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PORTLAND CEMENT ASSOCIATION

Soil-Cement Inspector's Manual

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Contents

Foreword

This second edition of *Soil-Cement Inspector's Manual* outlines and illustrates procedures for inspection of soil-cement construction. Each step of proper inspection and control is explained; sample problems are given to show how to compute material quantities and perform field tests. Tables and charts to simplify these calculations are also included.

Other PCA publications of interest to the soil-cement inspector are listed at the back of this manual.

An Introduction to Soil-Cement

Soil-cement is a mixture of pulverized soil material and measured amounts of portland cement and water, compacted to high density. As the cement hydrates, the mixture becomes a hard, durable paving material. A bituminous wearing course is placed on the soil-cement base to complete the pavement.

Only three basic ingredients are needed for soil-cement: soil material, portland cement, and water. The soil in soil-cement can be a wide variety of materials. Either in-place or borrow material can be used. Old granular-base roads, with or without their bituminous surfaces, can be recycled to make soil-cement.

Soil-cement is sometimes called cement-treated base or cement-stabilized-aggregate base. Regardless of what it is called, the principles governing its composition and construction are the same.

Before construction with soil-cement starts, the soil materials that will be treated with cement should have been identified and representative samples of each type tested. These tests determine the minimum cement content required to harden each material adequately and the approximate optimum moisture content and density values for use in construction.

Soil-cement road construction involves two steps—preparation and processing. Variations in these steps are dictated by the type of mixing equipment used. Regardless of the equipment and methods used, it is essential to have an adequately compacted, thorough mixture of soil material with the proper amounts of cement and moisture. The completed soil-cement must be adequately cured.

Soil, cement, and water can be (1) mixed in place using traveling mixing machines, or (2) mixed in a central mixing plant. The types of mixing equipment are

1. Traveling mixing machines
   a. Flat-transverse-shaft type
      Single-shaft mixer
      Multiple-shaft mixer
   b. Windrow-type pugmill

2. Central mixing plants
   a. Continuous-flow-type pugmill
   b. Batch-type pugmill
   c. Rotary-drum mixers

Steps for construction with traveling mixing machines are

1. Preparation
   a. With in-place soil material
      Shape roadway to crown and grade.
      Scarify roadway soil material.
      Pulverize if necessary.
      Prewet as needed.
      Shape prepared soil material.
   b. With borrow material
      Shape subgrade to crown and grade.
      Compact subgrade.
      Place borrow material.
      Shape borrow material.
2. Soil-cement processing
      Spread portland cement and mix.
      Apply water and mix.
      Compact.
      Finish.
      Cure.

Construction steps for central-mixing-plant construction are

1. Preparation
      Shape subgrade to crown and grade.
      Compact subgrade.
2. Soil-cement processing
      Mix soil material, cement, and water in plant.
      Haul mixed soil-cement to roadway and spread.
      Compact.
      Finish.
      Cure.

Compacted and finished soil-cement contains sufficient moisture for adequate cement hydration. A moisture-retaining cover is placed over the soil-cement soon after completion to retain this moisture and permit the cement to hydrate. Most soil-cement is cured with bituminous material, but other materials (see page 57) are satisfactory.

Chapter 1

Checklist

Field inspection of soil-cement construction involves the control of five factors:

Cement content
Moisture content
Mixing
Compaction
Curing

The inspector can easily control these factors by organizing the inspection steps into a routine that fits in with the sequence of construction operations.

The following checklist covers the inspection steps required to assure quality soil-cement:

1. Have soil surveys, laboratory reports, plans, and specifications been reviewed and correlated with job conditions?
2. Have all soft subgrade areas been corrected? Has the roadway been shaped to crown and grade? Have manhole covers and other obstacles been removed or lowered?
3. Is all of the construction equipment properly adjusted and in good working condition?
4. Have the soil materials been pulverized sufficiently, and will their moisture contents allow them to mix readily with cement?
5. Has the proper quantity of cement been spread uniformly? Has the central mixing plant been properly calibrated?
6. Is the soil-cement mixture between optimum moisture and 2% above optimum moisture?
7. Is the mixture uniform and thoroughly mixed? Are the width and depth of treatment according to the plans?
8. Is the finished surface moist, dense, and free of compaction planes?
9. Is the soil-cement mixture at the transverse construction joint well mixed and compacted?
10. Are the specified density and depth of treatment being achieved?
11. Is sufficient curing material for complete coverage being applied? Where subjected to traffic, has the bituminous material been sanded sufficiently to prevent pickup?

12. Have any defects been repaired for full depth of treatment?

The proper methods of controlling each of these 12 items are described in following chapters.

Chapter 2

Inspection of Site Preparation

Before processing begins, laboratory reports, soil surveys, plans, and specifications are reviewed by the inspector. The inspector should be thoroughly familiar with the specifications and must insist upon compliance with them. The construction site is inspected to make sure that the soil materials are at proper grade and adequately pulverized, and that the subgrade is stable throughout the project.

Identification of Soil Materials

Cement requirements are determined in the laboratory before construction and are tabulated in the laboratory reports along with identification information for the soil. (See Fig. 1.)

The soil materials to be processed in the field are compared with the identification data given in the laboratory report and with information given in the plans and specifications. This will assure the use of the proper amount of cement. If there is an obvious difference between the materials tested and the soil materials on the site, further testing may be necessary.

Site Preparation

Areas of unstable subgrade must be corrected before processing starts, since proper compaction of soil-cement will not be possible if the subgrade cannot support the compaction equipment.

Unstable subgrade soils, which usually contain excess moisture, can generally be detected by observing their stability under the wheels of the motor grader as it shapes the area prior to soil-cement processing. Shallow wet spots can be improved by aerating and drying. When deep unstable areas are encountered, it is usually necessary to remove the underlying soil and replace it with better material. An alternate method of correction is to treat the subgrade with cement.

When in-place soil materials are used, the grade at the start of construction will influence the final cross section. Therefore, before processing is started, the roadway should be shaped to approximate crown and grade. Maintenance of

Soil-Cement Laboratory, Form Sheet No. 13

Date tests completed ____

SUMMARY OF TESTS ON SOIL-CEMENT MIXTURES

State ____ Project ____ Soil No. C

County ____ Field Project No. ____

Sampling location Represents top 6 in. of old gravel road. Taken at station 50+00

GRADATION

% passing	Soil mortar	Total sample
2-in. sieve (50mm)		100
¾-in. sieve (19mm)		95
No. 4 sieve (4.75mm)		82
No. 10 sieve (2.00mm)	100	66
No. 18 sieve (1.00mm)	83	55
No. 35 sieve (0.50mm)	68	45
No. 40 sieve (0.45mm)	65	43
No. 60 sieve (0.25mm)	55	36
No. 140 sieve (0.106mm)	38	25
No. 200 sieve (0.075mm)	32	21
% smaller than		
0.05mm	26	17
0.005mm	12	8
0.002mm	9	6

U.S. DEPT. OF AGRICULTURE SOIL CLASSIFICATION

Soil series ____

Soil horizon ____

Textural class Gr. coarse sandy loam

Color of moist soil Brown

PHYSICAL TEST CONSTANTS

L.L. 26

P.I. 8

AASHTO SOIL CLASSIFICATION

A-2-4(0)

COMPRESSIVE STRENGTH*, psi (MPa)

Cement content, % by wt	Age when tested, days: 2	7	28
6	295 (2.03)	540 (3.72)	770 (5.31)
10	340 (2.34)	795 (5.48)	965 (6.65)

*Specimens saturated in water before testing

DATA FROM WET-DRY AND FREEZE-THAW SPECIMENS

Cement content, % by wt	Total soil-cement loss, %: Wet-Dry	Freeze-Thaw
5.0	–	20
7.0	7	8
9.0	–	2

MATERIAL RETAINED ON NO. 4 (4.75mm) SIEVE

Absorption, % 2.0

Bulk sp. gravity 2.55

RECOMMENDATIONS

Recommended cement content 6.0 % by weight

6.86 lb/cubic foot (110 kg/m³)

which is 5.15 lb/square yard/inch of compacted thickness

Laboratory optimum moisture content** 11.5 %

Laboratory maximum density** 121.2 lb/cubic foot (1941 kg/m³)

Tests made on total sample using ¾ in. (19 mm) maximum size material

**Moisture-density tests made during construction govern field control.

Remarks: ____

Fig. 1. Summary of soil and soil-cement tests on Soil No. C.

Fig. 2. Unstable subgrade areas can usually be detected by observing their stability under the motor-grader wheels. Soft areas must be corrected before processing starts.

crown and grade prior to soil-cement construction will permit rapid runoff of water during heavy rains and is good insurance against wet spots developing.

Prewetting of dry, in-place soil materials is common practice. Applying water during preparation saves time during actual processing operations because most of the required water will already have been added to the soil material. In very granular materials, prewetting prevents cement from sifting to the bottom of the mix by causing it to adhere more readily to the sand and gravel particles.

Guide stakes should be set 1 ft (0.3 m) beyond the proposed pavement edges to control the width of treatment and to guide the equipment operators during construction.

Soil-cement street processing is facilitated by removing manhole covers and frames and covering the holes with heavy sheet metal or planks just below the depth to be processed. This permits processing over manholes without difficulty or delay. Manhole locations should be accurately referenced with offset stakes. After final finishing but before the soil-cement has hardened, manhole frames and covers are replaced. Soil-cement is then tamped (to maximum density) around the structures, or ready mixed concrete is placed and finished to grade.

Equipment Check

All equipment necessary for construction must be at the jobsite and in good operating condition before processing begins. A short trial run is valuable in assuring proper operation and adjustment of equipment.

Listed below are items that should be checked prior to processing.

Central Mixing

1. **Cement feed.** Is the cement meter on the central plant in good condition and in an exposed location where it can conveniently be calibrated? Does the plant include a surge tank between the cement silo and the feeder to maintain a constant head of cement for the feeder? Have air jets been installed in the hoppers to produce a loose, uniform, accurate flow of cement? Is there a positive connection between the soil feed and cement feed apparatus so that if the cement feed stops, the soil supply will stop?
2. **Mixer.** Are the paddles all in place and in good condition? Does the spraybar give a uniform, constant spray of water? Can the required quantity of water be delivered through the plant under maximum production?
3. **Transporting equipment.** Is the equipment of sufficient capacity to meet the production requirements? Are protective covers provided for use during bad weather?
4. **Spreader.** Is it in good operating condition and adjusted to spread the mixed soil-cement to the proper loose depth and width?

Mixed in Place

1. **Cement spreader.** Is the conveyor belt or chain on the cement spreader in good condition? Does the spreader run

smoothly? Are the proper gears and plates installed? Is the truck hitch operating properly?

2. **Cement trucks.** Are the cement trucks equipped with special hitches for attaching the cement spreader? Are the truck beds tight enough to prevent loss of cement? Are the trucks equipped with tarpaulins for protection against rain?
3. **Mixing machines.** Are the tines or paddles all in place and in good condition? Does the spraybar on each mixer give a uniform, constant spray? Be sure that it does not leak water when turned off.

Water Source and Equipment

Is there any chance that the water source is contaminated? If so, has the water been tested in the laboratory? Is the water pump in good working order? Are all of the nozzles on the spraybars unclogged? Have all leaks been eliminated?

Motor Grader

Is the motor grader blade in good condition and not worn excessively?

Fig. 3. Checking for water truck spraybar leakage.

Fig. 4. Screening soil-cement mixture through No. 4 (4.75-mm) sieve to determine percent pulverization.

Compaction Equipment

Is the tamping roller filled with water or sand? Are the tamping feet the proper size, shape, and length for the type and thickness of soil to be processed? Are the rubber-tire and steel-wheel rollers of the proper weight?

Pulverization

Most soil materials require little if any pulverization before processing starts. However, the heavier clayey soils do require some preliminary work. The keys to pulverization of clayey soils are proper moisture control and proper equipment.

