

## ALDOT-416

### LABORATORY DESIGN OF SOIL-CEMENT AND FULL-DEPTH RECLAMATION MIXES

#### 1. Scope

- 1.1. This procedure establishes the laboratory guidelines for design of soil-cement and full-depth reclamation mixes.

#### 2. Referenced Documents

- 2.1. AASHTO M 85, Standard Specification for Portland Cement.
- 2.2. AASHTO M 92, Standard Specification for Wire-Cloth Sieves for Testing Purposes.
- 2.3. AASHTO M 231, Standard Specification for Weighing Devices Used in the Testing of Materials.
- 2.4. AASHTO T 134, Standard Method of Test for Moisture-Density Relations of Soil-Cement Mixtures.
- 2.5. ASTM D 1633, Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders.

#### 3. Equipment

- 3.1. Mold – the metal mold shall have an inside diameter of  $4.000 \pm 0.016$  in ( $101.60 \pm 0.41$  mm) and a height of  $4.584 \pm 0.005$  in ( $116.43 \pm 0.13$  mm). The mold shall have a detachable collar assembly  $2.375 \pm 0.050$  in ( $60.33 \pm 1.27$  mm) in high, to permit preparation of compacted specimens of the desired height and volume. The mold and collar assembly shall be fastened firmly to a detachable base plate made of the same material. The base plate shall be plane to  $0.005$  in ( $0.13$  mm). The mold shall have a capacity of  $1/30 \pm 0.0003$  ft<sup>3</sup> ( $0.000943 \pm 0.000008$  m<sup>3</sup>)
- 3.2. Rammer – A manually operated metal rammer having a flat circular face of  $2.000 \pm 0.010$  in ( $50.80 \pm 0.25$  mm) diameter and weighing  $5.50 \pm 0.02$  lb ( $2.495 \pm 0.009$  kg). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of  $12.00 \pm 0.06$  in ( $305 \pm 2$  mm) above the elevation of the sample. The guide-sleeve shall have at least four vent holes, no smaller than  $3/8$  in ( $9.5$  mm) diameter, spaced approximately 90 degrees ( $1.57$  rad) and approximately  $3/4$  in ( $19$  mm) from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

- 3.3. Sample Extruder – A jack, lever, frame or other device adapted for extruding compacted specimens from the mold.
- 3.4. Balances and Scales – A balance or scale of at least 44 lb (20 kg) capacity sensitive to 0.002 lb (0.001 kg) conforming to AASHTO M-231.
- 3.5. Sieves – 3 in. (75 mm),  $\frac{3}{4}$  in. (19.0 mm), No. 4 (4.75 mm), sieves conforming to the requirements of AASHTO M 92.
- 3.6. Polyethylene Freezer Bags – Ordinary freezer bags available from retail stores of at least 1 gal (4 L) capacity
- 3.7. Moisture Room – A moisture room capable of maintaining a temperature of  $73.4^{\circ} \pm 3^{\circ}\text{F}$  ( $23^{\circ} \pm 1.7^{\circ}\text{C}$ ) and having a relative humidity of not less than 95%.
- 3.8. Testing Machine – A hydraulic or screw type with a sufficient opening between the upper bearing surface and the lower bearing surface of the machine to permit testing of the samples specified herein. The machine shall be capable of applying at least 20,000 lb<sub>f</sub> (88,964 N) with an accuracy of  $\pm 1$  percent of the total load.
- 3.9. Straightedge – A hardened-steel straightedge at least 10 in. (254 mm) in length. It shall have one beveled edge and at least one longitudinal surface (used for final trimming of the sample).
- 3.10. Large Pans – Metal pans of sufficient size to allow thorough mixing of the material.
- 3.11. Small Pans or Dishes – Pie pans or evaporating dishes for weighing the cement and/or other admixtures.
- 3.12. Scoops - Scoops or other suitable devices for mixing and sampling the material .
- 3.13. Graduated Cylinder – A 1000 mL capacity glass or plastic graduated cylinder for measuring the mixing water.
- 3.14. Scarify Tool – A six-pronged ice pick or a similar apparatus to remove the smooth compaction plane from the top of the first and second layers of each specimen.

