PRELIMINARY STUDY OF THE CONSTANT DRY WEIGHT (NO WEIGHING) METHOD OF COMPACTION CONTROL

MICHIGAN
HIGHWAY RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

PRELIMINARY STUDY OF THE CONSTANT DRY WEIGHT (NO WEIGHING) METHOD OF COMPACTION CONTROL

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Research Project 62 E-24(1)
Research Report No. R-850

Michigan State Highway Commission

Lansing, March 1973

This study forms part of the Research Laboratory's continuing program for improving compaction control procedures in highway construction. Other areas of this program which have been completed and reported include the use of nuclear methods for compaction control, development of one-point charts for predicting maximum density obtainable by the T-99 and Michigan cone tests, and evaluation and calibration of the "Speedy" moisture meter. Results of these studies are now incorporated in the Department's compaction control procedures.

The present study was initiated at the request of R. L. Greenman after a review of a new compaction control method evaluated and used by the Department of Highways of Ontario, Canada and reported to be faster and more simple to perform than the conventional method using the T-99 and Rainhart tests (1). The new procedures, referred to as the Constant Dry Weight or CDW method, yield the percent compaction by comparing volume of the in-place material with a compacted volume of the same material. This eliminates the need for weighing the materials (a substantial saving in the cost of balances) and considerably reduces the number of recordings and calculations needed to obtain the required values, thereby minimizing potential sources of error. The name of the test is derived from the fact that the dry weight of the sample remains the same throughout the test. The Ontario method has been studied and some field comparisons made with the Rainhart test, and the results appear promising enough to warrant further consideration of its use in Michigan highway construction.

Description of the Constant Dry Weight Method

The Constant Dry Weight Method is a volumetric test in which the degree of field compaction is obtained by measuring the volume of the sample in place and the volume of the same sample after remolding by the AASHO T-99 or other compactive effort. The percent compaction is the ratio of the minimum volume of soil at the specified compaction effort to the volume of the same soil in place.

Specific testing procedures are:

1. Measure volume of the in-place soil in the same manner as is now done, using the Rainhart balloon to determine the volume of the soil removed. The soil removed is placed in a pan and examined by sight and touch to determine its approximate moisture content.

2. Adjust the moisture content of the sample, if necessary, to near optimum by the methods suggested in Reference 1.

3. Compact the sample, now believed to be near optimum moisture, in the standard Proctor mold (a higher mold without collar can be used) using the required compaction effort. The standard Proctor effort requires 75 blows (25 for each of three layers) for a sample volume of .033 cu ft. Because the soil removed may have been of a different volume the as-measured volume is used to adjust the number of compaction blows necessary to give a compaction effort equal to the standard. A chart is furnished for indicating the required number of blows for different measured volumes.

4. Determine the volume of the compacted sample by averaging five measurements made with a calibrated dip stick (measured at quarter points of the circumference and at the center of the sample surface).

5. Compute the percent compaction of the in-place soil by dividing the volume of the material obtained in the mold by the volume of the test hole as measured by the Rainhart device.

6. If at this point there is a question as to the estimate of the moisture content of the compacted sample, the moisture content should be adjusted and the sample re-compacted. The lowest volume obtained is used to compute the percent compaction. According to the Ontario report, one moisture adjustment is usually sufficient and there is little to be gained by making more than two moisture adjustments.

Possible Advantages of the Constant Dry Weight Method

Several advantages appear to be possible using the CDW method as compared with the conventional Rainhart procedures:

1. The CDW method compares in-place Rainhart density of the test site with the design density required for the same soil. In this method it is not necessary to use one value of maximum density as representative of an area containing a large number of in-place measurements. Instead, the in-place and maximum densities are determined for the same soil sample so that it is unnecessary to assume that one maximum density value is representative of a large field area. The two methods would be approximately equivalent if conventional testing required determination of a maximum density for each Rainhart test.

