DEPARTMENT OF TRANSPORTATION
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UNCONFINED COMPRESSIVE STRENGTH OF LIME TREATED SOILS AND AGGREGATES

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

A. SCOPE

This test is used to determine the unconfined compressive strength of laboratory compacted lime treated soils and aggregates.

B. APPARATUS

1. Riffle splitter, with chutes 19.0 mm wide or 1.5 x maximum size aggregate.
2. Scales, accurate to 0.2 % of the sample mass.
3. Water spray-metering device with turntable.
4. Mixing pans, trowel and approximately 2 L containers with close fitting lids.
5. Kneading compactor, conforming to the specifications in California Test 301.
6. Compactor accessories:
   a. Solid wall compaction mold shown in Figure 1 and conforming to the dimensions and tolerances on Transportation Laboratory Plan D-839.
   b. Mold holder constructed to hold the mold firmly in place on the compactor turntable during compaction.
   c. Rubber discs, 100 mm in diameter by 3 mm thick and having a durometer hardness of 80 ± 5.
7. 101.6 mm diameter by 101.6 mm high tin liners with caps.
8. Masking or adhesive tape.
9. Measuring device suitable for measuring the height of the compacted test specimens to the nearest 0.1 mm.
10. Cardboard discs, 100 mm in diameter, cut from approximately 68 kg manila stock.
11. Glass plates approximately 150 by 150 by 6 mm.
12. Compression testing machine with a spherically seated head which can be locked into a horizontal plane.
13. Oven capable of maintaining a temperature of 43.3 ± 2.7°C.
14. High strength capping plaster, U.S. Gypsum Co. "Hydrocal" or equivalent.

15. Tamping rod, 50 mm nominal diameter by 150 mm minimum length.

C. PREPARATION OF SOIL

1. Process the soil sample according to the instructions in California Test 201.

2. Split out a sufficient number of representative portions of the material to complete the desired testing. (Normally 1500 g is adequate for each specimen.)

   a. One portion is required for determining "as received" moisture content.

   b. Five portions are normally enough to determine optimum moisture.

   c. Strength tests should be in duplicate for each lime-soil combination.

3. Materials containing aggregate retained on a 4.75 mm sieve are to be recombined to their original grading.

4. Determine the "as received" moisture content of one representative portion according to the instructions in California Test 226.

D. FABRICATING AND CURING TEST SPECIMENS

It is important that laboratory tests for mix design be made using the same lime that will be used during construction. When making preliminary tests to determine the feasibility of treating a soil, select several trial lime contents; e.g., 3 %, 5 % and 7 %. Any of the lime products allowed in the standard specifications may be used.

NOTE: The minimum percent of lime to use in the trial batch can be established using pH value as described in the appendix of ASTM Designation: C 977.

1. Calculate the dry mass of the individual representative test portions based on the moisture content determined in C-4.

2. Calculate the amount of lime to be added by multiplying the dry mass of the soil by the desired percentage of lime.

3. Place the soil in the mixing pan and mix in the required amount of lime using the trowel to mix the materials.

4. Use the water-metering device to add the required amount of water to the material while mixing with a trowel.

   a. To samples being used to determine optimum moisture (Section F), add sufficient water to obtain at least 50 % of the estimated optimum moisture content. Estimate the required amount by observing the appearance of the wetted soil and its tendency to form a ball when squeezed.

   b. To samples being prepared for unconfined compressive strength tests, add all of the water necessary to attain optimum moisture as determined in Section F.

   c. Continue mixing only as necessary to uniformly distribute the lime and water. Do not mix longer than 1 min and do not deliberately break up lime chunks that would probably not be broken up during field mixing.

5. Place the material loosely in a container and secure the lid.

6. Allow the material to cure for a minimum of 16 h (up to 24 h maximum) at 21 ± 3°C.

E. COMPACTING TEST SPECIMENS

1. Following the prescribed curing period, return the mixture to the mixing pan and remix to assure uniform distribution of the lime and water. Do not deliberately break up lime chunks.

2. Assemble the compaction mold with the expansion liners, tin liner and bottom plunger in the correct position as shown in Figure 2.

