within the range of OM-4 to OM+2 on the family of curves.

The combined data for the laboratory MDD vs. one-point MDD, (calculated using corrected nuclear moistures) included 54 observations. Because the oven dry and corrected nuclear moistures were slightly different, both pairs of some one-point results did not plot within the range of OM-4 to OM+2. The soil at a few tests sites was air dried to bring the soil within the necessary moisture range. This voided the corrected nuclear moisture at these sites and contributed to the difference in the numbers of observations for the two comparisons.

The Se for the combined data for the laboratory MDD vs. one-point MDD (corrected nuclear moisture) was 2.9 pcf which is slightly larger than the 2.6 pcf for the duplicate tests. The difference between the 2 Se values (5.8 pcf for the one-point and 5.2 pcf for the duplicate tests) is 0.6 pcf. Thus, the relative error for one-point MDD determinations due to using corrected nuclear moistures is 0.6 pcf.

The Se value was 4.1 pcf for the laboratory MDD vs. the MDD selected in the field by visual-manual correlation. This correlation had 59 observations and the laboratory data was the same as for the one-point MDD (oven dry moisture) correlation. The difference between the 2 Se ranges is 3.0 pcf (8.2 pcf for MDD by visual-manual selection and 5.2 for MDD by duplicate laboratory tests). Thus, the visual-manual method of selecting MDD values results in a relative error of 3.0 pcf. This error is 2.4 pcf greater than that for one-point test results due to using corrected nuclear moisture results. Selecting the MDD of a soil by the visual-manual method must be more difficult than has been assumed.

Based on the Se of the laboratory duplicate tests, the relative accuracy for MDD, when the one-point results plot within the range of OM-4 to OM+2 on the family of curves, was determined to be:

1. One-point test (oven dry moisture) - equal accuracy.
2. One-point test (corrected nuclear moisture) - relative error of less than one pcf.
3. Visual-manual correlation - relative error of 3.0 pcf.

The correlation data for OM was subjected to the same reasoning. Based on the Se of the laboratory duplicate tests, the relative accuracy for OM, when the one-point results plot within the range of OM-4 to OM+2, was determined to be:

1. One-point test (oven dry moisture) - equal accuracy.
2. One-point test (corrected nuclear moisture) - relative error of less than 0.5 percentage point.
3. Visual-manual correlation - relative error of 2.0 percentage points.

The one-point test using either oven dry or corrected nuclear moisture gave a considerably better estimate of the MDD and OM of a soil than did the presently used visual-manual correlation when the one-point results plotted within the range OM-4 to OM+2 on the family of curves.

One-point results were more reliable when the moisture content was determined by oven drying. However, use of corrected nuclear moistures resulted in a relative error of less than one pcf for MDD and 0.5 percentage point for OM. These errors are considered acceptable for field use when the speed of obtaining nuclear moisture results is taken into consideration.

B. All One-Point Data

When all of the test results without restriction to the moisture range are compared, the one-point test and the present visual-manual correlations are about equally inaccurate. The Se values for MDD, Table 1, Section 2 are 4+ pcf for both, neither of which should be considered acceptable when compared to the 2.6 pcf Se of the laboratory duplicate tests. Comparison of the Se values for OM leads to the same conclusion. The main source of this error for the one one-point test was the results plotting more than OM+2 on the family of curves. The one-point test, using either oven dry or corrected nuclear moistures, furnished acceptable MDD and OM values when the one-point results were limited to those points plotting within the range of OM-4 to OM+2 on the family of curves. By using this limiting range for acceptable one-point results, the relative error is only about one-third of the relative error when all one-point results are used.

ANALYSIS OF PERCENT COMPACTION RESULTS

Results of two tests, in-place density and MDD, are required to compute percent compaction. Percent compaction was computed from the in-place density determined by the compaction inspector and the MDD determined by each of the following methods: (1) complete laboratory moisture-density relations test; (2) one-point test computed from both oven dry and corrected nuclear moisture; and (3) visual-manual correlation of the tested soil to a compaction standard. The base data was the percent compaction computed from the complete laboratory test.

Grouping of data for percent compaction correlations was the same as for the MDD and OM correlations.

A. <u>One-Point Data Within the Range of OM-4 to OM+2</u>

This correlation data is presented in Table 3, Section 1. Both the Se and correlation coefficients indicate the one-point method to be superior to the visual-manual method. MDD was the variable value for computing percent compaction in these comparisons. Therefore the accuracy of determining MDD, as would be expected, is reflected in the percent compaction comparisons. The order of accuracy for percent compaction is; (1) one-point method (oven dry moisture); (2) one-point method (corrected nuclear moisture) and (3) visual-manual correlation method. For the one-point methods, the difference between the Se values for percent compaction is slightly greater than for MDD. This reflects the relative error in the one-point MDD values due to using corrected nuclear moistures. The Se value of 5.8 percentage points for percent compaction is evidence that the visual-manual correlation method is considerably less accurate than the one-point method. This is also evidence that the 3.0 pcf relative error in MDD values by the visual-manual method greatly affected the percent compaction results.

