DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Transportation Laboratory
5900 Folsom Boulevard
Sacramento, California 95819-4612

METHOD OF TEST FOR RELATIVE COMPACTION OF UNTREATED AND TREATED SOILS AND AGGREGATES

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read "**SAFETY AND HEALTH**" in Section K of this method. It is the responsibility of the user of this method to consult and use departmental safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. GENERAL SCOPE

This method of test shall be used to determine the relative compaction of untreated and treated soils and aggregates.

Relative compaction in this method is defined as the ratio of the in-place wet density of a soil or aggregate to the test maximum wet density of the same soil or aggregate when compacted by a specific test method.

The in-place, wet density shall be determined in accordance with Part 1 of this method of test.

The laboratory test maximum wet density and percent relative compaction shall be determined in accordance with Part 2 of this method of test.

PART 1. IN-PLACE WET DENSITY

A. SCOPE

The principal use of the in-place wet density value is in the relative compaction control of earthwork construction; however, the identical procedure and apparatus are also employed to obtain data for volume-to-weight conversion factors and shrinkage or swell factors. The determination of the in-place wet density requires excavating and weighing a sample of soil from the area under investigation, measuring the volume of the sample excavation by back-filling with a calibrated test sand, and calculating the unit wet weight of the excavated sample.

B. TEST PROCEDURE

This test shall be done in accordance with AASHTO T 191, "Density of Soil In-Place by the Sand-Cone Method."

NOTE: Typically, the test hole excavation alone will not provide a sufficient volume of material required for completion of Part 2 of this test method. Therefore, it is necessary to obtain a bulk sample of soil immediately adjacent to the excavated test hole following the completion of the sand volume measurement.

C. RECORDING DATA

The block headed "Sand Volume Data" on the Relative Compaction Test Worksheet provides for the data accumulated at the in-place test hole site.

PART 2. LABORATORY COMPACTED TEST MAXIMUM WET DENSITY AND PERCENT RELATIVE COMPACTION

A. SCOPE

A bulk sample of soil is divided into smaller portions. These portions are prepared with varying moisture contents

to form test specimens, which are individually compacted by a uniform compactive effort, to determine the test maximum density for the particular soil under consideration.

NOTE: The test maximum density determination and percent relative compaction for Class A CTB is determined according to California Test 312.

B. APPARATUS

1. The standard California impact compaction test apparatus consisting of a split cylindrical mold, a 10.0 lb tamper, a metal piston, and a piston-handling rod, as illustrated in Attachment 1. (Note: see CTM 110 for calibration.)

2. A concrete base block, or an equally rigid body, approximately 1 cubic foot in size.

3. A balance or scale of at least 3 kg capacity and sensitive to 1 g.

4. Miscellaneous mixing bowls, spoons and spatulas, five moisture-sealed containers (approximately 1 gallon capacity) to be used to store each specimen and five moisture-sealed containers (approximately ¼ gallon capacity) to be used to store each portion of a specimen.

C. BULK SAMPLE

Obtain a bulk sample of soil, 35 lbs minimum in weight, at the site of the in-place density test hole. It is essential that the bulk sample be preserved at the same moisture as prevailed at the time of excavation for the duration of the test. Use only moisture-proof containers and protect from high temperatures.

D. PREPARATION OF TEST SPECIMENS

1. Separate the bulk sample on the ¾-inch sieve, and weigh both the retained and passing fractions and compute the percentage retained in terms of wet weight of the total bulk sample. If 10 % or more of the total weight is retained on ¾-inch sieve, follow the test procedure set forth in Section I of this Part 2. If the retained ¾-inch fraction comprises less than 10 % by weight of the total bulk sample, discard it and divide the passing ¾-inch fraction into representative test specimens of exactly equal weight, each sufficient in amount to form a compacted test specimen of 10 to 12 inches in height when compacted as specified in the following section E.

2. It is of the utmost importance that all of the bulk sample material be thoroughly mixed. Each test specimen must be representative of the mass, be of equal weight, be weighed in immediate succession, and be placed at once in the one-gallon moisture-sealed individual containers.

3. The correct weight for each test specimen will depend on the soil type and the moisture content; 2200 to 2700 grams wet weight is the usual range of weight.