3. Clamp the mold in place in the mold holder and lock this assembly in place on the compactor turntable.

4. Place a cardboard disc in the mold on top of the bottom plunger.

5. Distribute the prepared material evenly along the full length of the compactor feeder trough.

6. Feed the first 75 mm of material from the trough into the mold.

7. Set the compactor to operate at a foot pressure of 1723.7 ± 172.4 kPa and begin compacting the test specimen.

8. Feed the remainder of the material from the trough into the mold in 20 equal increments at a rate of one increment with each upstroke of the compactor ram beginning after the first stroke.

    a. When compacting the first specimen of a series from the same material, the height of the material in the compaction mold should be observed and the flow of material from the trough stopped when an estimated height of 101.6 mm is reached.

    b. The amount of prepared material placed in the trough may be adjusted for subsequent specimens so that the 101.6 m specimen height can be achieved. Adjustment of the sample mass shall be made only after the proper amount of soil, lime, and water have been uniformly mixed.

    c. When feeding the material manually, use a spatula shaped to conform to the inside contour of the trough to push the material into the mold.

    d. If the material pushes up around the foot during the loading operation, decrease the foot pressure as necessary to prevent excessive displacement. Record the actual pressure used.

9. When all of the material is in the mold, apply 10 additional strokes with the compactor to level and set the material.

10. Raise the compactor foot and remove any material adhering to the foot and upper portion of the mold.

11. Place a rubber disc on top of the material in the mold.

12. Set the compactor to operate at a foot pressure of 2413 kPa and continue compacting by applying 100 strokes.

    a. If the compactor foot displaces more than 6 mm of the surface of the test specimen, reduce the pressure as necessary to limit the displacement to 6 mm and record the actual pressure used.

    b. If free water appears around the bottom of the mold during compaction, the moisture content is excessive. Stop the compactor immediately and discard the test specimen.

13. Remove the assembled mold and holder from the compactor.

14. Remove the rubber disc from the surface of the test specimen.

15. If the surface of the test specimen is left uneven by the action of the compactor foot, smooth and level the surface by gently tamping with a flat-ended rod.

16. Place a cardboard disc on top of the test specimen.

17. Place the follower ram on top of the test specimen in the mold.

18. Position the assembled mold and test specimen in the testing machine with the head of the testing machine locked into the horizontal position.

19. Apply a vertical force of 19.6 kN (2.41 MPa) at a rate of 8.9 kN/min.

20. When the 19.6 kN total load is achieved, immediately release the force and remove the test specimen in its tin liner from the compaction mold.

21. Determine the height and mass of the compacted test specimen.

22. Place lids on both ends of the test specimen and seal with tape.

F. DETERMINING OPTIMUM MOISTURE

The optimum moisture content is the amount of total water in the lime-soil mixture that will provide the highest compacted density when the material is compacted according to the procedures in Section E. Because optimum moisture can be affected by differences in the amount and type of lime used to treat a soil, the optimum moisture must be determined for each combination of lime and soil to be tested. It is permissible to extrapolate the optimum moisture content for intermediate lime contents provided the optimum moisture has been established with at least two lime contents and the lime content is within 1 % of the lime content of a test specimen on which optimum moisture has actually been established.

1. Prepare a minimum of five test specimens by thoroughly mixing the soil, lime and water according to instructions in Section D.

2. Following the prescribed curing period, return the first test specimen to the mixing pan.

3. Add additional water through the metering device, while stirring the material with the trowel, to bring the water content up to the estimated optimum moisture.

4. Compact the material into the test mold according to instructions in Section E.

5. Determine the height and mass of the compacted test specimen and calculate the dry density using the formula:

$$D_d = \frac{12\,334 \text{ x } M_w}{(100 + M)H}$$

Where:

D_d = Dry density in kg/m^3
M_w = Wet mass of compacted test specimen (grams)
M = Percent total moisture in test specimen
H = Height of test specimen to nearest 0.1 mm

6. Add approximately 2 % more water to the second test specimen than was added to the first and compact it into the test mold.

   a. If the first test specimen was obviously excessively wet, the amount of water added to the second specimen should be less than was added to the first.

7. Determine the height and mass of the compacted test specimen and calculate the dry density.

8. Use the moisture/density relationships of the preceding test specimens to determine the amount of water to be added to each successive specimen.

   a. Adjustments to moisture contents should be in increments of approximately 2 %.

   b. Larger differences in moisture content may be made if there is reason to believe that the required range in moisture contents will not be achieved at 2 % increments.

c. The moisture/density relationships can be evaluated best by plotting each point onto a curve as they are obtained. See Figure 2.

9. Continue to compact test specimens at different moisture contents and calculate the compacted density until the maximum density is achieved.

   a. Maximum density is verified by significantly lower densities of at least one wetter and one dryer test specimen.

   b. It is not uncommon for lime treated soils to exhibit a broad range in moisture contents with very little difference in compacted density. For these materials, it may be necessary to use moisture adjustment increments greater than 2 %.