Most specifications require that, at the completion of moist mixing, 80% of the soil-cement mixture pass the No. 4 (4.75-mm) sieve and 100% pass the 1-in. (25-mm) sieve, exclusive of gravel or stone retained on these sieves. This is checked by making a pulverization test. The test consists of screening a representative sample of soil-cement through a No. 4 (4.75-mm) sieve. Any gravel or stone retained on the sieve is picked out and discarded. The clay lumps retained and the pulverized soil passing the No. 4 (4.75-mm) sieve are weighed separately and their dry weights determined. The degree of pulverization is calculated as follows:

$$\% \text{ pulverization} = \frac{\text{dry weight of soil-cement mixture passing No. 4 (4.75-mm) sieve}}{\text{dry weight of total sample exclusive of gravel retained on No. 4 (4.75-mm) sieve}} \times 100$$

For practical purposes, wet weights of materials are often used instead of the corrected dry weights. The wet-weight measurements are reasonably accurate and permit immediate adjustments in pulverization and mixing procedures if necessary.

Pulverization can be improved by

1. Slower forward speed of the mixing machine
2. Additional passes, if using a multiple-pass mixing machine
3. Replacing worn mixer teeth
4. Prewetting and premixing the soil before processing begins

Soil material that contains excessive moisture will not mix readily with cement; therefore, the moisture content of the material should be checked visually before cement is applied. The percentage of moisture in the material at the time of cement application should not exceed the optimum moisture content.

Chapter 3

Inspection of Processing Operations

Soil-cement construction operations are well suited to an orderly procedure of inspection and field control. This procedure is aimed at controlling the amount of cement and water, and the degree of mixing and compaction.

Daily processing is best carried out in several sections rather than one long section. This permits more efficient use of equipment and thus speeds up operations. It also permits compliance with time limits for moist-mixing, compacting, and finishing, as given in the specifications.

Cement Application

Since cement hydration practically ceases when temperatures approach freezing, cement should not be applied when air temperature is 40° F (4° C) or lower. Cement must not be applied when the soil material or subgrade is frozen.

The amount of cement required is specified either as a percentage of cement by weight of oven-dry soil material, or in pounds of cement per cubic foot (kilograms per cubic meter) of compacted soil-cement.* Fig. 5 can be used to convert from one to the other if the maximum dry density of the compacted soil-cement is known.

EXAMPLE 1.
Calculate the quantity of cement per cubic foot of compacted soil-cement.

GIVEN: Maximum dry density of compacted soil-cement .. 121.2 lb per cubic foot (1941 kg/m^3)

Specified cement content by dry weight of soil material . . . 6%

PROCEDURE: Calculate the weight of soil material by dividing the weight of soil-cement by the quantity 1 plus the cement content expressed as a decimal:

$$\frac{121.2}{(1.0 + 0.06)} = 114.3 \text{ lb per cubic foot (1831 kg/m}^3\text{)}$$

The quantity of cement in each cubic foot is

$$121.2 - 114.3 = 6.9 \text{ lb per cubic foot (110 kg/m}^3\text{)}$$

*Previous editions of this handbook used percentage of cement by volume as an alternate method of expressing cement content. This was based on a 94-lb (43-kg) U.S. bag of cement.

TABLE 1. Normal Range of Cement Requirements for B- and C-Horizon Soils*

AASHTO Soil Group	Cement, percentage by weight of soil	Cement, pounds per cubic foot of compacted soil-cement	Cement, kilograms per cubic meter of compacted soil-cement
A-1-a	3-5	5-7	80-110
A-1-b	5-8	7-8	110-130
A-2-4			
A-2-5			
A-2-6	5-9	7-9	110-140
A-2-7			
A-3	7-11	8-11	130-180
A-4	7-12	8-11	130-180
A-5	8-13	8-11	130-180
A-6	9-15	9-13	140-210
A-7	10-16	9-13	140-210

*A-horizon soils (topsoils) may contain organic or other material detrimental to cement reaction and thus require higher cement factors. For dark grey to grey A-horizon soils, increase the above cement contents 4 percentage points (4 lb/cu ft [60 kg/m³] of compacted soil-cement); for black A-horizon soils, 6 percentage points (6 lb/cu ft [100 kg/m³] of compacted soil-cement).

TABLE 2. Average Cement Requirements of Miscellaneous Materials

Material	Cement, percentage by weight of soil	Cement, pounds per cubic foot of compacted soil-cement	Cement, kilograms per cubic meter of compacted soil-cement
Caliche	7	8	130
Chat	7	8	130
Chert	8	8	130
Cinders	8	8	130
Limestone screenings	5	7	110
Marl	11	10	160
Red dog	8	8	130
Scoria containing plus No. 4 material	11	11	180
Scoria (minus No. 4 material only)	7	8	130
Shale or disintegrated shale	10	10	160
Shell soils	7	8	130
Slag (air-cooled)	7	8	130
Slag (water-cooled)	12	9	140

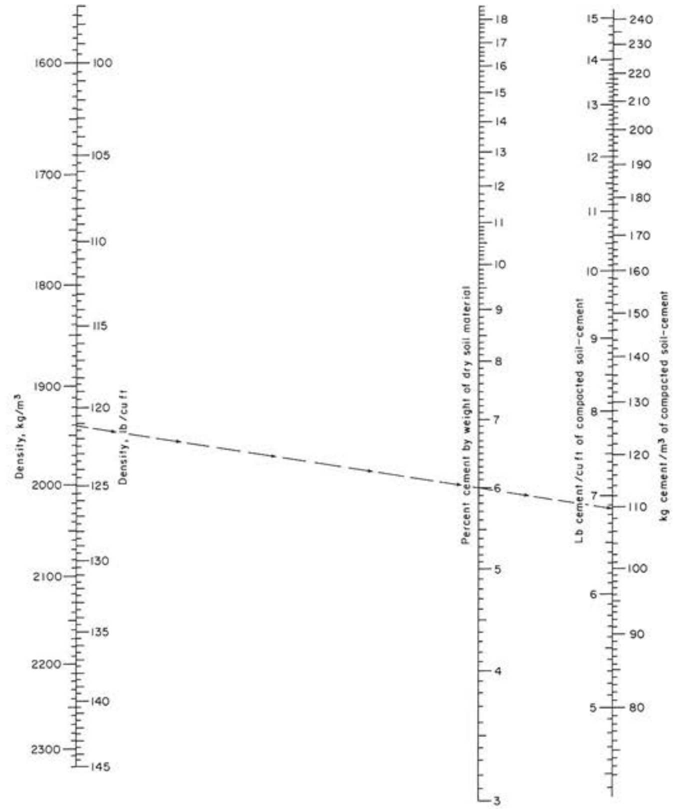


Fig. 5. Cement factor conversion chart.

Cement Application for Mixed-in-Place Construction

Bulk cement spreaders should be operated at a constant slow rate of speed and a relatively constant level of cement kept in the hopper to obtain a uniform cement spread. A true line at the edge of the pavement should be maintained by using a stringline. There should be no skips between spreading lanes.

Fig. 6 and Table 3 can be used to determine quantities of

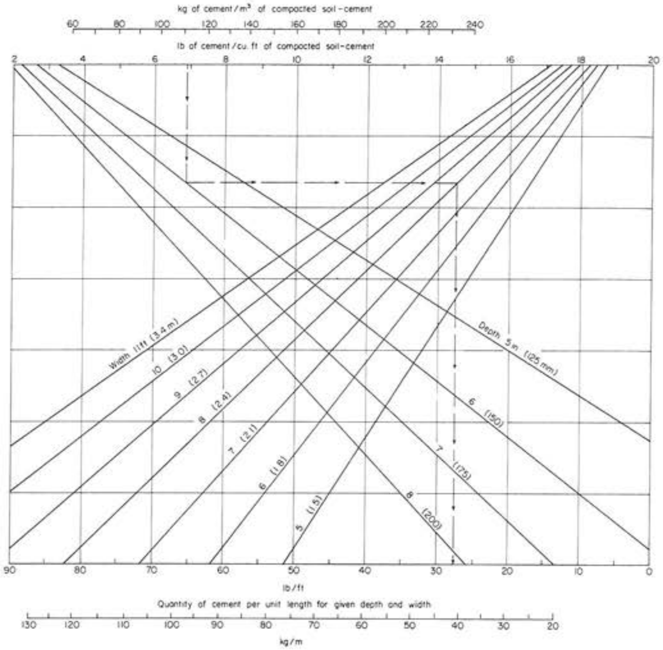


Fig. 6. Quantity of cement per unit length for given depth and width of treatment for specified cement contents.

cement per square yard (square meter) of pavement or per linear foot (meter). If the soil-cement is mixed in windrows, Fig. 7 can be used to determine cement quantities per linear foot (meter) of windrow.

Check on Cement Spread

A check on the accuracy of the cement spread is necessary to ensure that the proper quantity is actually being applied. When bulk cement is being used, the check is made in two ways:

1. Spot check. Place a canvas, usually 1 sq yd (1 m²) in area,

TABLE 3. Cement Spread Requirement, Pounds per Square Yard per Inch of Compacted Thickness (kg/m² per 10 mm)

Cement content, pounds per cubic foot of compacted soil-cement	Cement spread, pounds per square yard per inch of thickness of compacted soil-cement	Cement content, kilograms per cubic meter of compacted soil-cement	Cement spread, kilograms per square meter per 10 mm of thickness of compacted soil-cement
4.5	3.38	72	0.72
5.0	3.75	80	0.80
5.5	4.13	88	0.88
6.0	4.50	96	0.96
6.5	4.88	104	1.04
7.0	5.25	112	1.12
7.5	5.63	120	1.20
8.0	6.0	128	1.28
8.5	6.38	136	1.36
9.0	6.75	144	1.44
9.5	7.13	152	1.52
10.0	7.50	160	1.60
10.5	7.88	168	1.68
11.0	8.25	176	1.76
11.5	8.63	184	1.84
12.0	9.0	192	1.92
12.5	9.38	200	2.00
13.0	9.75	208	2.08
13.5	10.13	216	2.16
14.0	10.50	224	2.24
14.5	10.88	232	2.32
15.0	11.25	240	2.40
15.5	11.63	248	2.48
16.0	12.0	256	2.56

on the roadway ahead of the cement spreader. After the spreader has passed, carefully pick up the canvas and weigh the cement collected on it.

2. Overall check. Check the distance of area over which a truckload of cement of known weight is spread.

EXAMPLE 2.

Determine the linear distance a truckload of cement should travel to spread the required amount of cement.

GIVEN: Required cement content ..... 6.9 lb per cubic foot (110 kg/m³)
Depth of compacted soil-cement .... 6 in. (150 mm)
Width of spread .... 8 ft (2.4 m)
Weight of truckload of cement .... 15,400 lb (6990 kg)

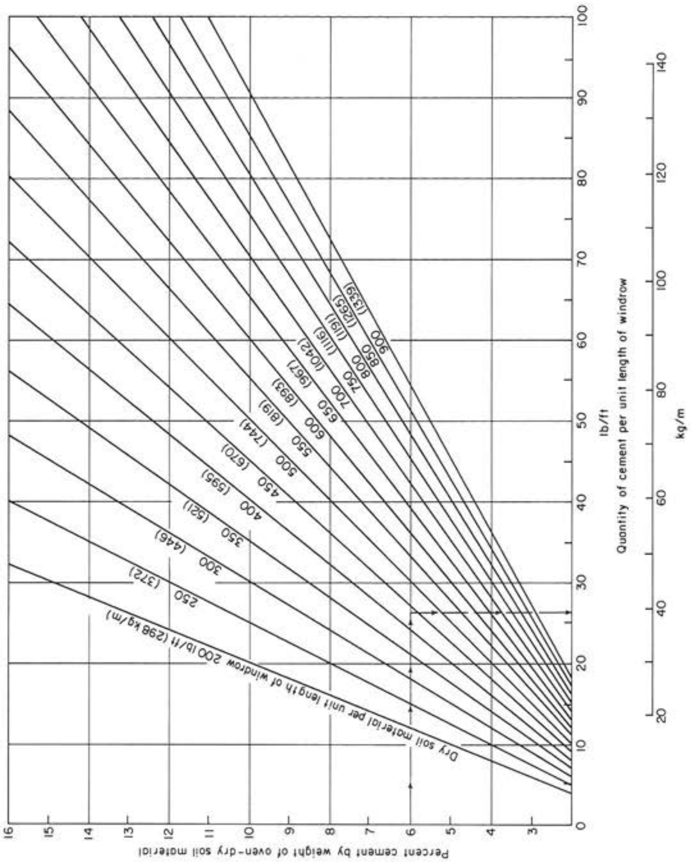


Fig. 7. Quantity of cement per unit length of windrow for specified cement content.