The 2 Se ranges for percent compaction of the one-point results, oven dry moisture and corrected nuclear moisture, are 4.8 and 6.2 percentage points, respectively. This means that the relative error in percent compaction due to using nuclear moistures is slightly more than 1.0 percentage point when the one-point results plot within the range of OM-4 to OM+2 on the family of curves. This amount of error is considered tolerable since corrected nuclear moisture results can be obtained in appreciably less time than can oven dry moisture results. However, one-point results using corrected nuclear moistures should be limited to those points plotting within the range of OM-4 to OM+2 on the family of curves unless further research indicates that the range can be expanded from OM-4 to OM-6 without a significant increase in the relative error.

B. <u>All One-Point Data</u>

Correlation data for percent compaction was developed for all of the results obtained during this study. This data is presented in Table 3, Section 2.

The trend of this data is similar to that previously discussed. However, the higher values for the Se and lower values for the correlation coefficient indicates that use of all one-point results, without restriction on the range of moisture, greatly decreases the accuracy of determining percent compaction. The 2 Se value for those one-point results (oven dry moisture) plotting within the range of OM-4 to OM+2 on the family of curves is 4.8 percentage points while the 2 Se value for all one-point results (oven dry moisture) is 8.4 percentage points. Thus, use of all one-point results (oven dry moisture) results in a relative error of 3.6 percentage points. A relative error of this magnitude justifies limiting use of one-point results to those that plot within a certain range on the family of curves.

EFFECT OF OUTLYING RESULTS ON ONE-POINT RESULTS

The family of curves is composed of the average individual curve for each MDD. The outlying results were removed from the data prior to obtaining the average values for each curve. It was deemed necessary to determine if one-point results would be adversely affected by these outlying observations.

A common reason for outlying results was starting the test at moisture contents too high or too low relative to the majority of the data in the tabulation. Frequently only one curve point would show a significant difference. This could be caused by operator error, as in weighing, or by a two humped curve characteristic of some soils. Rerunning the test would have been desirable but was impossible because samples had to be discarded due to insufficient storage space. Cause for most concern were those results where the OM was the outlying result. It was believed that these soils might be the cause of extreme variations between one-point and laboratory results.

To evaluate the effect of outlying observations, individual points, used to plot those moisture-density relations curves with outlying observations, were used to determine the MDD and OM from the developed family of curves. Only those curve points plotting within the range of OM-6 to OM+2 on the family of curves were used since this was believed to be the maximum useable range. Base values for this correlation data were the MDD and OM of the individual curve from the developed family of curves from which the outlying observations had been removed. Correlation data for the outlying observations and duplicate test results are tabulated below:

	Duplicate Test	Outlying Observations
Se for MDD	2.6 pcf	2.4 pcf
Se for OM	1.4 percentage points	1.4 percentage points

The Se values for the outlying observations are equal to or less than those for the duplicate tests, indicating the absence of extreme values. This is encouraging since extreme values for OM were anticipated due to the OM being the cause for some of the outlying observations. This type of data is not expected to cause a significant problem when the one-point results plot within the recommended range on the family of curves.

EFFECT OF SPECIFIC GRAVITY

It was thought that specific gravity might significantly affect the results of the moisture-density relations test and, if so, could be a possible basis for grouping soils. The specific gravity was determined in duplicate on the minus 4.75mm (No. 4) sieve material of all samples that were used in developing the family of curves. The combined specific gravity was determined on all samples containing plus 4.75mm material but could not be duplicated because of an insufficient quantity of plus 4.75mm material in most of the samples. The results discussed are on minus 4.75mm material.

Duplicate results were obtained on 506 observations. The Se was 0.014 and the correlation coefficient was 0.97 which is excellent correlation. The specific gravity test is one of the more precise soil tests. These specific gravity results ranged from 2.389 to 3.033 which is quite wide. The average values were 2.676 for the first test and 2.680 for the second test. These averages are quite close to the 2.67 generally accepted as the average specific gravity of soils.

The family of curves was developed from soils having a wide range in specific gravity. Laboratory and one-point results are in excellent agreement provided the one-point results are limited to a specific OM range on the family of curves. These points indicate that the specific gravity of soil does not have a significant effect on moisture-density relations results even though it undoubtedly makes a minor contribution to the variability.