2. Calculation of percent compaction, when using the conventional method, requires recording 16 columns of data, six of which must be computed. The CDW method requires only three columns of data, except for those conditions when additional compaction is required. Space on the data

sheet is provided for additional runs of compaction. Figures 1 and 2 compare the data sheets required for each method. Simplification of computations by the CDW method reduces the possibility of computational and recording errors.

3. The density inspector must play a more active role in the field testing when using the CDW method and must thoroughly understand the moisture and density relationship. Further, he must be able to recognize whether a soil is above or below optimum moisture and be able to adjust the moisture content accordingly.

4. Although the CDW procedure requires at least one compaction test of the sample and a possible moisture adjustment and an additional compaction, the method may still be faster than the conventional because of deletions of weighings, moisture content determination and many computations.

Accuracy of the CDW Method

Ontario investigators conducted over 500 field tests in which the Constant Dry Weight method was compared with their conventional Rainhart procedure and evaluated the effects of such factors as: different operators, different soil types, and variation between tests made within one square yard. Findings of these studies are summarized as follows:

1. Differences in test results obtained by the different operators were not statistically significant but further evaluation of this point was recommended.

2. No significant effect was noted due to different soil materials, which included fine sands, clays, and dense graded aggregate and crushed rock.

3. Average difference between results obtained by the Constant Dry Weight and the conventional methods was 0.4 pcf (the Constant Dry Weight results being the lower) with a standard deviation of 3.5 pcf. The 0.4 pcf bias was not considered to be statistically significant.

4. Conclusions of the report indicate that the accuracy and precision of the Constant Dry Weight method are comparable to those of the conventional method and because of its speed and simplicity is suitable for field compaction control.

In order to further evaluate the Constant Dry Weight method and to determine its applicability to Departmental construction operations, comparative tests were made on several construction projects using both the

CDW and conventional methods of compaction control. A total of 39 such tests were made using cohesive soils. For the CDW tests the soils were compacted at an estimated optimum moisture content so that no further moisture adjustments were made during the test. Results of these comparative tests are shown in Figure 3a. Further analysis of these data showed that, although the average moisture content for all of the tests was close to the desired optimum, there were individual tests which varied as much as 7.7 percent from optimum. The comparative results shown in Figure 3a show considerable scatter with a correlation coefficient of only 0.68.

When only those tests were considered in which the moisture contents were within two percent of optimum, there was considerably less scatter of the data with the correlation coefficient rising to 0.85 (Fig. 3b). Figure 4 shows the excellent correlation obtained between the two tests when used with a sandy subbase material, the density of which was relatively unaffected by the moisture content. These data illustrate the relative importance of moisture adjustment by the density inspector for different soil types.

Measurements in the laboratory revealed that the molded soil volumes, as measured by averaged dip stick readings, averaged 0.0008 cu ft less than the same volumes when measured by the Rainhart equipment. This resulted in density values of about two percent higher when using the dip stick to measure soil volume and this difference could account for most of the bias shown in Figures 3 and 4. The accuracy of the Rainhart volume measurement as compared to that obtained by averaging dip stick values remains to be determined, however.

Conclusions and Recommendations

As a result of this study it is concluded that the Constant Dry Weight method is valid in principle and, if performed as suggested in the Ontario report, will measure the degree of compaction with an accuracy comparable to that obtained with the conventional method. The test insures that proper design density is used as a basis of comparison for each in-place test location because the same soil is used to determine in-place and maximum design densities. The CDW method is easier to perform and requires less computations and data entry than do presently used conventional methods, but also requires greater responsibility and judgement on the part of the density inspector.