PROCEDURE: Enter Fig. 6 on the top edge at 6.9 lb of cement per cubic foot (110 kg/m³) and proceed vertically to the 6-in. (150-mm) depth line; proceed horizontally to intersection with line representing 8-ft (2.4-m) width of spread; then proceed

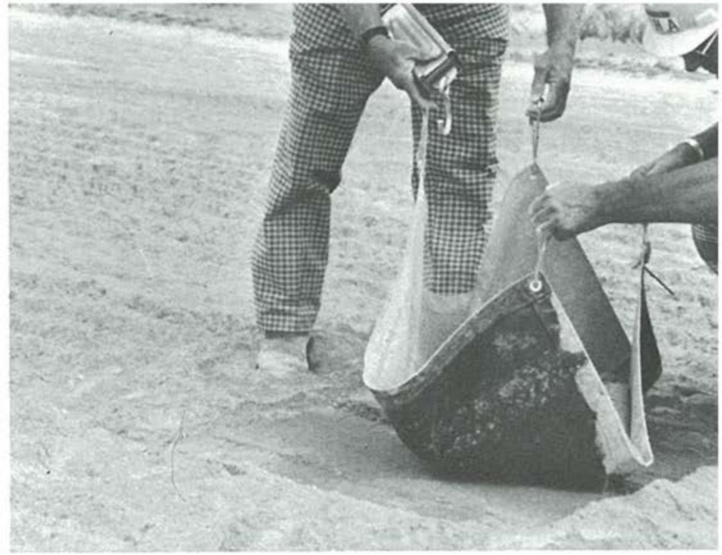


Fig. 8. Weighing cement collected on a square yard (m²) of canvas is a check on the quantity of cement spread.

vertically to the bottom edge and read the quantity of cement per unit length required: 27.6 lb per foot (41.1 kg/m).

The required distance of travel for the 15,400-lb (6990-kg) truckload of cement to obtain the specified cement spread equals the total weight of cement on the truck divided by the pounds (kilograms) per linear foot (meter) required:

$$\frac{15{,}400}{27.6} = 558 \text{ ft } (170 \text{ m})$$

If the truck traveled only 530 ft (161 m), more than the required quantity of cement was applied and the spreader should be adjusted to spread slightly less cement. The quantity of cement actually spread in this case is:

$$15{,}400 \text{ lb} \div 530 \text{ ft} = 29.1 \text{ lb/foot } (43.3 \text{ kg/m})$$

or

$$29.1 \text{ lb/ft} \div 4 \text{ cu ft/ft}^* = 7.3 \text{ lb per cubic foot } (117 \text{ kg/m}^3)$$

This is compared to 6.9 lb per cubic foot (110 kg/m³) required.

*Spread is for 1-ft (0.3-m) length, 8-ft (2.4-m) width, and 6-in. (150-mm) depth: 1 × 8 × 6/12 = 4 cu ft/ft (0.37 m³/m).

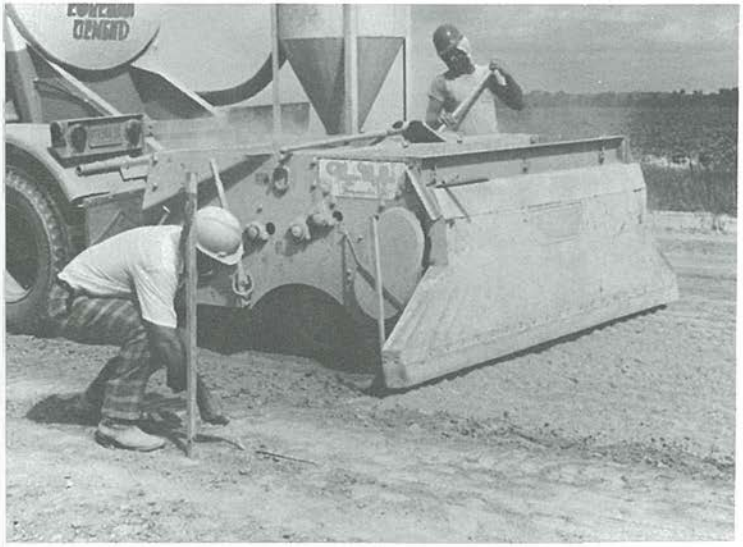


Fig. 9. The distance over which a truckload of cement of known weight spreads is a check on the quantity of cement spread.

Bulk cement that is spread mechanically on the top of a windrow of soil may be checked by forming a trough in the top of the windrow and placing a piece of canvas in the trough. Cement spread is checked by pushing two metal plates into the top of the windrow exactly 1 ft or 1 m apart. All cement between the plates is carefully collected and weighed. This is a direct method of finding the quantity of cement spread per unit length.

Generally, the spreader is first adjusted at the start of construction by checking the cement spread per unit length of windrow or per square yard (m^2). Then, when the proper adjustments have been made, a continuous check of the spread is easily made by determining the distance over which each truckload is spread. Bag cement is checked by counting the number of bags placed per 100-ft (30-m) station. It is important to keep a continuous check on cement-spreading operations.

Bagged-Cement Spread for Mixed-in-Place Construction

When bags of cement are used on small jobs, a simple but exact method for properly placing the bags is necessary. The bags should be spaced at approximately equal transverse and longitudinal intervals that will ensure the proper percentage of cement. Positions can be spotted by flags or markers fastened to chains at proper intervals to mark the transverse and longitudinal rows.

Calibrating Central Mixing Plants

When borrow materials are specified, central plants with pugmill-type mixers or rotary-drum mixers are often used to mix soil-cement. Use of such equipment makes it necessary to proportion the cement and the soil aggregate before they enter the mixing chamber. Central mixing plants can be calibrated as explained below.

Continuous-Flow Mixing Plant

The soil material alone is run through the plant for a given period of time and collected in a truck. This should be done for specific periods of time, such as 1, 2, and 3 minutes, to determine the uniformity of flow and the quantity of soil material going through the plant. The amount of moist soil per hour divided by the quantity 1 plus the moisture content (expressed as a decimal) will give the quantity of dry soil per hour.

EXAMPLE 3.

Find the hourly delivery rate of dry soil material.

GIVEN: Moist soil material going through the plant per hour .... 500 tons (454 t)*
Moisture content of material 5.5%

PROCEDURE: Delivery rate of dry soil material is

$$\frac{500}{(1.0 + 0.055)} = 474 \text{ tons per hour } (430 \text{ t/h})$$

Cement is calibrated in a similar manner by diverting it di-

*1 t = 1 tonne = 1000 kg = 1 Mg

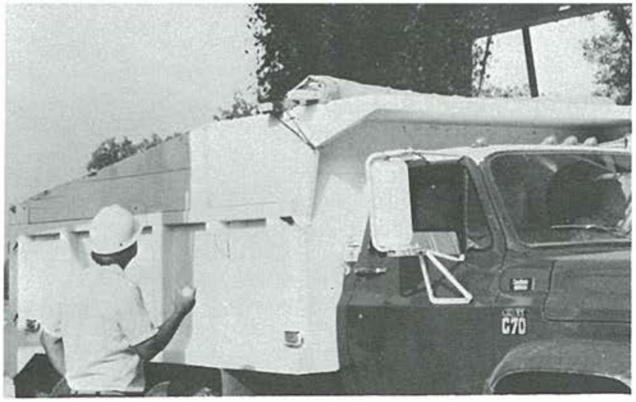


Fig. 10. Soil material is collected in a truck to determine rate of feed.

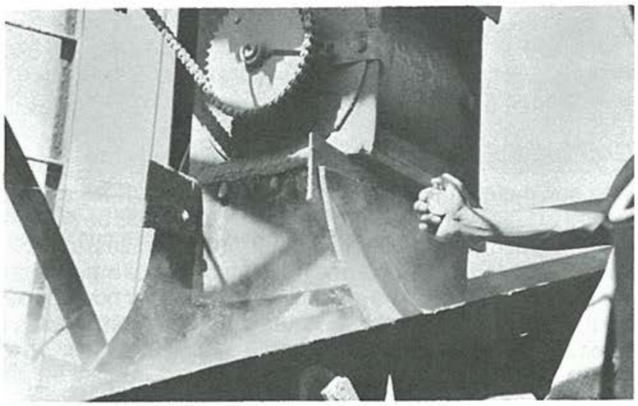


Fig. 11. Rate of cement feed is calibrated to revolutions of the cement feeder.

rectly from the cement feeder into a truck or suitable container while soil material is going through the plant. A diversion chute directs the cement from the cement meter to the container. The plant is run at full capacity during calibration so that operations will be comparable to those of actual running conditions and power drawdown will not affect calibration results during cement trials. Generally, periods of 15, 30, and sometimes 45 seconds are used to determine the uniformity of feed and the quantity of cement delivered.

Fig. 12. Collecting soil material from main feeder belt to determine dry weight and rate of feed.

EXAMPLE 4.

Determine the amount of cement required per minute.

GIVEN: Specified cement content by weight of dry soil material 6%

PROCEDURE: 474 tons per hour (430 t/h) (from Example 3) of dry soil material requires 474 × 0.06 = 28.4 tons of cement per hour (25.8 t/h), or

$$\frac{28.4 \times 2000}{60} = 948 \text{ lb of cement per minute (430 kg/min)}$$

Rather than arbitrarily adjusting the cement feeder until the correct amount of cement is being discharged, first determine the relationship between various feeder gate openings or revolutions per minute (depending on type of feeder) and amount of cement discharged. Plot this relationship to find the gate opening or revolutions per minute (RPM) for the required amount of cement.

A second method is to operate the plant with only soil aggregate material feeding onto the main conveyor belt. The material on a selected length of conveyor belt is collected and its dry weight determined. The plant is then operated with only cement feeding onto the main conveyor belt. If a variable-speed screw or vane cement feeder is being used, several trials are made at different revolutions-per-minute (RPM) settings on the cement feeder. If a belt cement feeder is being used, trials are made at different cement feeder gate openings. The cement on the selected length of conveyor belt is collected and weighed for each trial run. A calibration graph can then be drawn by plotting the RPM setting or gate opening on the cement feeder on the horizontal scale and the computed percent of cement by dry weight of soil material on the vertical scale. Thus, for a constant supply of soil material, the setting on the cement feeder for the required quantity of cement can be determined from the graph.

EXAMPLE 5.

Determine cement meter setting.

GIVEN: Specified cement content by weight of dry soil material 6%
Moisture content of material 5.5%

PROCEDURE: Determine the weight of soil material on the main conveyor belt at various feeder gate openings.

Gate opening		Moist soil material on belt	
in.	(mm)	lb on 5 ft	(kg on 1.5 m)
8	(200)	225	(100.4)
7	(175)	191	(85.3)
6	(150)	156	(69.6)
5	(125)	121	(54.0)

Calculate the weight of dry soil material by dividing the quantity of moist soil material by the quantity 1 plus the moisture content expressed as a decimal:

$$\frac{\text{Moist soil material}}{(1.0 + 0.055)}$$

Gate opening		Dry soil material on belt		Dry soil material per unit length of belt	
in.	(mm)	lb on 5 ft	(kg on 1.5 m)	lb/ft	(kg/m)
8	(200)	213	(95.2)	42.6	(63.5)
7	(175)	181	(80.8)	36.2	(53.9)
6	(150)	148	(66.0)	29.6	(44.0)
5	(125)	115	(51.2)	23.0	(34.1)

Determine weight of cement on main conveyor belt at various RPM settings of feeder:

RPM setting	Cement on belt		Cement per unit length of belt	
	lb on 10 ft	(kg on 3.0 m)	lb/ft	(kg/m)
14	28.7	(12.8)	2.87	(4.27)
12	25.5	(11.4)	2.55	(3.80)
10	22.2	(9.9)	2.22	(3.30)
8	19.0	(8.5)	1.90	(2.83)

For production, the main feeder belt is set at 8 in. (200 mm). Calculate the cement content by weight of dry soil material at 8-in. (200-mm) soil-aggregate feeder belt setting for each cement feeder setting.