4. Record the initial weight of the individual test specimens on line “I” of the Relative Compaction Test Worksheet.

E. COMPACTION OF TEST SPECIMENS

1. Divide one of the test specimens prepared as outlined in the foregoing Section D into five approximately equal portions by either weight or volume measurement, and store in separate ¼-gallon moisture-sealed containers. Place one portion in the test mold and compact it with 20 blows of the tamper dropping free from a height of 18 inches above the surface of the material in the mold. Repeat this operation for each of the remaining four portions. After the compaction of the fifth portion, place the piston in the mold and level the top of the compacted specimen with five blows of the tamper dropping free

from a height of 18 inches above the surface of the piston.

2. With the tamper foot resting on the piston atop the compacted test specimen, read the graduated tamper shaft to the nearest graduation at a point level with the top of the mold. Enter this value on line "J."

3. Obtain the adjusted wet density in grams per cubic centimeter from Table 1 corresponding to the tamper shaft graduation reading using the column corresponding to the initial wet weight of test specimen (line "I") and record it on line "K."

4. Save the specimen temporarily for possible later use. (See the first paragraph of Section G of this Part 2).

5. Adjust the moisture contents of the remaining test specimens to satisfy the following conditions:

   a. The object is to have at least one test specimen with a moisture content below test optimum, one close to optimum and one above optimum, at about 2 % moisture content increments, with a minimum of three test specimens. While the actual moisture contents will not be known, the moisture content of the test specimen with the highest adjusted wet density is the test optimum moisture content even though the moisture content is unknown. Therefore, the primary objective is to have a number of test specimens and a range of moisture contents such that at least one specimen will be compacted at a moisture content less than, and one at a moisture content greater than, the moisture content of the specimen having the highest adjusted wet density. If this condition cannot be satisfied with the minimum three test specimens it will be necessary to fabricate additional specimens.

   b. The first test specimen is generally compacted at the moisture content present in the bulk sample. If this specimen appears to be considerably drier than the optimum, mix additional water into each of the remaining specimens. If it appears to be definitely wetter than the optimum, reduce the moisture content of the other specimens by aeration. Partial oven drying may be used, but do not completely oven-dry the specimens and then remix with water. If it appears to be close to the optimum, increase the moisture content of one of the remaining test specimens and reduce it in the other one to bracket the initial specimen thought to be at optimum.

   c. The test optimum moisture content will usually be the minimum moisture content which will ball the soil readily when compressed into a roll by the grip of the hand, but still permit the roll to be broken without crumbling or pulverizing appreciably at the breaking point.

   d. The base plate of the test mold normally shows indications of dampness when a soil is compacted at the test optimum moisture content. Free water on the base plate definitely denotes excessive moisture content. A dry, dusty base plate signifies a deficiency of water.

6. After adjustment of the moisture content, compact each of the remaining test specimens in the mold, then record the water adjustment, tamper reading and the corresponding adjusted wet density from the chart on Table 1 using the column corresponding to the initial wet weight (line "I").

7. Regardless of the soil type or particle sizes involved, fresh soil (not soil

from previously compacted specimens) must be used in the compaction of each test specimen. The compactive effort being equal for each layer, it is also important that the thickness of layers be equal to assure uniformity of compaction between test specimens.

8. Throughout the compacting operation the test mold must stand either on the standard concrete base block or on an equally rigid body.

9. In reassembling the test mold after removing a core, the wing nut should be drawn up only finger tight. The purpose of the wrench is to release the wing nuts when locked by expansive soils in the mold. Excessive tightening of the nuts distorts the circular cross-section of the mold. In gauging the 18-inch height of fall for the tamper, the hook and rod arrangement, shown in Attachment 1, should be used.

F. COMPUTATION OF RELATIVE COMPACTION

Compute the percent relative compaction to the nearest 0.1 % by the formula:

% Relative Compaction = $(D_1/D_2) \times 100$

Where:

D_1 = In-place wet density as shown on line "H."
D_2 = Highest adjusted wet density as determined by this method.

For reporting and specification compliance purposes, show the percent relative compaction as a whole number. If the computed value ends in a number with a fractional portion of 0.5 % or greater, report the relative compaction as the next higher whole number. If the computed value ends in a number with a fractional portion of less than 0.5 %, report it without changing the whole number.

Attachment 3 presents an example of a properly completed Relative Compaction Test Worksheet.

G. MOISTURE CONTENTS

The moisture content of the specimen with the highest adjusted wet density is the optimum moisture. The moisture content of the specimen compacted without addition or reduction of water will represent the in-place moisture content of the soil at the test site. If either moisture content is desired, the determination is made in accordance with California Test 226. Once the moisture contents are determined, percent relative compaction can also be determined by relating dry in-place density to dry test maximum density.