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APPENDIX 1
TEST PROCEDURES

Department standard specifications state that the moisture-density relations of soil shall be determined in accordance with AASHTO T 99-70, Method C, replacing any material retained on a 3/4 inch sieve. Laboratory test results were obtained by the AASHTO procedure using two Rainhart automatic tampers. To insure good curve definition, 5 test points were used. For "heavy textured" soils, note 6 of AASHTO T 99 requires that the soil and water for each test point be mixed and stored in an airtight container for 12 hours prior to performing the test. Since "heavy textured" is not further defined in the AASHTO procedure, this note was applied to soils classified CH. The samples were reused for other soil classifications.

The field test was also performed in accordance with AASHTO T 99 procedures except for the mold support and the determination of only one test point. Since a 200 pound support is not readily transportable, a concrete support weighing approximately 75 pounds was used. This support was capped with a 8 in. x 8 in. x 1/2 in. steel plate. For enhanced uniform contact, a sheet of lead 1/8 in. in thickness was placed between the steel plate and the concrete.

In-place density and moisture were determined with Troxler Model 2401 nuclear moisture-density gauges. Soil density was determined in accordance with AASHTO T 238-73, Method B - Direct Transmission. Soil moisture was determined in accordance with AASHTO T 239-73 except that a moisture correction factor was determined for each soil in accordance with a Department test method designated MSHD T-35-3-75. In addition, a moisture sample was taken from each one-point test and transported to the laboratory for oven drying at 110± 5C (230±9F).

Specific gravity was determined in accordance with AASHTO T 100-74.

TABLE 1
MDD CORRELATION DATA

Section 1. One-Point Test Data Plotting Within the Range of OM-4 to OM+2

Project	Standard Error of Estimate[1]			Correlation Coefficient			t Value		
	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual
Route 50	2.0	1.5	–	0.88	0.90	–	1.138	0.431	–
Route I-470	2.2	2.3	–	0.93	0.90	–	0.451	1.502	–
Route 63	2.9	3.1	–	0.89	0.87	–	0.259	0.503	–
Route 61	2.1	1.5	–	0.93	0.96	–	0.178	0.123	–
Route I-155	2.5	2.0	–	0.84	0.85	–	2.152*	1.289	–
All Projects[2]	2.5	2.9	4.1	0.93	0.89	0.42	0.492	0.544	0.797

Section 2. All One-Point Test Data

Project									
Route 50	3.3	2.7	–	0.53	0.72	–	0.147	0.148	–
Route I-470	3.4	4.1	–	0.89	0.78	–	0.413	0.587	–
Route 63	4.7	5.0	–	0.85	0.84	–	0.707	0.868	–
Route 61	2.2	2.6	–	0.91	0.88	–	0.454	0.330	–
All Tests[2]	4.1	4.2	4.3	0.84	0.81	0.64	0.159	0.340	0.30

Section 3. Duplicate Laboratory Test Data

Standard Error of Estimate = 2.6 pcf Correlation Coefficient = 0.97 t Value = 0.007

* t significant at 95 percent confidence level
1 units of pcf
2 except Route I-155

TABLE 2
OM CORRELATION DATA

Section 1. One-Point Test Data Plotting Within the Range of OM-4 to OM+2

Project	Standard Error of Estimate[1]			Correlation Coefficient			t Value		
	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual
Route 50	1.3	1.0	–	0.86	0.85	–	0.165	0.409	–
Route I-470	1.3	1.4	–	0.92	0.88	–	0.573	1.569	–
Route 63	1.6	1.6	–	0.94	0.92	–	0.092	0.392	–
Route 61	1.6	1.1	–	0.83	0.91	–	0.117	0.621	–
Route I-155	1.0	1.2	–	0.89	0.72	–	2.258*	2.043	–
All Projects[2]	1.3	1.6	2.4	0.92	0.88	0.34	0.314	0.343	0.131

Section 2. All One-Point Test Data

Route 50	1.9	1.4	–	0.57	0.75	–	0.720	0.832	–
Route I-470	1.3	2.2	–	0.93	0.79	–	0.573	0.600	–
Route 63	1.3	2.1	–	0.95	0.87	–	0.000	0.517	–
Route 61	1.6	1.5	–	0.80	0.83	–	0.112	0.222	–
All Tests[2]	1.6	2.0	2.5	0.90	0.83	0.23	0.091	0.362	0.851

Section 3. Duplicate Laboratory Test Data

Standard Error of Estimate = 1.4 percentage points   Correlation Coefficient = 0.97   t Value = 0.317

* t significant at 95 percent confidence level
1 units of percentage points
2 except Route I-155

TABLE 3
PERCENT COMPACTION CORRELATION DATA

Section 1. One-Point Test Data Plotting Within the Range of OM-4 to OM+2

Project	Standard Error of Estimate[1]			Correlation Coefficient			t Value		
	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual	Lab Vs One-Point Oven Dry Moisture	Lab Vs One-Point Corrected Nucl Moisture	Lab Vs Field Visual-Manual
All Projects[2]	2.4	3.1	5.8	0.89	0.85	0.49	0.613	0.524	0.845