Example for RPM setting of 14:

$$\frac{2.87 \text{ lb cement}}{42.6 \text{ lb dry soil material}} \times 100 = 6.7\% \text{ cement}$$

RPM setting	Cement content by weight of dry soil material, %
14	6.7
12	6.0
10	5.2
8	4.5

An RPM setting of 12 will give the required cement content of 6% by weight of dry soil material.

EXAMPLE 6.

Find the production of the plant with the 8-in. (200-mm) feeder gate opening and 12-RPM cement feeder setting.

GIVEN: Total length of main feeder belt .... 165.0 ft (50.29 m)
Average time for one revolution of belt ...... 26.7 seconds

PROCEDURE: Calculate average belt speed:

$$165.0/26.7 = 6.18 \text{ ft/second } (1.88 \text{ m/s})$$

Dry soil material plus cement going through plant:

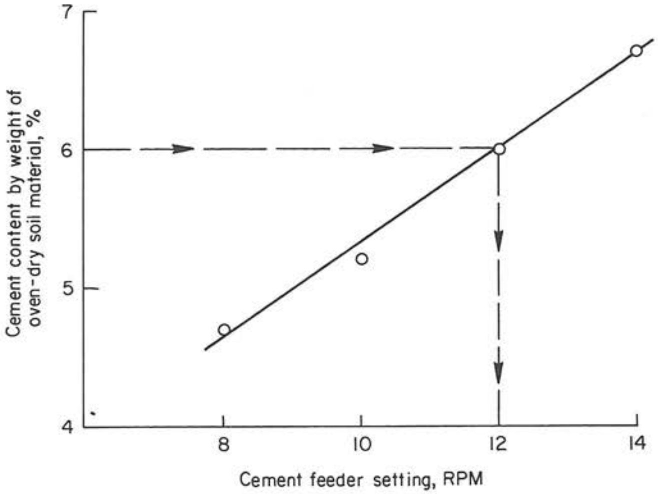


Fig. 13. Example of calibration curve for a central-mixing-plant cement feeder.

Soil:	42.6 lb × 6.18 ft/sec × 3600 sec ÷ 2000 lb = 474.0
Cement:	2.55 lb × 6.18 ft/sec × 3600 sec ÷ 2000 lb = 28.4
	502.4 tons per hour (455.8 t/h)

Once the plant is properly calibrated, only one check a day is usually necessary. A cement batch weigher between the silo and holding hopper will keep track of cement used. Occasionally, the silo should be emptied completely to check the amount of cement used against bulk transport weights.

Water is calibrated by weighing the amount discharged for one minute and comparing it with the water meter that measures rate of flow on the mixer.

To determine the quantity of water needed for the mixture, the moisture content in the soil material and the percent of moisture required must be known.

EXAMPLE 7.

Determine the amount of water needed per minute.

GIVEN: Optimum moisture content 11.5%

Add for evaporation loss 2%
Moisture in soil material 5.5%
From previous example, dry soil material used ....474 tons per hour (430 t/h)
From previous example, cement used.... 28.4 tons per hour (25.8 t/h)

PROCEDURE: Water in soil material: 474 × 0.055 = 26.1 tons per hour (23.7 t/h)
Soil material and cement: 474 + 28.4 = 502.4 tons per hour (455.8 t/h)
Water required: 502.4 × 0.135* = 67.8 tons per hour (61.5 t/h)
Water to add: 67.8 - 26.1 = 41.7 tons per hour (37.8 t/h)

or $\frac{41.7 \times 2000}{8.33^{**} \times 60}$ = 167 U.S. gal per minute (632 L/min)
or 139 imperial gallons per minute

Batch-Type Mixing Plant

When soil-cement is mixed in a batch-type pugmill or rotary-drum mixing plant, the proper quantities of soil material, cement, and water for each batch are weighed before being transferred to the mixer.

EXAMPLE 8.

Calculate the correct proportions for a 2000-lb (907-kg) batch of soil-cement to be mixed in a batch-type pugmill or rotary-drum mixing plant.

GIVEN: Cement content by weight of soil material 6%
Optimum moisture content by weight of soil material plus cement 11.5%
Moisture content of raw soil material 5.5%

PROCEDURE:

1. Weight of dry soil material plus cement per batch:

$$\frac{2000}{(1.0 + 0.135^{*})} = 1762 \text{ lb } (800 \text{ kg})$$

---

*Percentage of moisture required equals the optimum moisture content (11.5%) plus 2% for evaporation.

**1 U.S. gal weighs 8.33 lb.
1 imperial gallon (imp gal) weighs 10.0 lb.

Fig. 14. Each load of soil-cement from a central mixing plant is weighed for a continuous record of the quantity processed. Note tarp being placed over the soil-cement to minimize evaporative moisture lost during transport. Covering soil-cement also protects it from rain.

2. Weight of dry soil material:

$$\frac{1762}{(1.0 + 0.06)} = 1662 \text{ lb } (754 \text{ kg})$$

3. Weight of cement:

$$1762 - 1662 = 100 \text{ lb } (45 \text{ kg})$$

4. Weight of moist soil material:

$$1662 \times (1.0 + 0.055) = 1753 \text{ lb } (795 \text{ kg})$$

5. Weight of water in soil material:

$$1753 - 1662 = 91 \text{ lb } (41 \text{ kg})$$

6. Weight of water needed:

$$2000 - 1762 = 238 \text{ lb } (108 \text{ kg})$$

7. Weight of water to add:

238 - 91 = 147 lb (67 kg)
or 17.6 U.S. gal (67 L) (14.7 imp gal)

8. Batch weights corrected for moisture in soil material:

Cement	100 lb (45 kg)
Water	147 lb (67 kg)
Moist soil material	1753 lb (795 kg)
	2000 lb (907 kg)

Water Application

One of the five control factors for soil-cement is proper moisture content. The optimum moisture content determined in the laboratory is used as a guide when starting construction. At the conclusion of moist-mixing, a moisture-density test, AASHTO T134 or ASTM D558, is made on a representative sample of the mixture taken from the roadway. This test determines the optimum moisture and maximum density to be used for field control of the section under construction. These results may differ from laboratory values due to minor variations in the soil material or due to the effects of partial hydration of the cement during the mixing period.

In the moisture-density test, the soil-cement mixture is compacted in three layers of approximately equal thickness in a 1/30-cu-ft (943-cm^3) mold with collar attachment, sometimes called a Proctor mold. The mold should be on a rigid, uniform foundation.

Each layer is compacted by 25 uniformly distributed vertical blows of a 5½-lb (2.5-kg) rammer with a free fall of 12 in. (305 mm). The thickness of the layers is controlled so that the third layer extends above the top of the mold about ½ in. (13 mm) into the collar extension. After the collar is removed, the soil-cement is trimmed to the exact height of the mold; then the assembly is weighed. The net wet weight of the compacted

Fig. 15. Running a field moisture-density test.

MOISTURE-DENSITY RELATIONS

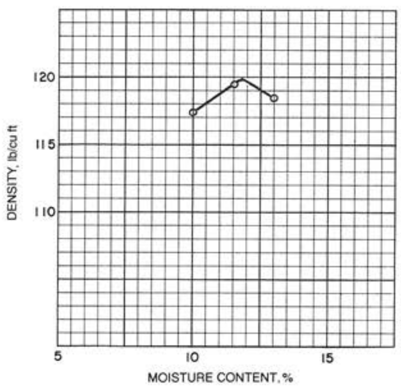
STATE: ______ DATE: ______

ROUTE: ______ COUNTY: ______ PROJECT NO.: ______

STATION: ______ REMARKS: ______

TEST NUMBER		1	2	3	4
(1) Wet weight specimen + mold	lb	12.80	12.95	12.96	
(2) Weight of mold	lb	8.50			
(3) Net wet weight specimen (1) − (2)	lb	4.30	4.45	4.46	
(4) Volume of mold	cu ft	1/30			
(5) Wet density (3) ÷ (4)	lb/cu ft	129.0	133.5	133.8	
(6) Wet weight sample + container	g	849	862	855	
(7) Dry weight sample + container	g	782	784	769	
(8) Weight of moisture (6) − (7)	g	67	78	86	
(9) Weight of container	g	100	110	105	
(10) Net weight dry sample (7) − (9)	g	682	674	664	
(11) Moisture content [(8) ÷ (10)] 100	%	9.8	11.6	13.0	
(12) Dry density (5) ÷ [1 + (11*)]	lb/cu ft	117.5	119.6	118.4	

*Expressed as a decimal



Maximum Density

120.0 lb/cu ft

Optimum Moisture

11.8 %

Inspector ______

Fig. 16. Typical field moisture-density data and curve in U.S. customary units.

material at different moisture contents is determined in this manner.

For each trial, the moisture content is determined and the

MOISTURE-DENSITY RELATIONS

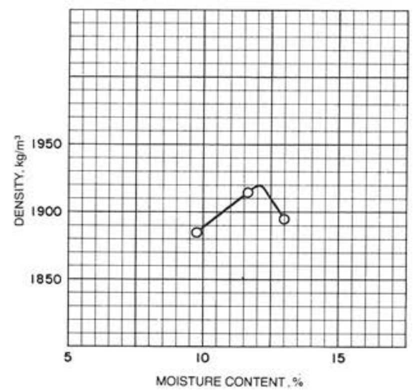
LOCATION: ______ DATE: ______

PROJECT: ______ PROJECT NO.: ______

STATION: ______ REMARKS: ______

TEST NUMBER		1	2	3	4
(1) Wet mass specimen + mold	kg	5.806	5.874	5.879	
(2) Mass of mold	kg	3.856			
(3) Net wet mass specimen (1) − (2)	kg	1.950	2.018	2.023	
(4) Volume of mold	cm³	943			
(5) Wet density (3) ÷ (4)	kg/m³	2068	2140	2145	
(6) Wet mass sample + container	g	849	862	855	
(7) Dry mass sample + container	g	782	784	769	
(8) Mass of moisture (6) − (7)	g	67	78	86	
(9) Mass of container	g	100	110	105	
(10) Net mass dry sample (7) − (9)	g	682	674	664	
(11) Moisture content [(8) ÷ (10)] 100	%	9.8	11.6	13.0	
(12) Dry density (5) ÷ [1 + (11*)]	kg/m³	1883	1918	1898	

*Expressed as a decimal



Maximum Density

1922 kg/m³

Optimum Moisture

11.8 %

Inspector ______

Fig. 17. Typical field moisture-density data and curve in SI units.

dry weight calculated and plotted against it to form a moisture-density curve (Figs. 16 and 17). The optimum moisture content is that at which the greatest dry density is obtained. This density is referred to as the "maximum density," and represents approximately the density to be attained in soil-cement construction.

Many engineers have devised shortcuts in making field moisture-density tests. For instance, the field sample, which is near optimum moisture, is split in three parts and one portion is used to establish a point near the peak of the moisture-density curve (Fig. 18). A second portion of material with the addition of a small increment of water is then used to establish a point on the wet side of the curve. The third part of the original field sample, which has dried slightly in the interim, is used to establish a dry point on the curve.