Provision is made at the bottom of the Relative Compaction Test Worksheet for determination of the Moisture Adjustment for Aggregate Base Pay Quantities, if desired.

H. MOISTURE-DENSITY CURVE

A moisture-density curve may be formed by plotting the adjusted wet density versus change in grams of water added or subtracted in adjusting the moisture contents of the test specimens. The sample curve appearing on Attachment 3 was plotted from the data presented on line "K" and the "Water Adjustment" line.

The highest point on the curve represents the maximum density, in this instance 2.14 at 0 grams of water ("0 grams" thus means in-place moisture content at test site is optimum moisture).

I. CORRECTION FOR OVERSIZE MATERIAL

1. The diameter of the test mold limits the size of particles that may be included in the test to that passing ¾-nch sieve. In those instances where the original material from which the test specimens are obtained contains 10 % or more by weight of particles retained on the ¾-inch sieve,

a correction must be applied to the test.

The density correction is calculated by the following:

$$\text{Corrected Density} = \frac{100}{\frac{\%\ -3/4\ \text{inch}}{G_1} + \frac{\%\ +3/4\ \text{inch}}{YG_2}}$$

G_1 = Specific gravity of – 3/4 inch material
G_2 = Specific gravity of +3/4 inch material
Y = Coefficient for +3/4 inch aggregate

% +3/4 inch	Y
20 or less	1.00
21-25	0.99
26-30	0.98
31-35	0.97
36-40	0.96
41-45	0.95
46-50	0.94

2. Record the total weight of bulk sample on line "L."

3. Separate the bulk sample on the ¾-inch sieve, wash the retained ¾-inch material, remove excess surface water by rolling sample in a large, absorbent cloth. Weigh in air and record on line "M."

1. Weigh the retained ¾-inch fraction in water and record on line "N."

5. The impact test is performed on the passing ¾-inch fraction as outlined in Sections C through E of this Part 2.

6. The remainder of the calculations necessary to compensate for the retained ¾-inch material and to determine percent relative compaction is shown on lines "O" through "V."

7. When a number of tests on soil containing essentially the same nature of retained ¾-inch material are anticipated, a constant may be developed to minimize the weighing in air and water operations.

J. SIMPLIFICATIONS FOR CONSTRUCTION CONTROL

Construction control by wet density tests may be expedited. If the relative compaction based on any test specimen density is below the specified minimum it may be immediately reported that the area under test has failed to meet the specifications. It is not necessary to fabricate additional test cores for the reason that if a higher wet density was reached with subsequent test cores the relative compaction based on this higher density would be still lower than that indicated by the single core. When the relative compaction indicated by a single test core is more than the minimum specified, additional cores are necessary to be certain that any increase in wet test maximum density attained with the subsequent cores does not lower the relative compaction value to below the specification minimum.

K. SAFETY AND HEALTH

Prior to handling, testing or disposing of any waste material, testers are required to read Part A, (Section 5.0), Part B, (Section 5.0, 6.0, 10), and Part C, (Section 1.0) of Caltrans Laboratory Safety Manual.

