DEVELOPMENT OF A RAPID FIELD METHOD FOR DETERMINING OPTIMUM MOISTURE AND MAXIMUM DENSITY OF SOILS

R. C. Mainfort
J. H. DeFoe

Research Laboratory Division
Office of Testing and Research
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Synopsis

Based on previous work elsewhere and a statistical analysis of some 100 Proctor density curves made for Michigan soils, a chart has been developed for obtaining maximum density and optimum moisture of a soil by means of a one-point Proctor compaction test. Extensive field and laboratory testing has shown the method to be suitable for the Department's density control inspection. Its use allows savings of considerable time and labor. Should future field evaluation so indicate, modifications of the chart will be made.

In most highway construction work involving soils and soil-aggregate mixtures, it is necessary to determine the design density at many locations in order that the degree of compaction can be properly controlled. This determination is usually made by the standard Proctor (T-99) compaction test, which is a laborious and time-consuming procedure. When materials within a given area vary considerably, it is not always practical or even possible to obtain sufficient density control values to permit the quality of compaction desired. A more rapid method for obtaining maximum density and optimum moisture content in the field would be of great help to density inspectors and contractors, and should certainly result in improved, lower-cost construction.

In an effort to speed up and improve density control procedures for the Department, R. L. Greenman, Assistant Testing and Research Engineer, requested the Research Laboratory Division to study this problem. As a result, Research Project R-61 E-24 was initiated with the objective of developing a rapid and simple field method for obtaining maximum density and optimum moisture of embankment, subgrade, and base course materials.