Section 2. All One-Point Test Data

Project									
All Projects[2]	4.2	4.5	5.9	0.75	0.73	0.47	0.250	0.617	0.713

1 units of percentage points
2 except Route I-155

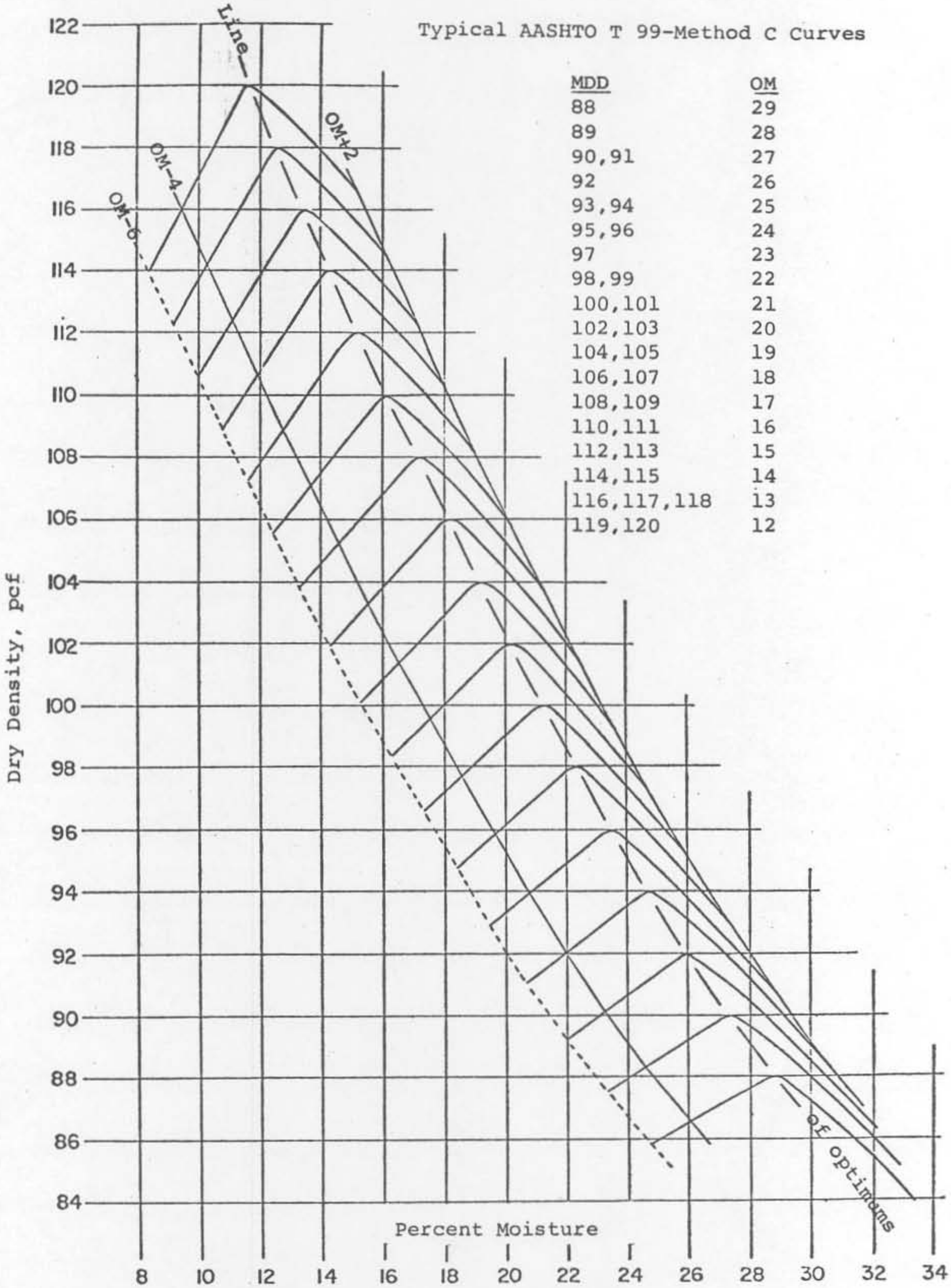
Typical AASHTO T 99-Method C Curves
MDD OM
88 29
89 28
90,91 27
92 26
93,94 25
95,96 24
97 23
98,99 22
100,101 21
102,103 20
104,105 19
106,107 18
108,109 17
110,111 16
112,113 15
114,115 14
116,117,118 13
119,120 12
Line of optimums
OM+2
OM-4
OM-6
Dry Density, pcf
122
120
118
116
114
112
110
108
106
104
102
100
98
96
94
92
90
88
86
84
Percent Moisture
8
10
12
14
16
18
20
22
24
26
28
30
32
34

Figure 1