With a little experience, an inspector can accurately judge when a soil-cement mixture is at optimum moisture by its feel and by the way it packs into the mold. Such shortcuts decrease the time required to make a moisture-density test and

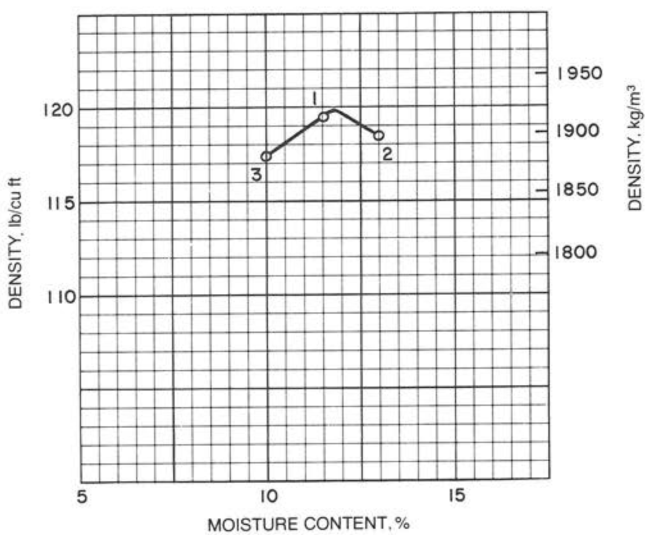


Fig. 18. Field moisture-density curve for soil-cement mixture at or near optimum moisture can be established by running the test in the order indicated.

produce reliable results when tests are performed by an experienced operator.

Field moisture-density tests are important and should be conducted regularly to control construction variables and assure satisfactory results. Figs. A-1 and A-2 in the Appendix are typical form sheets used for moisture-density determinations in the field.

Moisture Test

In order to estimate mixing-water requirements, representative moisture samples are obtained from the raw soil prior to mixing and water application.

The moist samples are weighed, then dried and reweighed. The moisture content is computed as follows:

$$\text{Percent moisture} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

For field testing, samples containing gravel retained on the No. 4 (4.75-mm) sieve should weigh at least 750 g. Samples containing no gravel should weigh at least 400 g. Tables 4 and 5 can be used to determine moisture contents for moist samples weighing either 750 or 400 g when their dry weights are known.

Fig. 19. Soils are dried on a portable stove to determine moisture content.

TABLE 4. Moisture Contents of Samples Weighing 750 g Wet and Having Final Dry Weight Shown

Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture
749.0	0.1	729.0	2.9	709.0	5.8	689.0	8.9
748.0	0.3	728.0	3.0	708.0	5.9	688.0	9.0
747.0	0.4	727.0	3.2	707.0	6.1	687.0	9.2
746.0	0.5	726.0	3.3	706.0	6.2	686.0	9.3
745.0	0.7	725.0	3.4	705.0	6.4	685.0	9.5
744.0	0.8	724.0	3.6	704.0	6.5	684.0	9.6
743.0	0.9	723.0	3.7	703.0	6.7	683.0	9.8
742.0	1.1	722.0	3.9	702.0	6.8	682.0	10.0
741.0	1.2	721.0	4.0	701.0	7.0	681.0	10.1
740.0	1.4	720.0	4.2	700.0	7.1	680.0	10.3
739.0	1.5	719.0	4.3	699.0	7.3	679.0	10.5
738.0	1.6	718.0	4.5	698.0	7.5	678.0	10.6
737.0	1.8	717.0	4.6	697.0	7.6	677.0	10.8
736.0	1.9	716.0	4.7	696.0	7.8	676.0	10.9
735.0	2.0	715.0	4.9	695.0	7.9	675.0	11.1
734.0	2.2	714.0	5.0	694.0	8.1	674.0	11.3
733.0	2.3	713.0	5.2	693.0	8.2	673.0	11.4
732.0	2.5	712.0	5.3	692.0	8.4	672.0	11.6
731.0	2.6	711.0	5.5	691.0	8.5	671.0	11.8
730.0	2.7	710.0	5.6	690.0	8.7	670.0	11.9

Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture
669.0	12.1	649.0	15.6	629.0	19.2	609.0	23.2
668.0	12.3	648.0	15.7	628.0	19.4	608.0	23.4
667.0	12.4	647.0	15.9	627.0	19.6	607.0	23.6
666.0	12.6	646.0	16.1	626.0	19.8	606.0	23.8
665.0	12.8	645.0	16.3	625.0	20.0	605.0	24.0
664.0	13.0	644.0	16.5	624.0	20.2	604.0	24.2
663.0	13.1	643.0	16.6	623.0	20.4	603.0	24.4
662.0	13.3	642.0	16.8	622.0	20.6	602.0	24.6
661.0	13.5	641.0	17.0	621.0	20.8	601.0	24.8
660.0	13.6	640.0	17.2	620.0	21.0	600.0	25.0
659.0	13.8	639.0	17.4	619.0	21.2	599.0	25.2
658.0	14.0	638.0	17.6	618.0	21.4	598.0	25.4
657.0	14.2	637.0	17.7	617.0	21.6	597.0	25.6
656.0	14.3	636.0	17.9	616.0	21.8	596.0	25.8
655.0	14.5	635.0	18.1	615.0	22.0	595.0	26.0
654.0	14.7	634.0	18.3	614.0	22.1	594.0	26.3
653.0	14.9	633.0	18.5	613.0	22.3	593.0	26.5
652.0	15.0	632.0	18.7	612.0	22.5	592.0	26.7
651.0	15.2	631.0	18.9	611.0	22.7	591.0	26.9
650.0	15.4	630.0	19.0	610.0	23.0	590.0	27.1

TABLE 5. Moisture Contents of Samples Weighing 400 g Wet and Having Final Dry Weight Shown

Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture
399.5	0.1	389.5	2.7	379.5	5.4	369.5	8.3
399.0	0.3	389.0	2.8	379.0	5.5	369.0	8.4
398.5	0.4	388.5	3.0	378.5	5.7	368.5	8.5
398.0	0.5	388.0	3.1	378.0	5.8	368.0	8.7
397.5	0.6	387.5	3.2	377.5	6.0	367.5	8.8
397.0	0.8	387.0	3.4	377.0	6.1	367.0	9.0
396.5	0.9	386.5	3.5	376.5	6.2	366.5	9.1
396.0	1.0	386.0	3.6	376.0	6.4	366.0	9.3
395.5	1.1	385.5	3.8	375.5	6.5	365.5	9.4
395.0	1.3	385.0	3.9	375.0	6.7	365.0	9.6
394.5	1.4	384.5	4.0	374.5	6.8	364.5	9.7
394.0	1.5	384.0	4.2	374.0	7.0	364.0	9.9
393.5	1.7	383.5	4.3	373.5	7.1	363.5	10.0
393.0	1.8	383.0	4.4	373.0	7.2	363.0	10.2
392.5	1.9	382.5	4.6	372.5	7.4	362.5	10.3
392.0	2.0	382.0	4.7	372.0	7.5	362.0	10.5
391.5	2.2	381.5	4.8	371.5	7.7	361.5	10.7
391.0	2.3	381.0	5.0	371.0	7.8	361.0	10.8
390.5	2.4	380.5	5.1	370.5	8.0	360.5	11.0
390.0	2.6	380.0	5.3	370.0	8.1	360.0	11.1

Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture	Dry weight, g	% moisture
359.5	11.3	349.5	14.4	339.5	17.8	329.5	21.4
359.0	11.4	349.0	14.6	339.0	18.0	329.0	21.6
358.5	11.6	348.5	14.8	338.5	18.2	328.5	21.8
358.0	11.7	348.0	14.9	338.0	18.3	328.0	22.0
357.5	11.9	347.5	15.1	337.5	18.5	327.5	22.1
357.0	12.0	347.0	15.3	337.0	18.7	327.0	22.3
356.5	12.2	346.5	15.4	336.5	18.9	326.5	22.5
356.0	12.4	346.0	15.6	336.0	19.0	326.0	22.7
355.5	12.5	345.5	15.8	335.5	19.2	325.5	22.9
355.0	12.7	345.0	15.9	335.0	19.4	325.0	23.1
354.5	12.8	344.5	16.1	334.5	19.6	324.5	23.3
354.0	13.0	344.0	16.3	334.0	19.8	324.0	23.5
353.5	13.2	343.5	16.4	333.5	19.9	323.5	23.6
353.0	13.3	343.0	16.6	333.0	20.1	323.0	23.8
352.5	13.5	342.5	16.8	332.5	20.3	322.5	24.0
352.0	13.6	342.0	17.0	332.0	20.5	322.0	24.2
351.5	13.8	341.5	17.1	331.5	20.7	321.5	24.4
351.0	14.0	341.0	17.3	331.0	20.8	321.0	24.6
350.5	14.1	340.5	17.5	330.5	21.0	320.5	24.8
350.0	14.3	340.0	17.6	330.0	21.2	320.0	25.0

Some agencies use the large calcium carbide/acetylene gas pressure moisture tester for determining moisture content. It can be used only for materials that pass the No. 4 (4.75-mm) sieve, and the sample size is very limited.

Mixing-Water Requirements for Mixed-in-Place Construction

The approximate percentage of mixing water required is equal to the difference between the optimum moisture content and the moisture content of the soil material as determined above. About 2% additional moisture must be added to account for the dry cement added to the soil and for evaporation that normally occurs during processing. The quantity of water required per unit length or per minute for 1% moisture can be determined by using Fig. 20.

EXAMPLE 9.

Determine water required.

GIVEN:

In-place moisture content of raw soil material 5.5%
Optimum moisture content 11.5%
Maximum density .... 121.2 lb per cubic foot (1941 kg/m^3)
Compacted depth .... 6 in. (150 mm)
Mixing width .... 8 ft (2.4 m)
Mixing rate .... 30 ft per minute (9.1 m/min)

PROCEDURE:

1. The approximate percentage of moisture required equals the difference between the optimum moisture content and the moisture content of the raw soil material, plus 2% of the total mixture (for evaporation): 11.5 - 5.5 + 2 = 8%.
2. Enter Fig. 20 at the left edge at 8-ft (2.4-m) width of processing and proceed horizontally to the 6-in. (150-mm) depth line; then proceed downward until the 121.2-lb/cu ft (1941-kg/m^3) density line is intersected. Proceed horizontally to the right and read gallons per foot (L/m) for 1% moisture: approximately 0.58 U.S. gal per foot, or 0.48 imp gal per foot (7.2 L/m).
3. Multiply gallons per foot (L/m) by the 8% moisture required: 8 × 0.58 = 4.6 U.S. gal per foot, or 3.8 imp gal per foot (8 × 7.2 = 58 L/m).

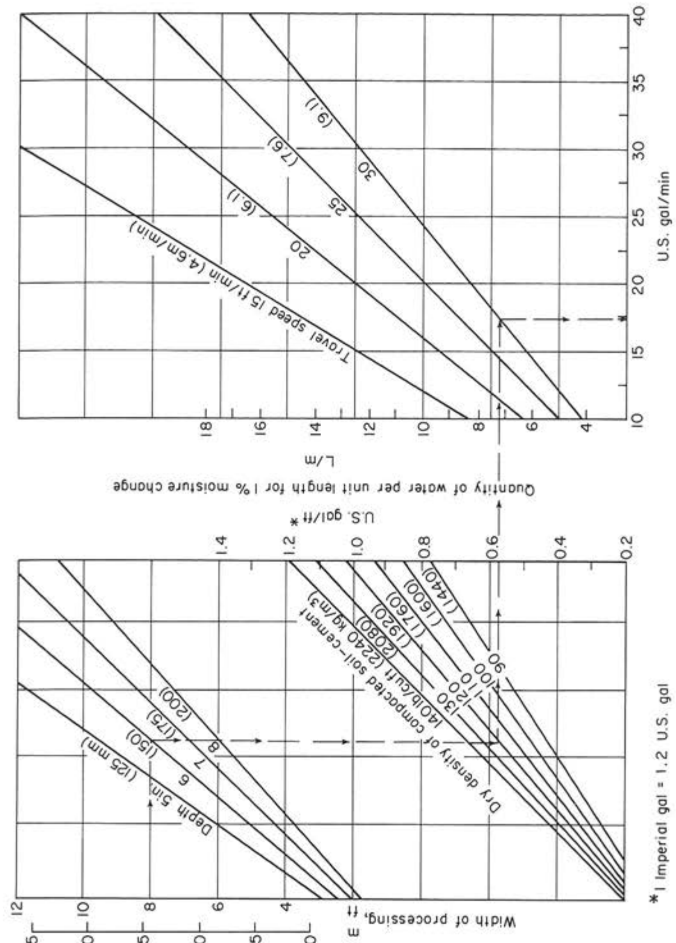


Fig. 20. Quantity of water required to raise the moisture content of soil-cement mixture one percentage point.