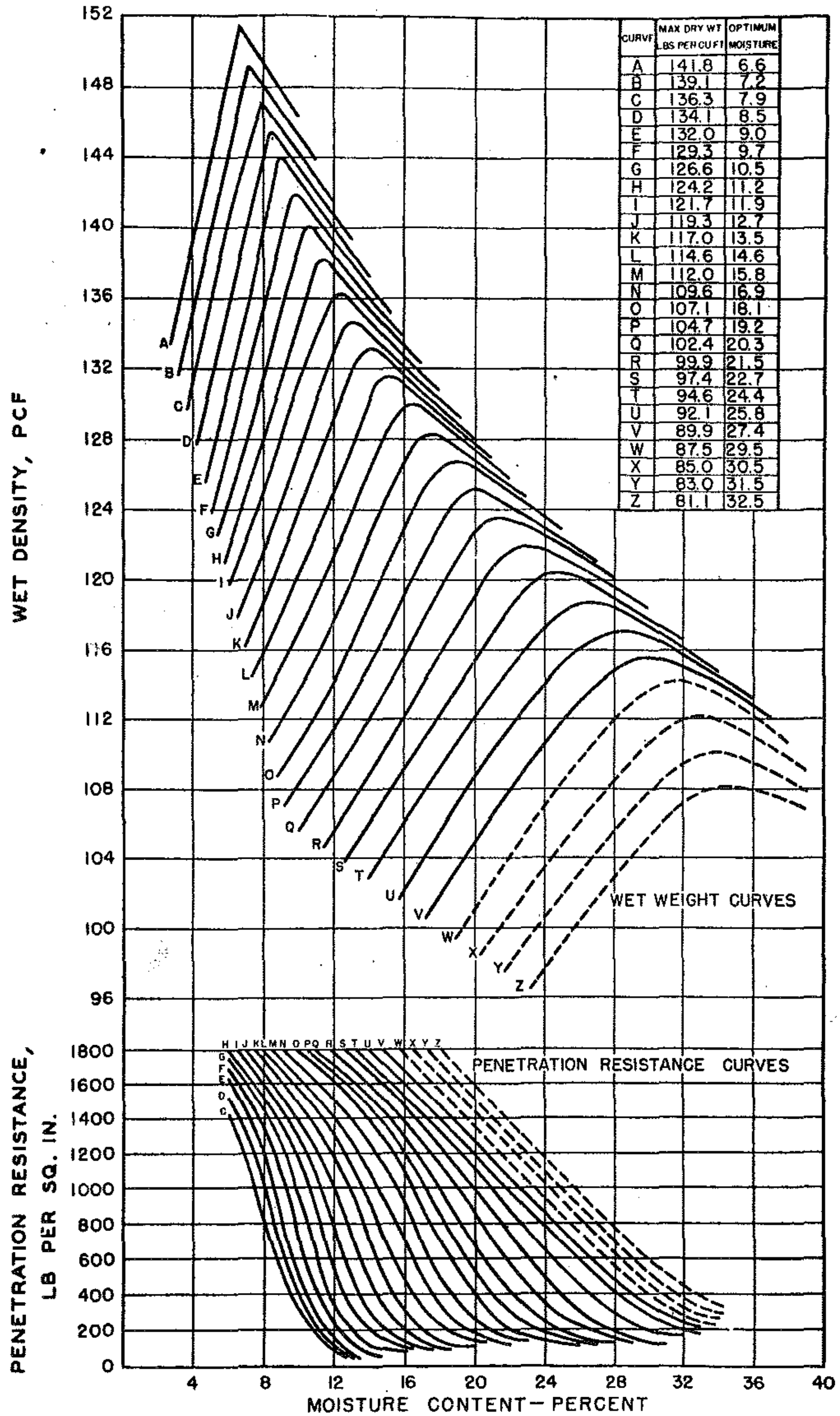
Selection of Method

Several organizations have made studies to simplify and improve methods for controlling field compaction of soils. Some of these are rather complicated and do little to improve conditions for the field inspector. A review of existing methods was made to see if any could be applied to the solution of Department problems. Among the procedures considered were the "Humphres Method" (1), suited for use with granular materials only; the "Bureau of Reclamation Method" (2), which requires a three-point compaction test curve; and the "Ohio Department of Highways' Method" (3), requiring use of a large number of typical compaction curves.

The most promising approach, from the standpoint of simplicity and adaptability to Michigan density control procedures, appeared to be the Ohio method, which could be used for a one-point compaction control procedure. This method is based on the fact that most soils of the same maximum unit weight have similar moisture-density curves under a given compactive effort, and that the moisture-density curves of a group of soils having different maximum densities will fall into a particular family relationship when plotted together as a group. These relationships allow the study and reasonable prediction of moisture and density relationships under different conditions. The validity of these relationships has been clearly established by the Ohio Department of Highways in over 10,000 moisture-density tests (Fig. 1). The companion set of curves used to determine the field moisture content of a molded sample by means of a penetration needle is also shown in Fig. 1. The two groups of curves must be used together in order to select the proper curve (designated by capital letters in Fig. 1) for the conditions being tested. However, the use of penetration tests to determine moisture contents over such a wide range of soil gradations as are encountered in Michigan makes this method of moisture determination unacceptable to the Department. For this reason, it was decided to use the family of curves portion of Ohio's procedure but to determine moisture contents by drying or other methods. A convenient method now being evaluated by the Research Laboratory is the calcium carbide pressure method, commercially available as the "Speedy Moisture Tester."

<u>Development of the Michigan One-Point Chart</u>

Except for unusually low specific gravity soils (volcanic, micaceous, diatomateous, etc.) the shape and position of moisture-density curves plotted as a group are a function of unit weight, and such curves should have a wide geographic application. In order to check their applicability to Michigan soils, more than 100 moisture-density curves, obtained from the Testing Laboratory Division and Michigan field projects, were studied as plotted in the form of the Ohio curves. In general, the agreement was good.