It is recommended that further study, extending through at least one construction season, be made to determine the following questions concerning the Constant Dry Weight methods:

1. How much time, if any, can be saved by using the test?

2. Would there be any difficulties training inspectors to correctly perform the test?

3. Is the method suitable for routine testing under normal field conditions?

Because these questions can be answered best under actual field construction procedures it is suggested that any approved study be conducted jointly by the Research Laboratory and the Soils and Materials Section. After an introductory course to acquaint District Density Inspectors with the CDW method, the Research Laboratory would provide special data sheets for use by the District Inspectors who would periodically perform CDW compaction tests in conjunction with Construction Density Inspectors who would be performing their operations using conventional compaction control procedures. Time of tests and any problems encountered would be recorded with test results. At the conclusion of the construction season the comparative values would be analyzed, statistically, by the Research Laboratory. On the basis of these records and study of operational procedures, final recommendations would be made concerning the suitability of the Constant Dry Weight method for supplementing or replacing present Rainhart method of compaction control.

REFERENCES

1. R. Schonfeld, "The Constant Dry Weight Method - A No-Weighing Field Compaction Test," Department of Highways, Ontario, Canada, Report No. RR141, Sept. 1968.

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
Office of Testing and Research
Soils Division

PERCENT COMPACTION DETERMINATION OF SOILS - CDW METHOD

State Proj. No. __________
Date __________ 19 _____
Tested By __________ Proj. Engr. __________

Original Test No.	Recheck Test No.	Volume of Soil in Place	Volume of Compacted Soil If moisture correction is necessary, use extra columns to record volume. Use minimum volume to compute percent compaction. Sample was: Wetted ☐ Dried ☐				Percent Compaction $\frac{\text{Col. 2}}{\text{Col. 1}}$	LOCATION OF TEST				
								Station	Dist. from ℄ Lt.	Dist. from ℄ Rt.	Depth Below Plan Grade	Item of Work
		1	2				3	4	5	6	7	8

DENSITY REQUIREMENTS

	% Density	Depth	Item of Work
Original Ground			
Road Embankment Areas (if specified)	90	9"	OG
Bridges --- Area defined by 1:1 line sloping from edges of footing down to original ground	90	9"	OG
Cut Areas			
Cuts requiring Sand Subbase	95	9"	CS
Cuts not requiring Sand Subbase	95	18"	CN

	% Density	Item of Work
Embankments		
Regular	95	E
Abutments with Piling	95	AP
Abutments without Piling -- Area defined by 1:1 line sloping from edges of footing down to original ground	100	AN
Backfill for Subgrade Undercuts	95	B

	% Density	Item of Work
Backfill for Bridges, Culverts, Sewers, Manholes, Catch Basins, Edge Drains	95	B
Sand Subbase	95	S
Selected Subbase		
(Constructed as a part of aggregate base)	100	AB
(Constructed separately)	95	SS
Aggregate Base Course	100	AB
Shoulders -- Class AA	100	SAA
Shoulders Class A and B	95	SA

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REMARKS: __________

Figure 1. Data sheet required to obtain compaction by Constant Dry Weight (CDW) method.

MOISTURE AND DENSITY DETERMINATION OF SOILS

Form 582 (Rev. 3/72)
Previous editions may be used until 9/72.

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
Testing and Research Division
Soils

Control Section Identification ____________________ Job No. ____________

Date ____________________ Weather ____________________

Tested By ____________________ Project Engineer ____________________

Original Test No.	Recheck Test No.	Per-cent Mois-ture	VOL. OF SAMPLE (In Cu. Ft.)		DENSITY DETERMINATION								LOCATION OF TEST				
					Weight in Grams				Pounds per cu. ft.					Dist. from ℄			
			Rain-hart	Mold	Wet Soil + Pan	Pan	Wet Soil	Wet Soil, lbs.	Com-pacted Soil Wet	Com-pacted Soil Dry	Max. Density	Per-cent of Com-paction	Station	Lt.	Rt.	Depth Below Plan Grade	Item of Work
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

NOTE: Col. 7 = $\frac{\text{Col. 6}}{453.59}$ or Col. 6 x 0.0022 | Col. 8 = $\frac{\text{Col. 7}}{\text{Col. 2 or 3}}$ | Col. 9 = $\frac{\text{Col. 8}}{\text{Col. 1} + 100}$ x 100 | Col. 11 = $\frac{\text{Col. 9}}{\text{Col. 10}}$ x 100

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REMARKS: ____________________

Figure 2. Data sheet required for obtaining compaction data by the conventional method (as used in the 1972 construction season).