4. Continue on Fig. 20 horizontally from gallons per foot (L/m) for 1% moisture until the travel-speed line of 30 ft per minute (9.1 m/min) is intersected. Then proceed

downward and read gallons per minute (L/min) for 1% moisture change: 17.4 U.S. gal or 14.5 imp gal (65.9 L).

5. Multiply gallons per minute (L/min) for 1% moisture change by the 8% moisture required: 17.4 × 8 = 139 U.S. gal per minute or 116 imp gal per minute (526 L/min).

If the soil-cement is being processed in windrows, the approximate mixing water requirements are based on the quantity of soil material and cement per unit length of windrow.

EXAMPLE 10.

Calculate quantity of water required.

GIVEN: Weight of soil material at field moisture content per unit length of windrow .... 460 lb per foot (685 kg/m)
Moisture content of in-place raw soil material 5.5%
Optimum moisture content of soil-cement mixture ... 11.5%
Forward speed of mixing machine, approximately 12 ft per minute (3.7 m/min)

PROCEDURE:

1. Convert weight of soil material per unit length of windrow at its in-place moisture content to weight of the ovendry soil material:

$$\frac{460}{(1.0 + 0.055)} = 436 \text{ lb ovendry soil material per linear foot } (649 \text{ kg/m})$$

2. Quantity of cement required per unit length of windrow:

   436 × 0.06 = 26.2 lb per foot (39 kg/m)

3. Quantity of dry soil material plus cement per unit length of windrow:

   436 + 26.2 = 462.2 lb per foot (688 kg/m)

4. Quantity of water in soil material per unit length of windrow:

   460 - 436 = 24 lb per foot (35.7 kg/m)

5. Estimate quantity of water required per unit length of windrow to bring mixture to required moisture (optimum moisture content, 11.5%, plus 2% for evaporation):

   462.2 × 0.135 = 62.4 lb per foot (92.9 kg/m)

6. Subtract water in the soil material:

62.4 - 24 = 38.4 lb per foot (57.1 kg/m)
38.4/8.33 = 4.6 U.S. gal per foot or 3.8 imp gal per foot (57 L/m)

This is the quantity of water to be added per unit length of windrow.

7. Quantity of water to be added per unit of time:

   4.6 × 12 ft per minute (forward speed of mixer) = 55.2 U.S. gal per minute or 46.0 imp gal per minute (209 L/min)

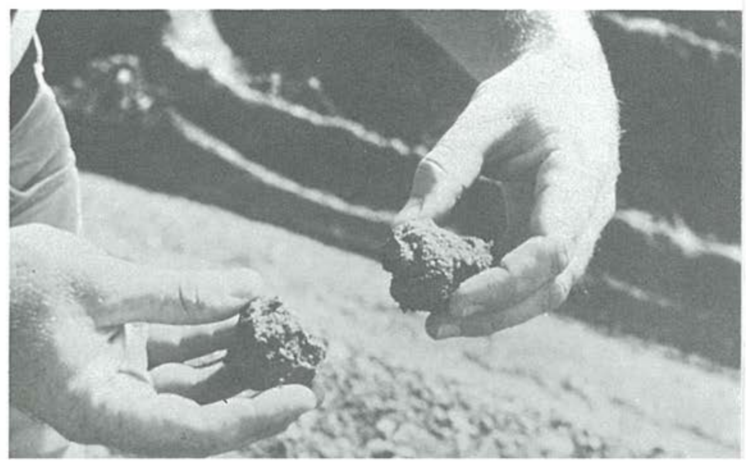
Mixing-Water Requirements for Central Mixing Construction

The quantity of water required in central mixing plants to bring the soil-cement mixture to optimum moisture is based on the quantity of soil material and cement entering the plant. The calculations for the quantity of water required are included in the examples in the section "Calibrating Central Mixing Plants."

Hand-Squeeze Test for Moisture Content

With a little experience, an inspector can estimate the moisture content of a soil-cement mixture by observation and feel. A mixture near or at optimum moisture content is just moist enough to dampen the hands when it is squeezed in a tight cast. Mixtures above optimum will leave excess water on the

Fig. 21. Soil-cement at optimum moisture casts readily when squeezed in the hand and can be broken into two pieces without crumbling.



hands, while mixtures below optimum will tend to crumble easily. If the mixture is near optimum moisture content, the cast can be broken into two pieces with little or no crumbling.

The hand-squeeze test is not a replacement for the standard moisture-content test, but it does reduce the number of these tests required during construction. The moisture-determination test validates what has been determined by visual inspection and the hand-squeeze test.

Moisture for Compaction and Finishing

At the start of compaction, the moisture content of the soil-cement mixture must be at slightly above optimum. A final check of moisture is made at this time. Proper moisture is necessary for proper compaction and for hydration of the cement. Because of evaporation, it is better to have a slight excess of moisture than a deficiency when compaction begins.

During compaction and finishing, the surface of the soil-cement mixture may become dry, as evidenced by greying of the surface. When this occurs, very light applications of water are made to bring the moisture content back to optimum. A pressure distributor is used to make these fog applications of water. Proper moisture in the compacted soil-cement is evidenced by a smooth, moist, tightly knit surface free of checks, cracks, or ridges.

Uniformity of Mix: Depth and Width of Treatment

A thorough mixture of pulverized soil, cement, and water is necessary to make quality soil-cement. The uniformity of mix is checked by digging trenches or a series of holes at regular intervals for the full depth of treatment and then inspecting the color of the exposed material. The area between mixing lanes should also be checked. When the mixture is of uniform color and texture from top to bottom, the mix is satisfactory. A mixture that has a streaked appearance has not been mixed sufficiently.

Depth of mixing is usually checked at the same time as uniformity. Usually 8 to 9 in. (200 to 230 mm) of loose mix will produce about a 6-in. (150-mm) compacted thickness. This relationship varies slightly with the type of soil being processed. Routine depth checks should be made during mixing operations to assure that the specified thickness is attained.

Line stakes set 1 ft (0.3 m) outside the desired roadway edge are used to control width of processing. It is important that a uniform mix be obtained at the edges.

Fig. 22. Uniform color indicates thorough mixing.

Fig. 23. A stick with marks on it can be used to check the depth of the loose soil-cement. Frequent depth checks of the loose mixture should be made.

In street construction, special attention should be given to the mixing of soil-cement adjacent to curbs and gutters. All soil and cement should be moved away from the gutter section for the full depth of processing using the point of the motor-grader blade, a plow, or other devices. After mixing is performed, the material is bladed back and compacted.

Compaction

The principles governing compaction of soil-cement are the same as those for compacting the same soil materials without cement treatment. The soil-cement mixture at optimum moisture should be compacted and finished immediately. Moisture loss by evaporation during compaction and finishing, indicated by a greying of the surface, should be replaced with light applications of water.

Tamping (sheepsfoot) rollers are generally used for initial compaction except for the more granular soils. To obtain adequate compaction, it is sometimes necessary to operate the rollers with ballast to give greater unit pressure. The general rule is to use the greatest contact pressure that will not exceed the bearing capacity of the soil-cement mixture and that will still "walk out" in a reasonable number of passes.

When tamping rollers are used for initial compaction, the mixed material must be loose so that the feet will pack the bottom material and gradually walk out on each succeeding pass. If penetration is not being obtained, the scarifier on a motor grader or a traveling mixer can be used to loosen the mix during start of compaction, thus allowing the feet to penetrate.

Vibratory-steel-wheel rollers, grid rollers, and segmented rollers can be used satisfactorily to compact soil-cement made of granular soil materials. Vibratory-plate compactors are used on nonplastic granular materials.

Pneumatic-tire rollers can be used to compact coarse sand and gravel soil-cement mixtures with very little plasticity and very sandy mixtures such as dune, beach, or blow sand, which have little or no binder material. Some rollers permit rapid inflation and deflation of the tires while compacting.

Pneumatic-tire rollers pulled by track-type tractors equipped with street plates can be used to compact cohesionless sand mixtures. The weight and vibration of the tractor aid in compaction.

Fig. 24. Compacting the soil-cement with a vibratory steel wheel roller.

Heavy three-wheel steel rollers can be used to compact coarse granular materials containing little or no binder. Gravelly soils that have low plasticity are best suited for compaction with these rollers.

For best results, compaction should start immediately after the soil material, cement, and water have been mixed. Required densities are then obtained more readily, there is less water evaporation, and daily production is increased.

Finishing

There are several acceptable methods for finishing soil-cement. The exact procedure depends on equipment, job conditions, and soil characteristics. Regardless of method, the fundamental requirements of adequate compaction and optimum moisture must be met to produce a high-quality surface. The surface should be smooth, dense, and free of ruts, ridges, or cracks.

When shaping is done during finishing, all smooth surfaces, such as tire imprints and blade marks, should be lightly scratched with a weeder, nail drag, coil spring, or spiketooth harrow to remove cleavage or compaction planes from the surface. The reason for this is that a thin layer of soil-cement placed on top of these compaction planes may not adhere properly and in time may fracture, loosen, and spall. For good bond, the area must be rough and damp. Scratching should be done on all soil-cement mixtures except those containing appreciable quantities of gravel.

The surface should be kept damp during finishing operations. Steel-wheel rollers can be used to smooth out ridges left by the initial pneumatic-tire rolling. Steel-wheel rollers are particularly advantageous when rock is present in the surface. A broom drag can sometimes be used advantageously to pull binder material in and around pieces of gravel that have been set by the steel-wheel roller. Instead of using a steel-wheel roller, surfaces can be shaved with the motor grader and then rerolled with a pneumatic-tire roller to seal the surface. Shaving consists of lightly cutting off any small ridges left by the finishing equipment. Only a very thin depth is cut and all material removed is bladed to the edge of the road and should not be used. The final operation usually consists of a light application of water and rolling with a pneumatic-tire roller to seal the surface. The finished soil-cement is then cured.

Regardless of the method used, the surface should be maintained at not less than optimum moisture content during finishing and the compacted surface should be smooth, dense, and free of compaction planes and cracks.

A complete discussion of finishing of soil-cement, including a suggested step-by-step procedure to be used for various soil types, can be found in the PCA publication *Soil-Cement Construction Handbook*, EB003.

Joint Construction

At the end of each day's construction, a transverse construction joint is formed by cutting back into the completed soil-cement, using the toe of the motor-grader blade or axes. The resulting joint should be vertical and firm.

During processing of the abutting section, it is important that the material next to the joint be mixed well. The joint is cleaned of all dry and unmixed material and retrimmed if necessary. Then the mixed moist material is bladed back to the joint. The material next to the joint must be thoroughly compacted. The joint should be left slightly high; then during final blading it is trimmed to grade with the motor grader and rerolled.

Degree of Compaction and Final Depth Check

The most common density test methods are

1. Nuclear method
2. Sand-cone method
3. Balloon method

If the test is performed with care, these and other methods can be used to determine the degree of compaction obtained. Various types of apparatus are available for all these methods. A comparison of dry densities is used to determine the degree of compaction obtained; however, a rough check on the degree of compaction can be made quickly by comparing wet densities.

Densities should be determined at several locations on the first few sections completed; the tests are made immediately after final rolling. Comparison of these densities with the results of the field moisture-density test indicates any adjustments in compaction procedures that may be required to ensure compliance with job specifications. Specifications generally require that the density obtained not be less than 96% as determined by the field moisture-density test. After compaction procedures have been adjusted, only routine daily density checks are required.

In street construction, special attention to compaction adjacent to the curb, gutter, and utility structures is necessary. The wheels of a motor grader can be used to obtain additional compaction along the gutter line.