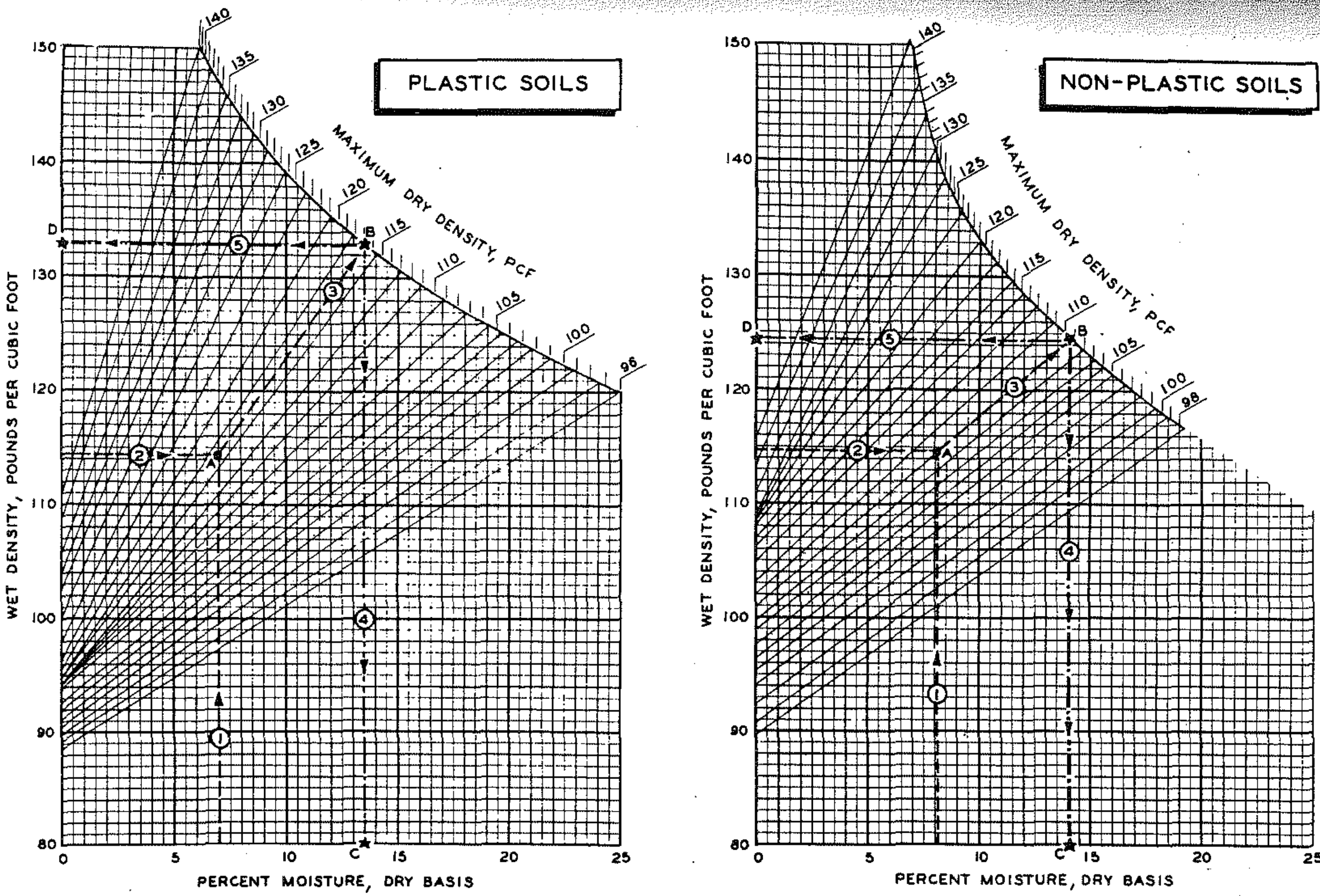
CURVE	MAX DRY WT LBS PER CU FT	OPTIMUM MOISTURE
A	141.8	6.6
B	139.1	7.2
C	136.3	7.9
D	134.1	8.5
E	132.0	9.0
F	129.3	9.7
G	126.6	10.5
H	124.2	11.2
I	121.7	11.9
J	119.3	12.7
K	117.0	13.5
L	114.6	14.6
M	112.0	15.8
N	109.6	16.9
O	107.1	18.1
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

Figure 1. Pattern of moisture-density curves for soils of different maximum unit weights (from the Ohio State Highway Testing and Research Laboratory).

In this connection, it should be realized that Ohio's curves have been idealized and about half are interpolations so that a perfect correlation should not be expected.

After careful study and statistical analysis of the Michigan data, it was thought that two sets of charts would be best suited for field use; one for plastic soils and one for non-plastic soils. Fig. 2 shows the first curves developed, based on this premise. These curves were tested in the field and in the laboratory and found to be satisfactory. It was noted, however, that most of the testing involved the use of the plastic soil chart--which also gave the higher design density.

At a meeting between personnel of the Road Construction Division and the Office of Testing and Research, it was recommended that a single chart be furnished for field evaluation even though it might not be quite as accurate as the two-chart method. Available data was re-analyzed and the chart shown in Fig. 3 was developed. This is a single chart which allows the optimum moisture, maximum dry density, and maximum wet density to be obtained from a single density and moisture determination by the standard T-99 compaction effort. The chart is self-contained so that all values can be obtained directly by simple operations. The shape and position of the curves are similar to those of the Ohio curves (which is to be expected) and the manner of using the curves is similar to that of a method described by the Bureau of Public Roads (4). There are modifications, however, permitting better correlation with Michigan soil conditions.



PROCEDURE

Compact field sample to standard Proctor (AASHO T-99-57) effort and obtain wet density and moisture content of this single sample.

Enter appropriate chart with these values and establish point "A" (steps 1 and 2).

From point "A" proceed between radial lines to intersection of boundary curve at point "B" (step 3).