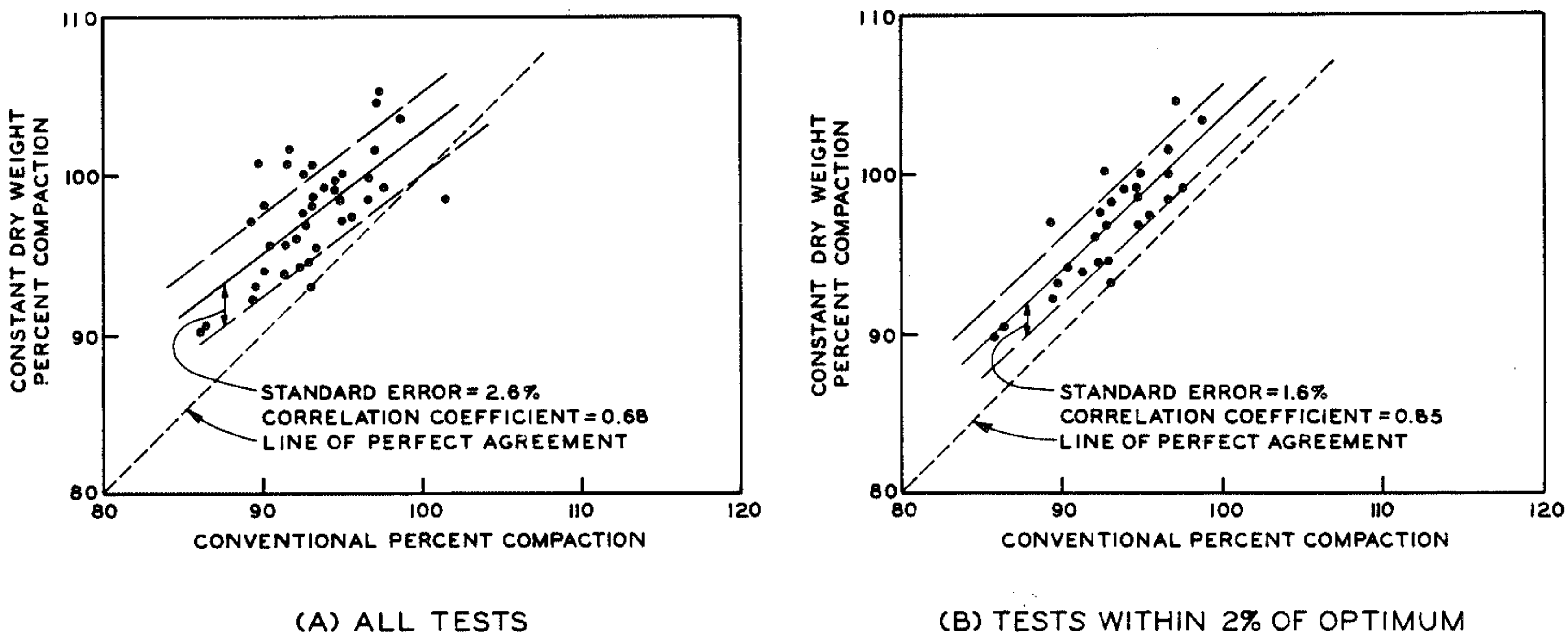

Figure 3. Comparison of Constant Dry Weight method and conventional compaction results.