REFERENCES
California Tests 231, 312, 226 and 110
ASTM D 1556

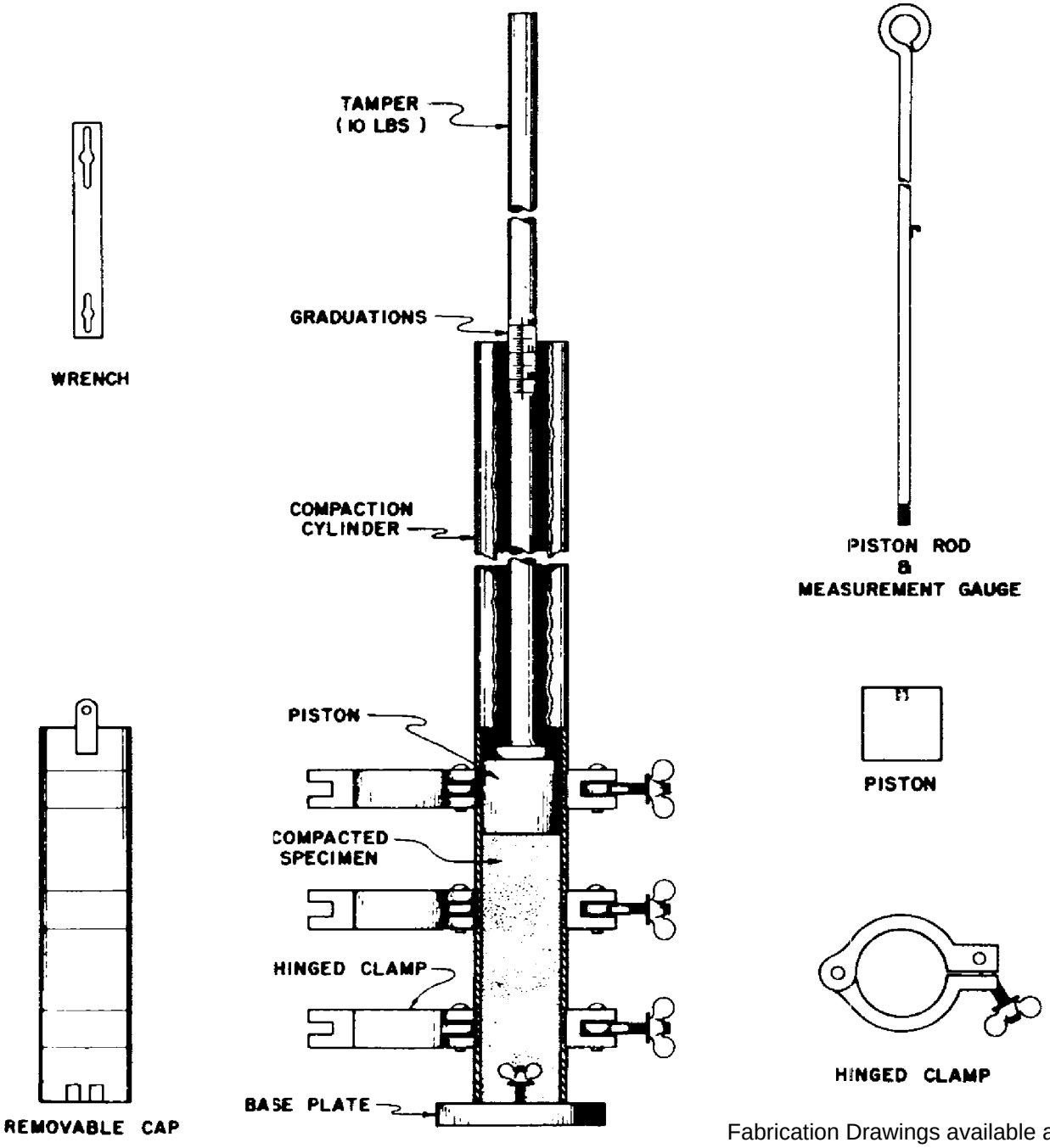
End of Text
(California Test 216 contains 9 pages)

TABLE 1
CALIFORNIA IMPACT TEST APPARATUS CONVERSION TABLE

Tamper Reading to Grams per Cubic Centimeter for Impact Test Core Weights

Tamper Reading	Weight of Test Core (g)										
	2200	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700
10	2.09	2.13	2.18	2.23	2.27	2.32	2.37	2.42	2.46	2.51	2.56
10.1	2.06	2.11	2.16	2.21	2.25	2.30	2.35	2.39	2.44	2.49	2.53
10.2	2.04	2.09	2.14	2.18	2.23	2.28	2.32	2.37	2.42	2.46	2.51
10.3	2.02	2.07	2.12	2.16	2.21	2.25	2.30	2.35	2.39	2.44	2.48
10.4	2.01	2.05	2.10	2.14	2.19	2.23	2.28	2.32	2.37	2.42	2.46
10.5	1.99	2.03	2.08	2.12	2.17	2.21	2.26	2.30	2.35	2.39	2.44
10.6	1.97	2.01	2.06	2.10	2.15	2.19	2.24	2.28	2.33	2.37	2.41
10.7	1.95	1.99	2.04	2.08	2.13	2.17	2.21	2.26	2.30	2.35	2.39
10.8	1.93	1.97	2.02	2.06	2.11	2.15	2.19	2.24	2.28	2.33	2.37
10.9	1.91	1.96	2.00	2.04	2.09	2.13	2.17	2.22	2.26	2.30	2.35
11	1.90	1.94	1.98	2.03	2.07	2.11	2.15	2.20	2.24	2.28	2.33
11.1	1.88	1.92	1.96	2.01	2.05	2.09	2.13	2.18	2.22	2.26	2.31
11.2	1.86	1.90	1.95	1.99	2.03	2.07	2.12	2.16	2.20	2.24	2.29
11.3	1.85	1.89	1.93	1.97	2.01	2.06	2.10	2.14	2.18	2.22	2.26
11.4	1.83	1.87	1.91	1.95	2.00	2.04	2.08	2.12	2.16	2.20	2.25
11.5	1.81	1.85	1.90	1.94	1.98	2.02	2.06	2.10	2.14	2.18	2.23
11.6	1.80	1.84	1.88	1.92	1.96	2.00	2.04	2.08	2.12	2.17	2.21
11.7	1.78	1.82	1.86	1.90	1.94	1.98	2.03	2.07	2.11	2.15	2.19
11.8	1.77	1.81	1.85	1.89	1.93	1.97	2.01	2.05	2.09	2.13	2.17
11.9	1.75	1.79	1.83	1.87	1.91	1.95	1.99	2.03	2.07	2.11	2.15
12	1.74	1.78	1.82	1.86	1.90	1.94	1.97	2.01	2.05	2.09	2.13