Estimated maximum dry density can be read directly from designated curve at point "B."

Estimated optimum moisture can be obtained by proceeding vertically downward from point "B" to an intersection with the percent moisture abscissa at point "C" (step 4).

Estimated maximum wet density can be obtained by proceeding horizontally to the left from point "B" to an intersection with the wet density ordinate at point "D" (step 5).

Figure 2. Michigan's original one-point compaction charts for plastic and non-plastic soils.

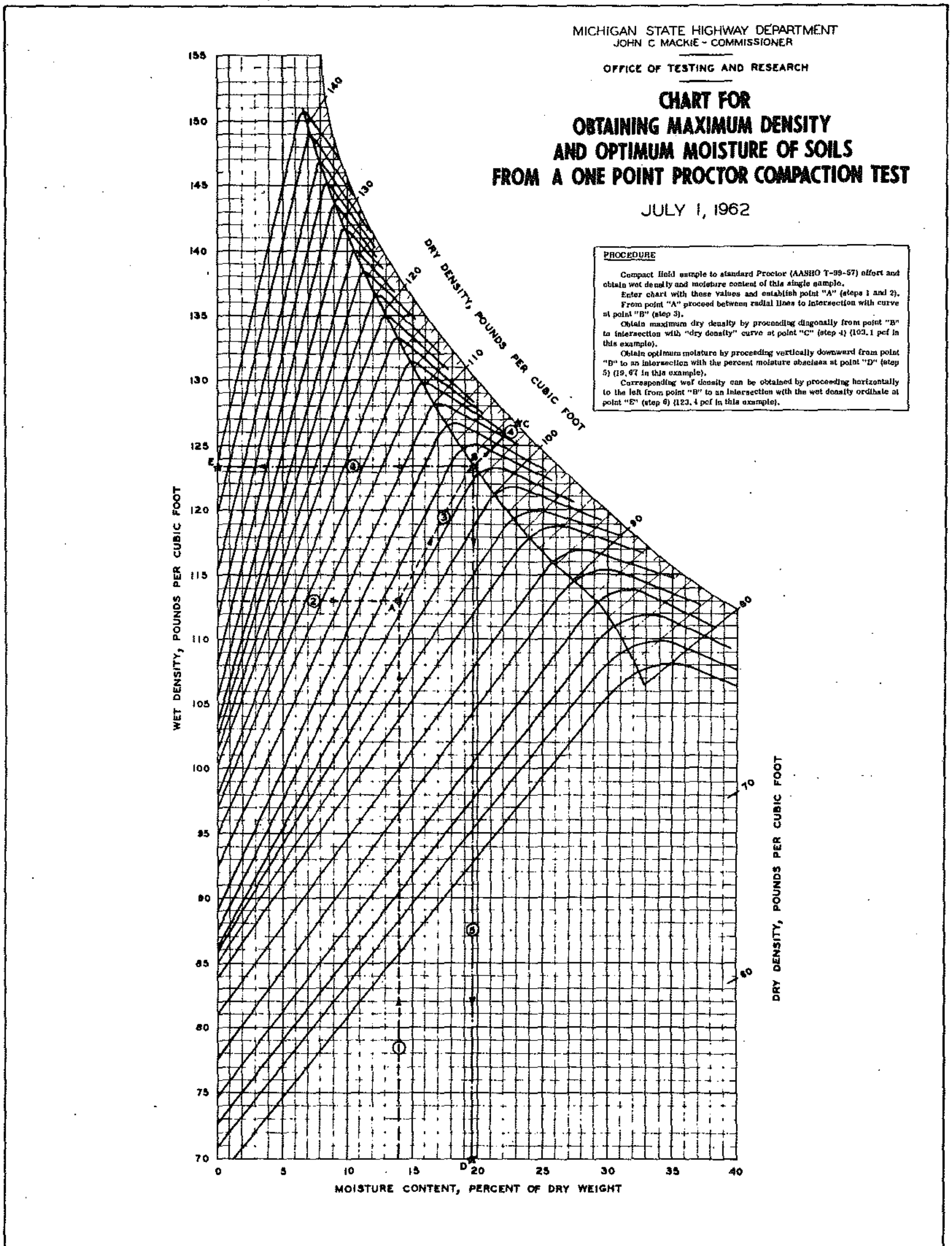


Figure 3. Michigan's single chart used to obtain maximum density and optimum moisture from a one-point compaction test.