#### **4. Sample Preparation**

##### **4.1. Soil-Cement Mixes**

- 4.1.1. Prepare sample in accordance to AASHTO T 134, Method A.
- 4.1.2. Select a representative sample of the soil enough for three batches of approximately 6 lb (2.7 kg) each to determine the Moisture-Density Relationship. In addition, weigh three batches of approximately 24 lb (11 kg) each of

representative soil sample for the determination of the compressive strength. Additional material may be needed to perform supplementary tests as per Subsection 7.7

- 4.1.3. Weigh the required amount of cement, conforming to AASHTO M 85, necessary to produce soil-cement mixes at 3%, 5%, and 7% cement for the determination of the Moisture-Density Relationship and determination of compressive strength.

#### **4.2. Full-Depth Reclamation Mixes**

- 4.2.1. Prepare sample in accordance to AASHTO T 134, Method B.
- 4.2.2. Select a representative sample of the soil enough for three batches of approximately 11 lb (4.99 kg) each to determine the Moisture-Density Relationship. In addition, weigh three batches of approximately 44 lb (20 kg) each of representative soil sample for the determination of the compressive strength. The sample for the determination of compressive strength shall be made out by combining the material passing the No. 4 (4.75 mm) sieve and the material passing the  $\frac{3}{4}$  in (19.0 mm) sieve but retained on the No. 4 (19 mm) sieve. Additional material may be needed to perform supplementary tests as per Subsection 7.7
- 4.2.3. Weigh the required amount of cement, conforming to AASHTO M 85, necessary to produce soil-cement mixes at 3%, 5%, and 7% cement for the determination of the Moisture-Density Relationship and determination of compressive strength.

### **5. Procedure for Moisture-Density Relationship**

- 5.1. To determine the Moisture-Density Relationship of soil-cement mixtures, follow AASHTO T 134, Method A.
- 5.2. To determine the Moisture-Density Relationship of full-depth reclamation mixtures, follow AASHTO T 134, Method B.
- 5.3. Plot the Moisture-Density Relationship and determine the “optimum moisture content” and the “maximum dry density” of the mixture (See Figure 1 for example graph).

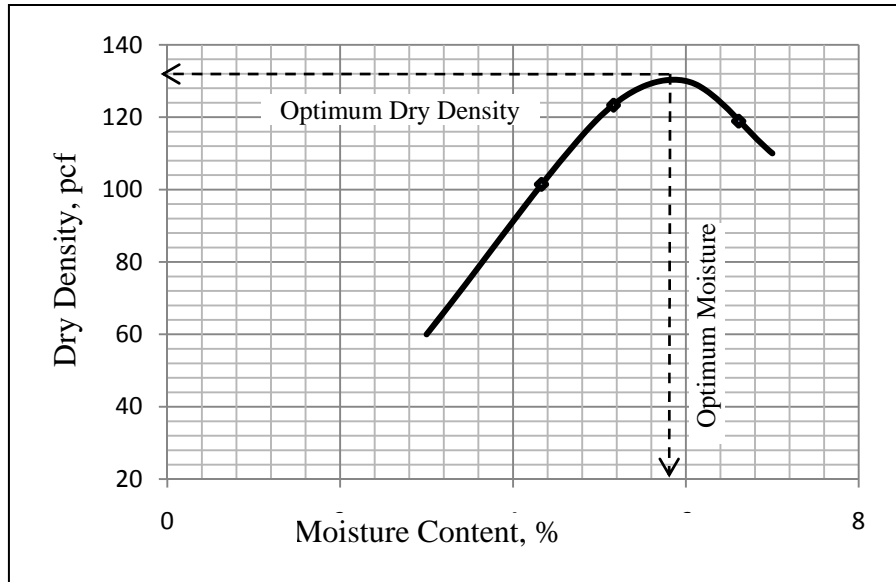


Figure1: Example of a Moisture-Density Relationship graph.