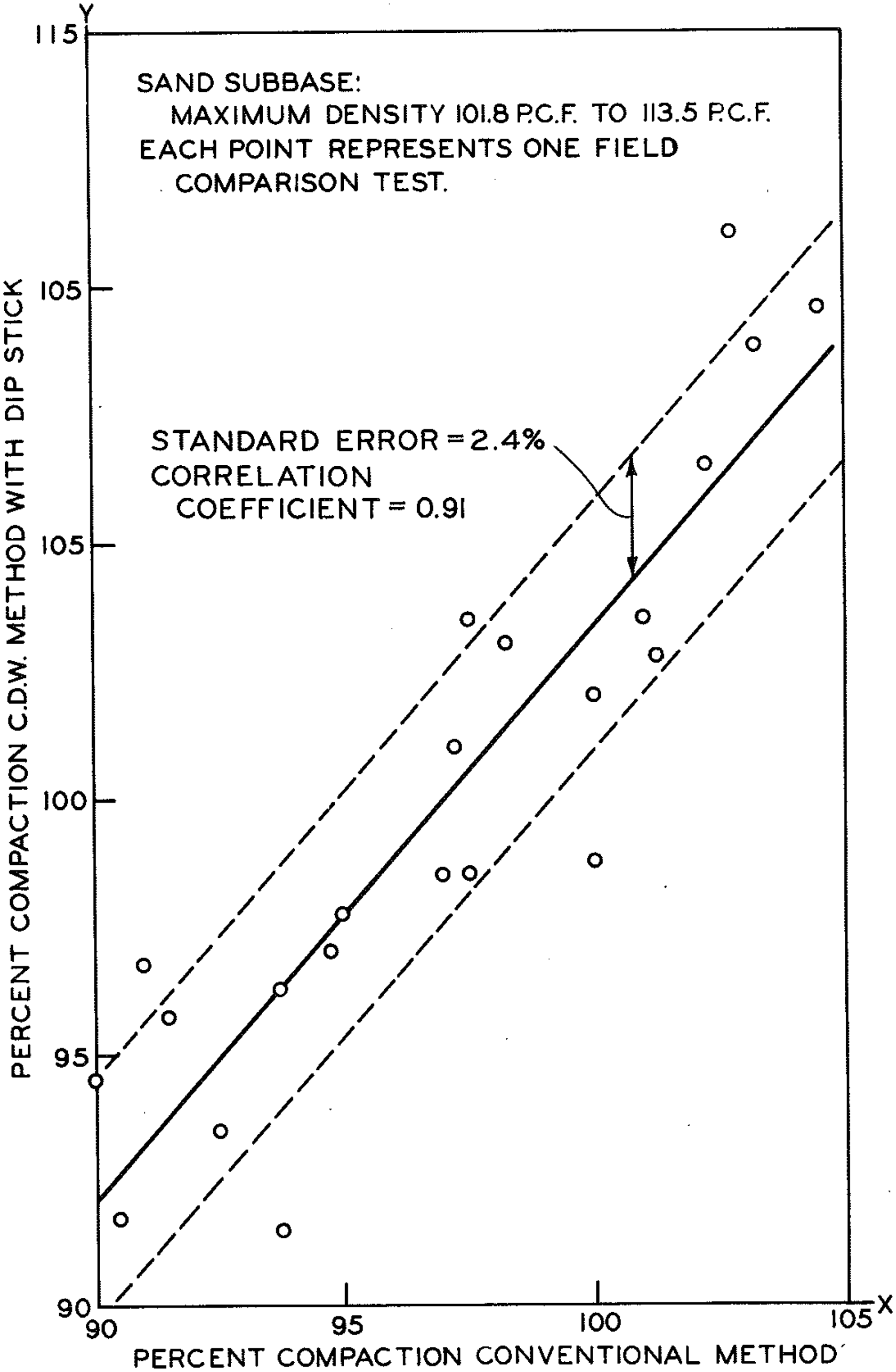

Figure 4. Conventional compaction results compared with CDW method.