CALIFORNIA IMPACT COMPACTION APPARATUS



Fabrication Drawings available at:

Transportation Laboratory
5900 Folsom Blvd
Sacramento, CA 95819
916-227-7000

ATTACHMENT 1

STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

RELATIVE COMPACTION TEST

TL-297 (REV 10/2005)

Job Stamp	Location	Test No.
	Material	From
	Impact by	Sand Vol. By
	Date	Date

SAND VOLUME DATA		
A	Initial Wt. of Sand (g)	
B	Wt. of Residue (g)	
C	Wt. of Sand Used (A-B)	
D	Cone Correction (g)	
E	Wt. of Sand in Hole (C-D)	
F	Sand Density (g/cc)	
G	Volume of Hole (E/F)	
H	Wet Density (g/cc) (L/G)	

Remarks:

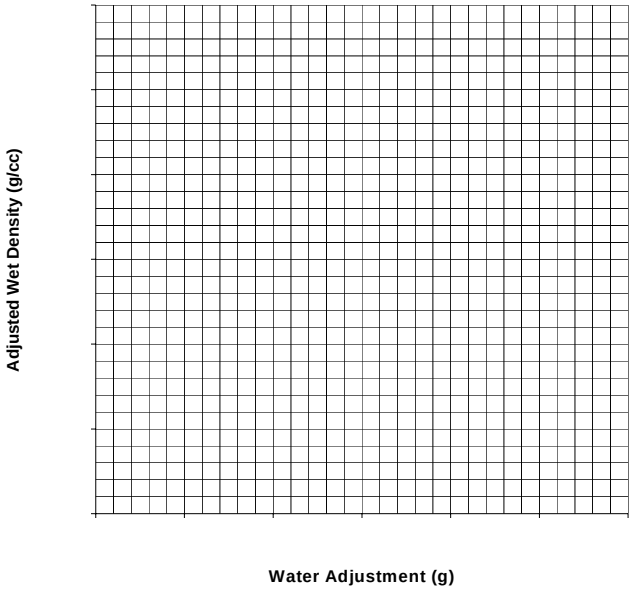
IMPACT TEST DATA

I	Initial Wet Weight of Test Specimen (g)				
	Increment	**1**	**2**	**3**	**4**
	Water Adjustment (g)				
J	Tamper Reading				
K	Adjusted Wet Density (g/cc)				

ROCK CORRECTION			
L	Total Sample Weight	(g)	
M	+ 3/4-inch Weight in Air	(g)	
N	+3/4-inch Weight in Water	(g)	
O	+3/4-inch Volume	(M - N)	
P	% +3/4-inch	100 * (M / L)	
Q	% -3/4-inch	100 - P	
R	Density of +3/4-inch	(M / O)	
S	(%+3/4-inch) / Density of +3/4-inch	(P / RY)	
T	(%-3/4-inch) / Density of -3/4-inch	(Q / K)	
U	Sum of S and T	(S + T)	
V	Average Adjusted Wet Density	(100 / U)	