## 6. Procedure for Compressive Strength

### 6.1. Soil-Cement Mix

- 6.1.1. Place 24 lb (11 kg) of air-dry soil and 3.0% cement in a large pan. Mix the materials thoroughly to a uniform color.
- 6.1.2. Add the amount of potable water to dampen the mixture to the optimum moisture content based on the optimum moisture determined from the Moisture-Density Relationship test. Mix thoroughly.
- 6.1.3. Form a specimen by immediately compacting the prepared mixture in a mold (with collar attached) in three equal layers to give a total compacted height of about 5 in. (127 mm). The soil-cement mixture is compacted with the same compaction equipment used to determine the Moisture-Density Relationship.
- 6.1.4. Compact each layer by 25 uniformly distributed blows from the rammer dropping freely from a height of 12 in (305 mm) above the elevation of the soil-cement mixture.
- 6.1.5. The top surfaces of the first and second layers are scarified to remove smooth compaction planes before placing and compacting succeeding layers. The scarification shall form grooves at right angles to each other, approximately 1/8 in. (3.2 mm) deep and 1/4 in. (6.4mm) apart.
- 6.1.6. After the third layer has been compacted, remove the collar of the mold and level the surface of the specimen with a straightedge. Remove all particles that extend

above the top level of the mold. Holes in the surface of the specimen shall be corrected by hand-tamping fine material into the irregularities and leveling the specimen again with a straightedge.

- 6.1.7. Extrude the sample from the mold and seal it in a polyethylene freezer bag. Mark the bags with the percentage of cement used.
- 6.1.8. Prepare three specimens for each soil-cement mixture containing the same cement percentage and optimum water.
- 6.1.9. Place the three specimens in the moisture room and cure for 7 days.
- 6.1.10. Repeat Items 6.1.1. thru 6.1.9. for the 5% and 7% cement contents.

## **6.2. Full-Depth Reclamation Mix**

- 6.2.1. From the 44 lb (20 kg) sample, place the designed quantity of air-dry soil passing the No. 4 (4.75 mm) sieve and the 3% cement in a large pan. Mix the materials thoroughly to a uniform color
- 6.2.2. Add the amount of potable water to dampen the mixture to the optimum moisture content based on the optimum moisture determined from the Moisture-Density Relationship test. Mix thoroughly.
- 6.2.3. Add the designed quantity of saturated surface-dry material passing the  $\frac{3}{4}$  in (19.0 mm) sieve but retained in the No. 4 (4.75 mm) sieve to the soil-cement-water mixture from Item 6.2.2. Mix thoroughly.
- 6.2.4. Form a specimen by immediately compacting the prepared mixture in a mold (with collar attached) in three equal layers to give a total compacted height of about 5 in. (127 mm). The soil-cement mixture is compacted with the same compaction equipment used to determine the Moisture-Density Relationship.
- 6.2.5. Compact each layer by 25 uniformly distributed blows from the rammer dropping freely from a height of 12 in (305 mm) above the elevation of the soil-cement mixture.
- 6.2.6. The top surfaces of the first and second layers are scarified to remove smooth compaction planes before placing and compacting succeeding layers. The scarification shall form grooves at right angles to each other, approximately  $\frac{1}{8}$  in. (3.2 mm) deep and  $\frac{1}{4}$  in. (6.4mm) apart.
- 6.2.7. After the third layer has been compacted, remove the collar of the mold and level the surface of the specimen with a straightedge. Remove all particles that extend above the top level of the mold. Holes in the surface of the specimen shall be

corrected by hand-tamping fine material into the irregularities and leveling the specimen again with a straightedge.