Nuclear Method

Many agencies that are engaged in compaction control on a fairly regular basis use the nuclear method in the direct transmission mode of operation (ASTM D2922 and D3017, AASHTO T238 and T239). Many of these nondestructive tests can be run in a short time. Proper calibration, operation, and maintenance of the equipment are essential. A license is required and operator instructions and safety precautions must be adhered to.

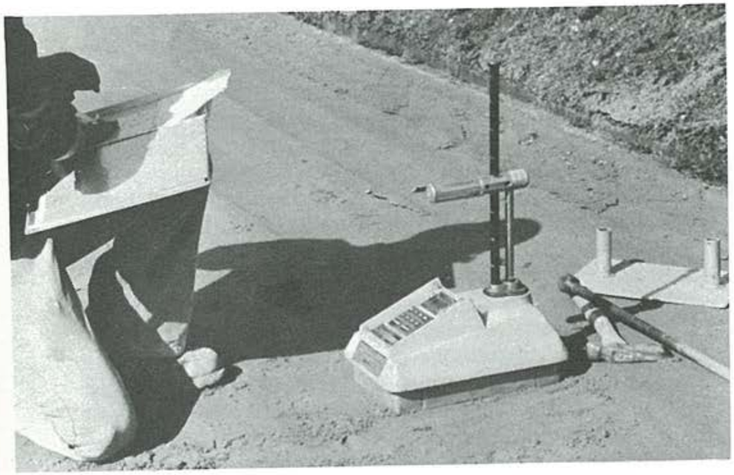


Fig. 25. Density of compacted soil-cement being determined by the nuclear method in the direct transmission mode of operation.

Sand-Cone Method

The sand-cone method, AASHTO T191 or ASTM D1556, is one of the most common for determining in-place densities. Fig. 26 shows the apparatus used.

The sand should be clean, dry, uniform, uncemented, durable, and free-flowing. The sand should be comprised of natural subrounded or rounded particles. The maximum-size particle should pass the No. 10 (2.0-mm) sieve with less than 3% passing the No. 60 (0.25-mm) sieve. The sand must be air-dry both at the time its bulk density is determined and when it is used for in-place density determinations.

The procedure for calibrating the sand and funnel and for making the test follows.

Calibration of Sand and Apparatus

1. Determine the weight of the density apparatus.
2. Pour the air-dry sand into the inverted apparatus through the open valve until the jug and the pycnometer top are full. During this operation the funnel shall be approximately half-full of sand at all times. Avoid jarring or vibrating the density apparatus while the sand is flowing. When the sand stops flowing, close the valve and remove the excess sand in the funnel. Weigh the apparatus and sand and determine the net weight of sand. Remove the sand from the density apparatus.
3. Determine the volume of the jug and pycnometer top with water. Pour water into the inverted density apparatus through the open valve until water appears in the funnel. Close the valve, remove excess water, and dry the funnel and outside surfaces of the apparatus. Weigh the apparatus and the water and determine the net weight of water. Remove the water and dry the apparatus.

Fig. 26. Density of compacted soil-cement being determined by the sand-cone method. A hole is dug in the base, and the dry weight of the material removed and the volume of the hole are computed.

EXAMPLE 11.

Determine unit weight of sand and calibrate funnel.

PROCEDURE:

1. Weight of apparatus filled with sand .... 17.91 lb (8.124 kg)
2. Weight of apparatus .... 4.20 lb (1.905 kg)
3. Weight of sand, (1) - (2) .... 13.71 lb (6.219 kg)
4. Weight of apparatus filled with water .... 12.75 lb (5.783 kg)

5. Weight of water, (4) - (2) .... 8.55 lb (3.878 kg)
6. Volume of apparatus, (5) / 62.4* .... 0.137 cu ft ($0.00388\ m^3$)**
7. Unit weight of sand, (3) / (6) .... 100.1 lb/cu ft ($1603\ kg/m^3$)

Calibration of Funnel

To determine the weight of sand required to fill the funnel, invert the density apparatus full of sand on the metal base plate on a smooth, flat surface; then open the valve until the sand stops flowing. Close the valve and remove the apparatus and unused sand.

EXAMPLE 12.

Calculate the amount of sand needed to fill the funnel and base plate.

PROCEDURE:

1. Weight of apparatus and sand at start .... 17.91 lb (8.124 kg)
2. Weight of apparatus and unused sand .... 13.98 lb (6.341 kg)
3. Weight of sand to fill funnel and base plate, (1) - (2) .. 3.93 lb (1.783 kg)

Density Test

1. Level the surface of the test area. Using the base plate as a guide, dig a hole approximately 5 in. (125 mm) in diameter almost through the depth of treatment, using a hammer and chisel or soil auger. To avoid enlargement of the hole by pressure of the excavating tools, material should be loosened in the test hole by cutting. Carefully remove all loosened material in the test hole and place it in a tightly covered container. Clean the hole with a brush and remove all loose particles. Use care during the test to avoid losing any material removed from the test hole.
2. Determine the volume of the test hole by the use of the density apparatus and calibrated sand. Fill the jug with the sand and weigh the apparatus and sand. Invert the apparatus and place the funnel rim over the hole and in the groove provided in the base plate. Open the valve and allow the sand to fill the test hole and funnel. Avoid jarring or vibrating the density apparatus during the test. After the sand has stopped flowing, close the valve and weigh the apparatus and remaining sand. The sand used to fill the test hole is the weight of sand released in the test minus the weight of sand in the upper cone.
3. Determine the moist weight of all material removed from the test hole. Mix the material thoroughly, then take a representative sample and determine its moisture content. Using this moisture content, calculate the dry weight of material removed from the test hole.
4. For gravelly soils, determine the percentage of gravel retained on the No. 4 (4.75-mm) sieve of the material removed from the test hole.

*1 cu ft of water weighs 62.4 lb.
**1 m^3 of water has a mass of 1000 kg.

Calculations

1. The moisture content and the ovendry weight of material removed from the test hole are calculated as follows:

$$\%\ \text{moisture of representative sample} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

$$\text{Dry weight of material from test hole} = \frac{\text{wet weight}}{1.0 + (\%\ \text{moisture}/100)}$$

$$\%\ \text{retained on No. 4 (4.75-mm) sieve} = \frac{\text{weight retained on No. 4 (4.75-mm) sieve}}{\text{total dry weight of sample}} \times 100$$

2. The volume of the test hole, in cubic feet (m^3), is calculated as follows:

$$\frac{\text{weight of sand used minus sand in upper cone, lb (kg)}}{\text{unit weight of the sand, lb/cu ft } (kg/m^3)}$$

3. The in-place, ovendry density, in pounds per cubic foot (kg/m^3) of the soil-cement equals

$$\frac{\text{dry weight of material removed from hole, lb (kg)}}{\text{volume of hole, cu ft } (m^3)}$$

Rubber-Balloon Method

As with the sand-cone method, the density hole is dug and all the material removed is placed in a container and its dry weight determined. The volume of the hole is then determined directly using a calibrated apparatus containing water. A pressure bulb exerts pressure on the water and a rubber balloon containing water is forced into the confines of the density hole (ASTM D2167, AASHTO T205). The difference between the initial and final water volume readings is the volume of the hole. Like other methods, the rubber-balloon method has limitations and care must be taken in running the test.

Record of Field Density Tests

A record of density and depth data should be kept. The procedure for keeping records is illustrated on the form sheet (Fig. A-3) in the Appendix.

Correcting for Differences in Gravel Content

Occasionally, field densities of soil-cement containing large percentages of gravel do not agree with the moisture-density test results. The percentage of gravel in the material taken from the density hole may be different from that in the sample used in the field moisture-density test. This difference in density can be corrected by using Fig. 28. A similar chart is given in AASHTO T224.

Fig. 27. Measuring depth of treatment through the density hole. A phenolphthalein solution can be squirted down the side of a freshly cut face of newly compacted soil-cement. The soil-cement will turn pinkish-red while the untreated subgrade material will retain its natural color.

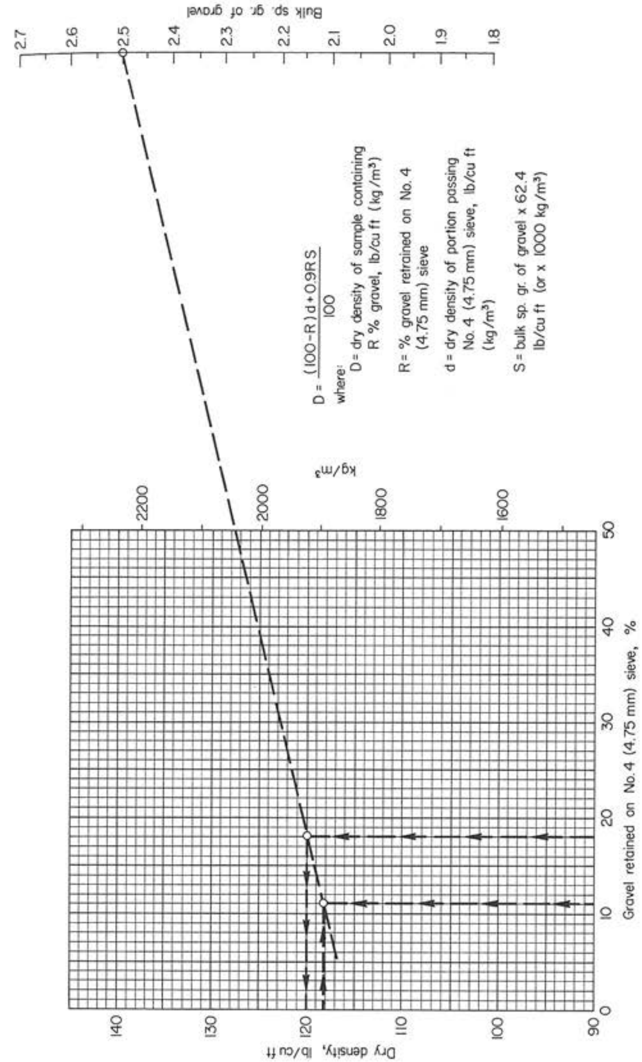


Fig. 28. Density correction chart for differences in gravel content.

EXAMPLE 13.

Find density corrected for gravel content.

GIVEN:
Percentage of gravel larger than No. 4 (4.75-mm) sieve in field moisture-density test sample 18%
Percentage of gravel larger than No. 4 (4.75-mm) sieve in sample from field density hole 11%
Bulk specific gravity of gravel 2.50*
Maximum density from field moisture-density curve determined on sample containing 18% gravel ..... 120.0 lb per cubic foot (1922 kg/m^3)

PROCEDURE:
On the grid (Fig. 28) locate the intersection of 120.0 lb per cubic foot (1922 kg/m^3) dry density and 18% gravel. With a straightedge, intersect this point and the specific gravity of 2.50, then extend this line until it intersects the vertical line on the grid representing 11% gravel. Project this point horizontally to the dry density scale on the left edge: 118.2 lb per cubic foot (1893 kg/m^3)

ANSWER:
The density of 118.2 lb per cubic foot (1893 kg/m^3) is the corrected theoretical maximum dry density of the field moisture-density test for a sample containing 11% gravel instead of 18% gravel. The in-place dry density of the material tested should be compared to this corrected density.

After the density determination is made, the compacted depth is measured. The depth of treatment is usually quite apparent because of the difference in color between the subgrade and the soil-cement mixture. However, it is sometimes difficult to distinguish the bottom of treatment by color, in which case water is poured into the density hole and allowed to stand. The subgrade will be softened while the full depth of treatment will remain firm. The bottom of treatment can then

---

*Bulk specific gravity of gravel (pycnometer method) = $\frac{A}{B + Y - Z}$

A = ovendry weight of gravel, grams
B = saturated surface-dry weight of gravel, grams
Y = weight of pycnometer filled with water, grams
Z = weight of pycnometer and saturated surface-dry gravel, filled with water, grams

be determined by probing with a pointed instrument.
A phenolphthalein solution can be squirted down the side of a freshly cut face of newly compacted soil-cement. The soil-cement will turn pinkish-red while the untreated subgrade material will retain its natural color.