During the 1962 construction season, the chart was tested by Department density inspectors under the supervision of Soils Division density personnel. Approximately 500 check tests were made and the chart has proved to be very accurate for predicting optimal density values. Laboratory check tests have also proved the value of this one-point density method.

Although this chart is designed for use for all soil moisture conditions, best results have been obtained when the sample is molded at optimum moisture or within a few percentage points below. Although provision is made to handle moisture contents above optimum, this portion of the chart does not have the accuracy of the portion below optimum values. Very dry conditions should also be avoided, to eliminate the effect of the "dog-leg" shape of many density curves in the low moisture range.

Although this chart has proved to be satisfactory under most field and laboratory conditions, it should be used with discretion. Statistical analysis shows a good correlation between test results and values predicted by the chart (Fig. 4). In evaluating this correlation it should be realized that the T-99 compaction test results do not always give results that can be exactly duplicated, and this also would cause some variation in the relationships. The value of the chart is quite evident, however, from the relationships shown in Fig. 4. Nevertheless, occasional soils may be found that do not conform too closely to the average conditions. In most cases such differences will be obvious and can be handled by the experienced density inspector in the field.

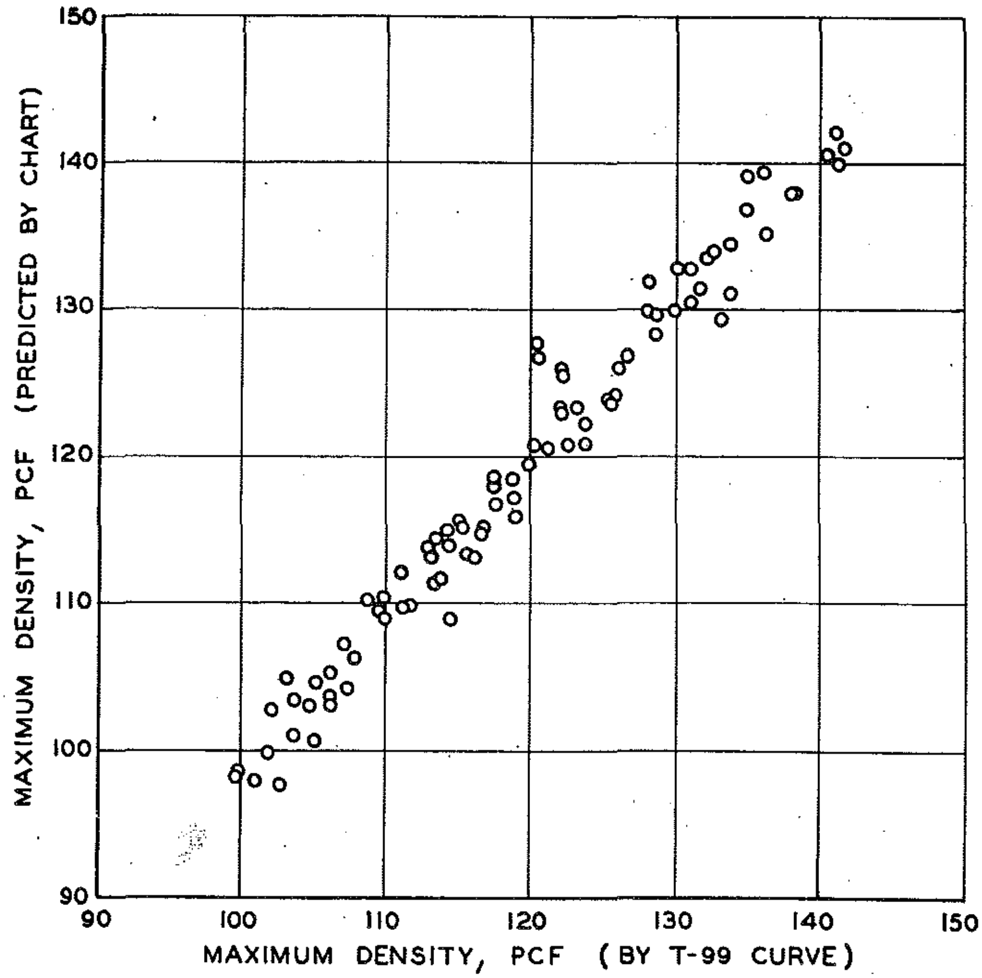


Figure 4. Correlation between maximum density values obtained by T-99 curve and by the one-point density chart.

Although the MSHD one-point density chart has been successfully used so far, it may be necessary to alter it from time to time to improve its accuracy and usefulness to the density inspector.

References

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