G. CURING AND TESTING FOR UNCONFINED COMPRESSIVE STRENGTH

1. Compact the test specimens and seal in tin liners according to instructions in Section E.

2. Cure the sealed specimens in a 43.3 ± 2.7°C oven for seven days.

3. At the end of the seven day curing period, remove the test specimens from the oven and allow to cool.

4. Remove the caps and tin liners.

5. Cap both ends of the test specimen with capping plaster.

   a. Use lubricated glass plates to form a smooth surface on the caps.

   b. The smooth surface of the cap must extend slightly outside the width of the test specimen on all sides.

   c. The capping plaster will not adhere firmly to many lime treated soils. It will be necessary in these cases to allow a small excess of plaster to flow over the edge of the test specimen to grip the sides and hold the cap in place.

   d. The surfaces of the top and bottom caps should be as nearly as possible at right angles to the axis of the test specimen and parallel to each other.

6. Allow the plaster caps to harden, then remove the glass plates.

   a. Care must be taken not to loosen the caps from the specimen as the glass plates are removed.

   b. The glass plates should slide off easily after approximately 30 min. If the glass plates are still difficult to remove after 30 min, it may be necessary to allow a longer setting time or to apply warm water to the surface of the plate.

7. Position the test specimen on the test machine and apply an increasing load with the press set to travel at a rate of 1.27 mm/min.

   a. The spherically seated head must be free to adjust to the plane of the plaster cap.

   b. Apply the load continuously and without shock.

8. Increase the load until the test specimen begins to fracture. Record the maximum load applied.

9. Report the unconfined compressive strength as megapascals (MPa).

a. When the total load applied is recorded, convert to megapascals by dividing the total load in Newton's by the end area of the test specimen. The standard test specimen has an end area of 8107 mm^2.

H. SAFETY & HEALTH

Caution must be exercised in the operation of the compactor so as not to allow any object other than the sample itself to intercede between the compactor foot and the mold at any time while the ram is in motion. The clearance between the inside edge of the mold and the compactor foot is approximately 1.6 mm. The applied shearing force of 4900 N could cause severe injury to an operator's hand if caught between the compactor foot and the mold. A clear plastic guard has been designed for the California compactor and should be used as an aid in safeguarding against this hazard.

A heat-producing chemical reaction occurs as water combines with quicklime. Burns can result from allowing quicklime to contact the body when it is wet from perspiration or other moisture.

If quicklime gets into the eyes, rinse them immediately with a heavy flow of water and seek medical assistance.

Prior to handling, testing or disposing of any waste materials, testers are required to read: Part A (Section 5.0), Part B (Sections: 5.0, 6.0 and 10.0) and Part C (Section 1.0) of the Caltrans Laboratory Safety Manual. Users of this method do so at their own risk.

REFERENCES
California Tests 201, 226,301
ASTM Designation: C 977

End of Text (California Test 373 contains 9 Pages)