- 6.2.8. Extrude the sample from the mold and seal it in a polyethylene freezer bag. Mark the bags with the percentage of cement used.
- 6.2.9. Prepare three specimens for each soil-cement mixture containing the same cement percentage and optimum water.
- 6.2.10. Place the three specimens in the moisture room and cure for 7 days.
- 6.2.11. Repeat Items 6.2.1 thru 6.2.10 for the 5% and 7% cement contents.

## 7. Testing and Calculations

- 7.1. For each percentage of cement content, test three samples for unconfined compressive strength as per ASTM D 1633, except that the curing of the specimens shall be done as described in this procedure. Do not cap the specimens.
- 7.2. Vertically load the samples in the testing machine at a loading rate of 0.05 in./min (1.27 mm/min) until failure.
- 7.3. Calculate the compressive strength for each cylinder as follows:

$$f_c = \frac{L}{A}$$

Where:

$f_c$  = Compressive strength, psi (MPa)

L = Maximum load at failure, lb<sub>f</sub> (N)

A = Horizontal cross sectional area of sample, in<sup>2</sup> (mm<sup>2</sup>)

- 7.4. No consideration shall be given to the length-to-diameter (l/d) ratio (K-factor).
- 7.5. The 7-day compressive strength for the mix shall be within the following range;
  - 7.5.1. Soil-cement mix - minimum of 250 psi and maximum of 600 psi.
  - 7.5.2. Full –depth reclamation – minimum of 300 psi and maximum of 400 psi.
- 7.6. For each percentage of cement content average the compressive strengths of the three (3) samples tested. Compare the average to the appropriate strength criteria in Subsection 7.5 above.

- 7.7. If all the three average compressive strengths are either above or below the desired compressive strength, perform an additional test varying the percent cement based on the values obtained.
- 7.8. Plot the compressive strength versus the percentage of cement content (See Figure 2 for example graph). From the graph determine the optimum percent cement ( $P_c$ ) at the desired compressive strength.

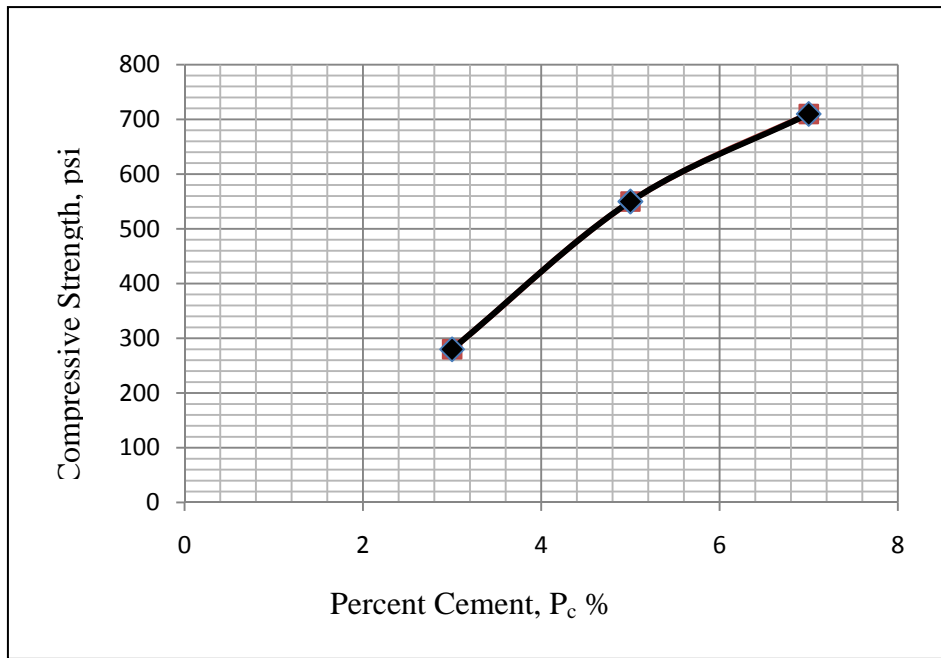


Figure 2: Example of a Compressive Strength versus Percent Cement graph.