Curing

Soil-cement at optimum moisture contains sufficient moisture for adequate cement hydration. After final compaction, a moisture-retaining cover is placed over the soil-cement to permit the cement to hydrate. Moist soil-cement is cured with bituminous material, but other materials such as waterproof paper or plastic sheets, wet straw or sand, fog-type water spray, and wet burlap or cotton mats are entirely satisfactory. The bituminous materials most commonly used are emulsified asphalt SS-1, RC-250, MC-250, and RT-5.

The rate of application varies from 0.15 to 0.30 gal per square yard (0.7 to 1.4 L/m^2). Before the bituminous material is applied, the surface of the soil-cement should be moist and free of dry, loose material. In most cases a light application of water precedes the bituminous cure.

When the air temperature is expected to reach the freezing point, the soil-cement should be protected from freezing for 7 days after its construction and until it has hardened.

Fig. 28. Water truck applies light water spray to soil-cement surface to maintain moisture throughout compaction, finishing, and curing operations.

Opening to Traffic

Completed portions of soil-cement can be opened immediately to local traffic and to construction equipment providing the soil-cement has hardened sufficiently to prevent marring or distorting of the surface, and providing the curing material is not impaired. If the bituminous moisture-retaining cover has not dried sufficiently to prevent pick-up, sufficient sand or grandular cover should be applied.

Maintenance

Specifications require that the contractor maintain the soil-cement in good condition until all work has been completed and accepted. Any defects that occur should be repaired immediately by replacing the soil-cement for the full depth of treatment. Areas deficient in thickness should also be remedied by replacing the material for full depth of treatment rather than by adding a thin layer of soil-cement to the completed work.

Appendix

Equipment for Field Tests

1. Field laboratory.
2. Two-burner field stove.
3. Split moisture-density mold and rammer (1/30-cu-ft [943-cm³] mold; sleeved 5½-lb [2.5-kg] rammer).
4. Balance with weights, 750-g capacity.
5. Scale with weights, 20-lb (9-kg) capacity.
6. Three 3x3-ft (1x1-m) pieces of canvas.
7. Spring scale, 100-lb (45-kg) capacity.
8. Set of 8-in.-diameter (200-mm) sieves: 2 in. (50 mm), ¾ in. (19 mm), and No. 4 (4.75 mm).
9. Sand-cone density apparatus with supply of dry sand of known unit weight.
10. A 5-in.-diameter (125-mm) soil auger and No. 2 short-handled square-pointed shovel.
11. Hammer and two 1-in. (25-mm) mason's chisels.
12. Six tin pie plates and six ½-gal (2-L) containers with lids.
13. Two 10-in.-diameter (250-mm) frying pans.
14. A 100-ml glass graduated cylinder.
15. A 10-in. (250-mm) butcher knife, 12-in. (300-mm) steel straightedge, and 10-in. (250-mm) trowel.
16. Two 12-qt (11-L) pails, two large spoons, and a 2-in. (50-mm) paint brush.
17. A 5x5-ft (1.5x1.5-m) canvas sample cloth.
18. Ruler and 50-ft (15-m) tape.

Moisture-Density Relations
(U.S. Customary Units)

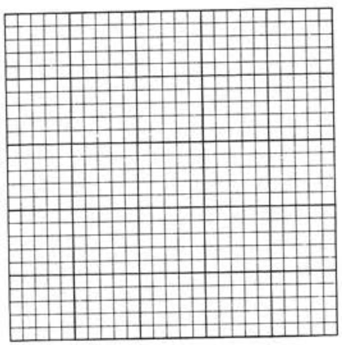
STATE:__________ DATE:______

ROUTE:________ COUNTY:________ PROJECT NO.:______

STATION:________ REMARKS:________

TEST NUMBER		1	2	3	4
(1) Wet weight specimen + mold	lb				
(2) Weight of mold	lb				
(3) Net wet weight specimen (1) − (2)	lb				
(4) Volume of mold	cu ft				
(5) Wet density (3) ÷ (4)	lb/cu ft				
(6) Wet weight sample + container	g				
(7) Dry weight sample + container	g				
(8) Weight of moisture (6) − (7)	g				
(9) Weight of container	g				
(10) Net weight dry sample (7) − (9)	g				
(11) Moisture content [(8) ÷ (10)] 100	%				
(12) Dry density (5) ÷ [1 + (11*)]	lb/cu ft				

*Expressed as a decimal



Maximum Density

________ lb/cu ft

Optimum Moisture

________ %

Inspector ________

Fig. A-1. Form sheet for recording field moisture-density data (U.S. customary units).

Moisture-Density Relations
(SI Units)

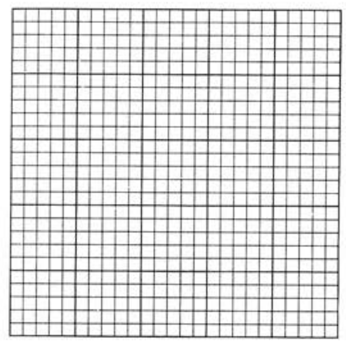
LOCATION:__________ DATE:______

PROJECT:__________ PROJECT NO.:______

STATION:________ REMARKS:________

TEST NUMBER		1	2	3	4
(1) Wet mass specimen + mold	kg				
(2) Mass of mold	kg				
(3) Net wet mass specimen (1) − (2)	kg				
(4) Volume of mold	cm^3				
(5) Wet density (3) ÷ (4)	kg/m^3				
(6) Wet mass sample + container	g				
(7) Dry mass sample + container	g				
(8) Mass of moisture (6) − (7)	g				
(9) Mass of container	g				
(10) Net mass dry sample (7) − (9)	g				
(11) Moisture content [(8) ÷ (10)] 100	%				
(12) Dry density (5) ÷ [1 + (11*)]	kg/m^3				

*Expressed as a decimal



Maximum Density

________ kg/m^3

Optimum Moisture

________ %

Inspector ________

Fig. A-2. Form sheet for recording field moisture-density data (SI units).

Field Density

LOCATION: ______________________ DATE: __________

PROJECT: ______________________ PROJECT NO.: __________

REMARKS: ______________________

Wet Weight of Sample from Test Hole			
(1)	Wet Weight of Sample + Pan	______ lb	______ kg
(2)	Weight of Pan	______ lb	______ kg
(3)	Wet Weight of Sample From Test Hole (1) − (2)	______ lb	______ kg
Volume Determination of Test Hole			
(4)	Initial Weight of Apparatus + Sand	______ lb	______ kg
(5)	Final Weight of Apparatus + Sand	______ lb	______ kg
(6)	Weight of Sand Used (4) − (5)	______ lb	______ kg
(7)	Less Weight of Sand in Funnel	______ lb	______ kg
(8)	Weight of Sand Used to Fill Test Hole (6) − (7)	______ lb	______ kg
(9)	Unit Weight of Sand (as calibrated)	______ lb/cu ft	______ kg/m³
(10)	Volume of Test Hole (8) ÷ (9)	______ cu ft	______ cm³
Moisture Content Determination			
(11)	Wet Weight of Sample + Container	______ g	
(12)	Dry Weight of Sample + Container	______ g	
(13)	Weight of Container	______ g	
(14)	Weight of Moisture (11) − (12)	______ g	
(15)	Dry Weight of Sample (12) − (13)	______ g	
(16)	Moisture Content [(14) ÷ (15)] 100	______ %	
Density			
(17)	Dry Weight of Sample from Test Hole (3) ÷ [1 + (16)*]	______ lb	______ kg
(18)	Dry Density (17) ÷ (10)	______ lb/cu ft	______ kg/m³
(19)	Maximum Dry Density (from field M-D relations)	______ lb/cu ft	______ kg/m³
(20)	Degree of Compaction [(18) ÷ (19)] 100	______ %	
Depth			
(21)	Depth of Treatment	______ in	______ mm

*Expressed as a decimal

____
Inspector

Fig. A-3. Form sheet for in-place density test—sand-cone method.

Field Density

LOCATION: ______________________ DATE: __________

PROJECT: ______________________ PROJECT NO.: __________

REMARKS: ______________________

Wet Weight of Sample from Test Hole			
(1)	Wet Weight of Sample + Pan	12.93 lb	5.865 kg
(2)	Weight of Pan	3.10 lb	1.406 kg
(3)	Wet Weight of Sample From Test Hole (1) − (2)	9.83 lb	4.459 kg
Volume Determination of Test Hole			
(4)	Initial Weight of Apparatus + Sand	17.91 lb	8.124 kg
(5)	Final Weight of Apparatus + Sand	6.46 lb	2.930 kg
(6)	Weight of Sand Used (4) − (5)	11.45 lb	5.194 kg
(7)	Less Weight of Sand in Funnel	3.93 lb	1.783 kg
(8)	Weight of Sand Used to Fill Test Hole (6) − (7)	7.52 lb	3.411 kg
(9)	Unit Weight of Sand (as calibrated)	100.1 lb/cu ft	1603 kg/m³
(10)	Volume of Test Hole (8) ÷ (9)	0.0751 cu ft	213 cm³
Moisture Content Determination			
(11)	Wet Weight of Sample + Container	1210 g	
(12)	Dry Weight of Sample + Container	1126 g	
(13)	Weight of Container	376 g	
(14)	Weight of Moisture (11) − (12)	84 g	
(15)	Dry Weight of Sample (12) − (13)	750 g	
(16)	Moisture Content [(14) ÷ (15)] 100	11.2 %	
Density			
(17)	Dry Weight of Sample from Test Hole (3) ÷ [1 + (16)*]	8.84 lb	4.010 kg
(18)	Dry Density (17) ÷ (10)	117.7 lb/cu ft	1883 kg/m³
(19)	Maximum Dry Density (from field M-D relations)	120.0 lb/cu ft	1922 kg/m³
(20)	Degree of Compaction [(18) ÷ (19)] 100	98 %	
Depth			
(21)	Depth of Treatment	6-1/4 in	159 mm

*Expressed as a decimal

____
Inspector

Fig. A-4. Example of in-place density test data—sand-cone method.

Related Publications

The following publications are available for purchase from the Portland Cement Association.

Cement-Treated Aggregate Base, SR221
PCA Soil Primer, EB007
Properties and Uses of Cement-Modified Soil, IS411
Soil-Cement Construction Handbook, EB003
Soil-Cement Laboratory Handbook, EB052
Suggested Specifications for Soil-Cement Base Course, IS008
Thickness Design for Soil-Cement Pavements, EB068

The publications listed above can be obtained by writing, calling, or faxing Customer Service, Portland Cement Association, 5420 Old Orchard Road, Skokie, Illinois 60077-1083, Phone: 847.966.6200, Fax: 847.966.9666 or for a complete listing of all our products visit our Web site at: www.portcement.org.

Warning: Contact with wet (unhardened) concrete, mortar, cement, or cement mixtures can cause SKIN IRRITATION, SEVERE CHEMICAL BURNS (THIRD-DEGREE), or SERIOUS EYE DAMAGE. Frequent exposure may be associated with irritant and/or allergic contact dermatitis. Wear waterproof gloves, a long-sleeved shirt, full-length trousers, and proper eye protection when working with these materials. If you have to stand in wet concrete, use waterproof boots that are high enough to keep concrete from flowing into them. Wash wet concrete, mortar, cement, or cement mixtures from your skin immediately. Flush eyes with clean water immediately after contact. Indirect contact through clothing can be as serious as direct contact, so promptly rinse out wet concrete, mortar, cement, or cement mixtures from clothing. Seek immediate medical attention if you have persistent or severe discomfort.

KEYWORDS: calibration, cement application, compaction, curing, density, equipment, finishing, inspection, maintenance, mixing plants, moisture, moisture density, pulverization, site preparation, soil-cement processing, soil identification, soil materials, uniformity, water application.

ABSTRACT: Describes procedures for inspecting soil-cement construction. Sample problems are given that show typical calculations required for computing material quantities, and for field test. Tables and charts to simplify these calculations are included.

REFERENCE: *Soil-Cement Inspector's Manual* (PA050.03), Portland Cement Association, 2001.