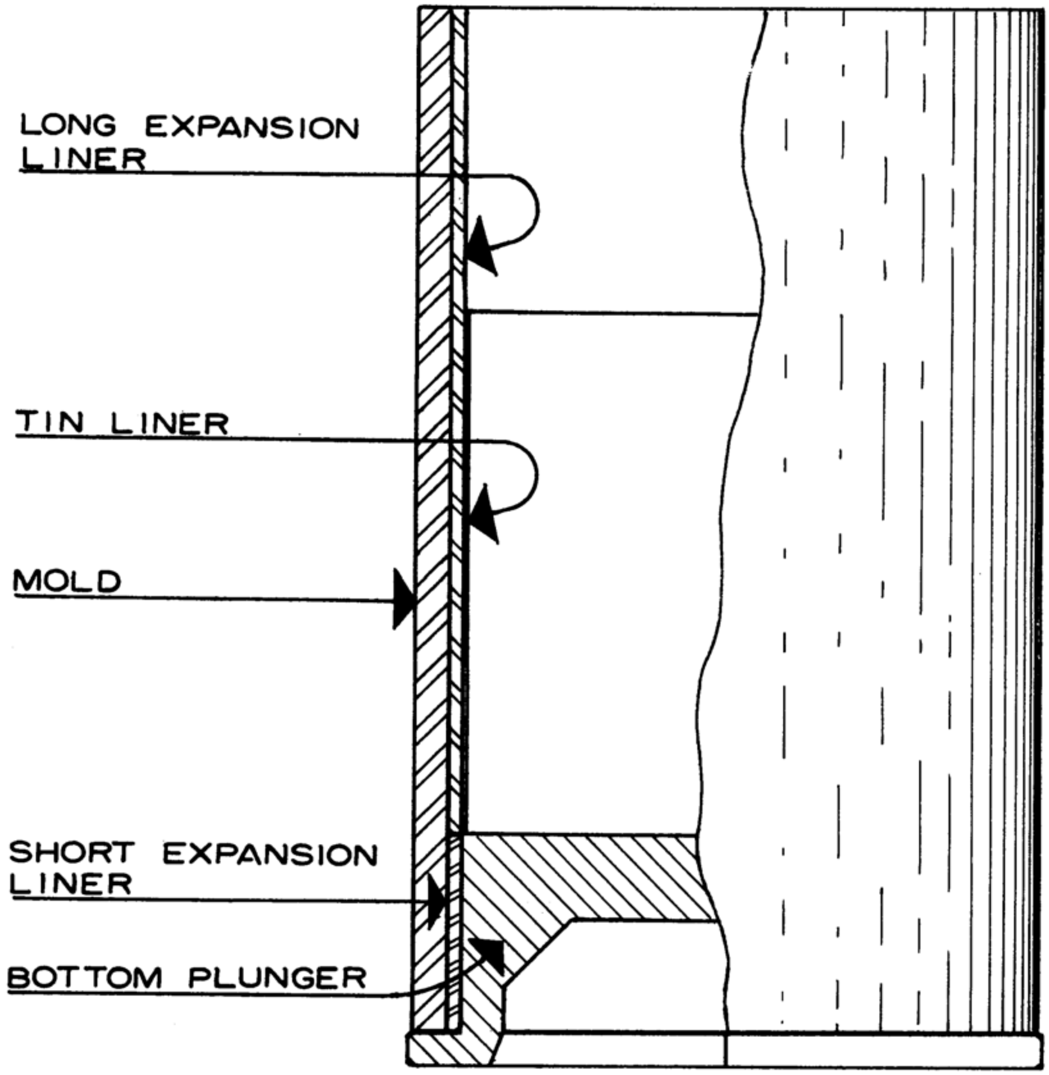

Figure 1
Solid Wall Compaction Mold

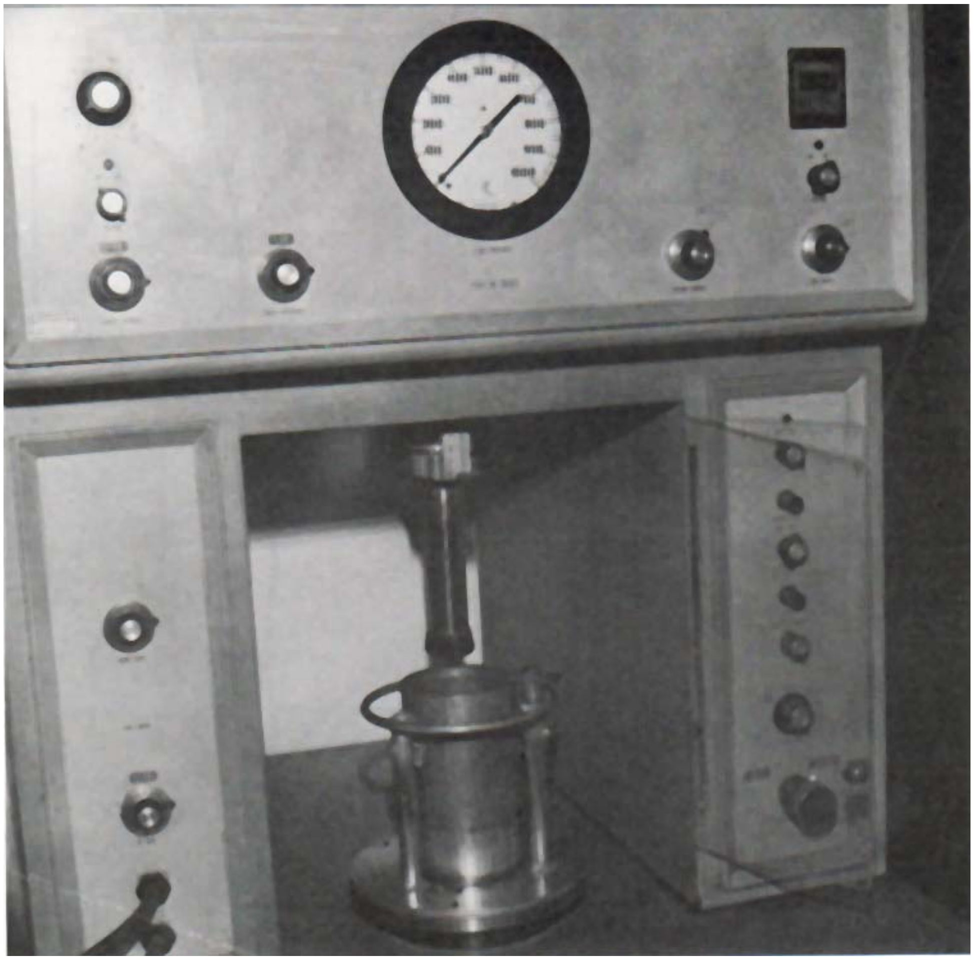

Figure 2
Compaction Mold in Kneading Compactor

MOISTURE—DENSITY RELATIONSHIP

Test Specimen	A	B	C	D	E
Initial Mass (g)	1500	1500	1500	1500	1500
Initial Moisture (%)	3.3	3.3	3.3	3.3	3.3
Dry Mass of Soil (g)	1452	1452	1452	1452	1452
Lime Added (%)	3.0	3.0	3.0	3.0	3.0