- 7.9. Plot the optimum moisture content determined on Subsection 5. versus the percentage of cement content used (See Figure 3 for example graph).
- 7.10. From the graph determine the optimum moisture content using the optimum cement content ( $P_c$ ) determined on Subsection 7.8 above.

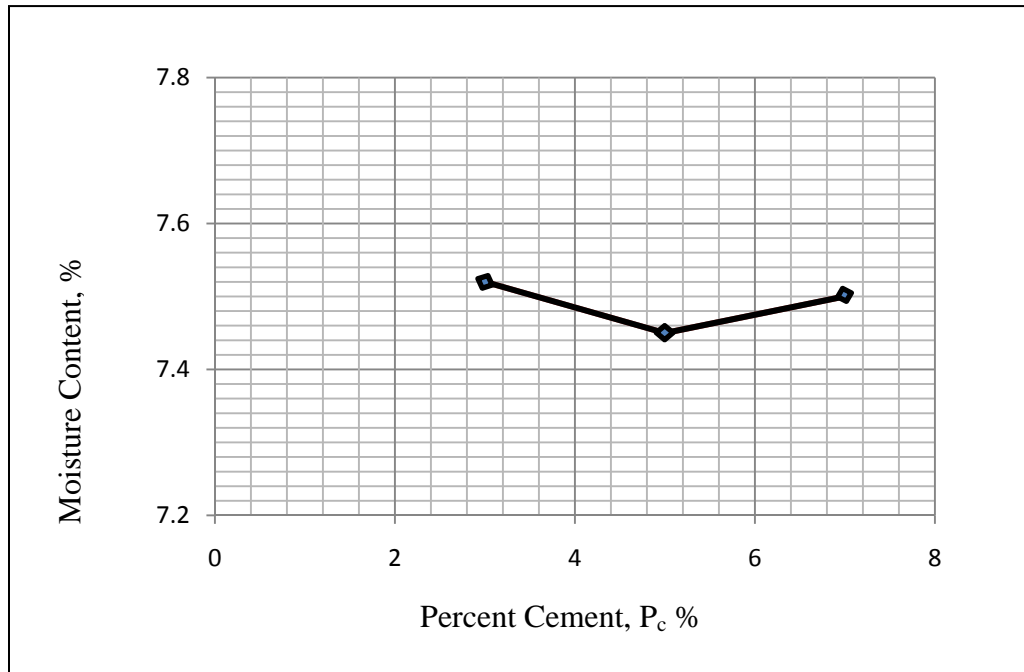


Figure 3: Example of a Moisture Content versus Percent Cement graph.

## 8. Report

- 8.1. The report of the mix design shall be submitted to the Materials and Tests Engineer for verification.
- 8.2. The percentage of cement content may be adjusted from 3%, 5%, and 7% to obtain an acceptable compressive strength, but in no case it shall be less than 3%.
- 8.3. The report shall include the minimum following information:
  - 8.3.1. Proposed mix design proportions, mix materials, and materials sources,
  - 8.3.2. The method used to determine optimum moisture content and maximum density (Method A or Method B) as per AASHTO T 134.
  - 8.3.3. The optimum moisture and maximum density for each of the three soil-cement contents tested.
  - 8.3.4. The determined design of the optimum moisture content and optimum percent of cement content.
  - 8.3.5. The theoretical maximum dry density determined for the optimum moisture content at the optimum percent of cement content.



- 8.3.6. Moisture-Density relationship graphs, Compressive Strength versus Percent-Cement Content graph, and Moisture Content versus Percent-Cement graph,
- 8.4. Any other supporting information relevant to the mix design.