Percent Relative Compaction*	Spec	Failed	or less
		Passed	

*(H / K) for 10% or less +3/4-inch; (H / V) for > 10% +3/4-inch



MOISTURE ADJUSTMENT FOR AGGREGATE BASE PAY QUANTITY					
a	In-place Wet wt.		**e**	Test Spec. Wet Wt. (opt.)	
b	In-place Dry wt.		**f**	Test Spec. Dry Wt.	
c	In-place Water (a - b)		**g**	Test Spec. Water (e - f)	
d	In-place % Water (c / b)		**h**	Test Spec. % Water (g / f)	
Moisture Corr. (h + 1%) - d =					
Moisture Corr. in excess of Opt. + 1%				% Moisture by CTM 226	

+ 3/4-inch Aggregate Adjustment (Y)

% + 3/4-inch (P)	Adjustment
20 or less	1.00
21-25	0.99
26-30	0.98
31-35	0.97
36-40	0.96
41-45	0.95
46-50	0.94

ATTACHMENT 2

STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

RELATIVE COMPACTION TEST

TL-297 (REV 10/2005)

Job Stamp	Location	Test No.
	Material	From
	Impact by	Sand Vol. By
	Date	Date

SAND VOLUME DATA

A	Initial Wt. of Sand (g)	11250
B	Wt. of Residue (g)	1429
C	Wt. of Sand Used (A-B)	9821
D	Cone Correction (g)	1641
E	Wt. of Sand in Hole (C-D)	8180
F	Sand Density (g/cc)	1.55
G	Volume of Hole (cc) (E/F)	5277
H	Wet Density (g/cc) (L/G)	2.06

Remarks:

IMPACT TEST DATA

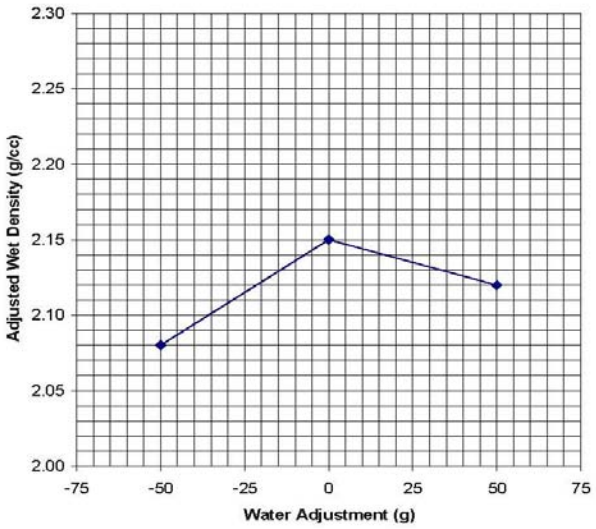
I	Initial Wet Weight of Test Specimen (g)	2500			
	Increment	1	2	3	4
	Water Adjustment (g)	-50	0	50	
J	Tamper Reading	11.4	11.0	11.2	
K	Adjusted Wet Density (g/cc)	2.08	2.15	2.12	

ROCK CORRECTION

L	Total Sample Weight	(g)	10865
M	+3/4-inch Weight in Air	(g)	3568
N	+3/4-inch Weight in Water	(g)	2322
O	+3/4-inch Volume	(M - N)	1246
P	% +3/4-inch	100 * (M / L)	32.8
Q	% -3/4-inch	100 - P	67.2
R	Density of +3/4-inch	(M / O)	2.86
S	(%+3/4-inch) / Density of +3/4-inch	(P / RY)	11.8
T	(%-3/4-inch) / Density of -3/4-inch	(Q / K)	31.3
U	Sum of S and T	(S + T)	43.1
V	Average Adjusted Wet Density	(100 / U)	2.32

Percent Relative Compaction*	Spec	Failed	89 or less
	90	Passed	

*(H / K) for 10% or less +3/4-inch; (H / V) for > 10% +3/4-inch



MOISTURE ADJUSTMENT FOR AGGREGATE BASE PAY QUANTITY

a	In-place Wet wt.		e	Test Spec. Wet Wt. (opt.)	
b	In-place Dry wt.		f	Test Spec. Dry Wt.	
c	In-place Water (a - b)		g	Test Spec. Water (e - f)	
d	In-place % Water (c / b)		h	Test Spec. % Water (g / f)	

Moisture Corr. (h + 1%) - d =

Moisture Corr. in excess of Opt. + 1%

% Moisture by CTM 226

+ 3/4-inch Aggregate Adjustment (Y)

% + 3/4-inch (P)	Adjustment
20 or less	1.00
21-25	0.99
26-30	0.98
31-35	0.97
36-40	0.96
41-45	0.95
46-50	0.94

ATTACHMENT 3