Lime Added (g)	43.6	43.6	43.6	43.6	43.6
Added Water (mL)	240	270	210	180	150
Total Water (mL)	288	318	258	228	198
Total Water (%)	19.3	21.3	17.2	15.2	13.2
Mass of Compacted Sample, M_w (g)	1751	1720	1720	1721	1724
Height of Compacted Sample H(g)	103.9	102.9	103.9	106.4	110.7
Dry Density, D_d (kg/m^3)	1742	1700 (wet)	1742	1732	1697

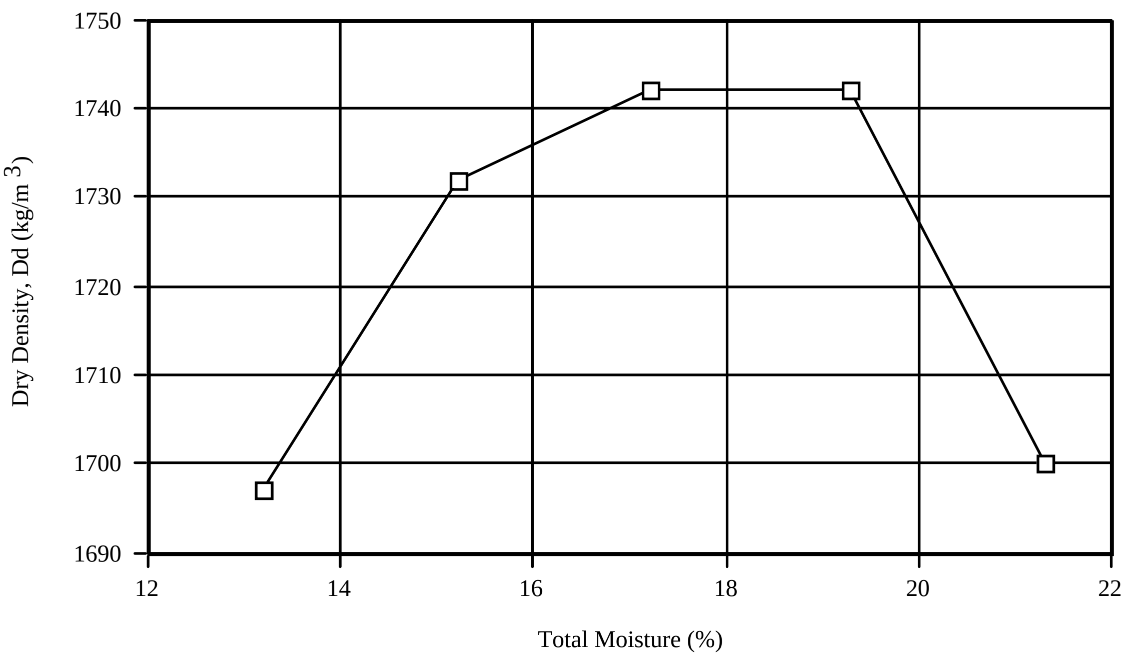

Figure 3