OHD L-53
METHOD OF TEST FOR
CEMENT TREATED BASE MIX DESIGN

1 SCOPE

1.1 This method determines the proportions of aggregates, cement, fly ash, and water to produce a cement treated base. This method is limited to aggregate meeting the requirements of Section 703.02, "Aggregates for Econocrete Base and Cement Treated Base". Stabilization of finer materials is covered under OHD L-50.

1.2 Laboratories performing cement-treated base mix designs shall be qualified by the Materials Division.

1.3 Technicians performing cement-treated base mix designs shall be qualified by the Oklahoma Highway Construction Materials Technician Certification Board. Technicians shall be certified in either Soils and Materials Sampler or Soils and Concrete.

2 APPARATUS

2.1 Balances and Scales. A balance or scale conforming to the requirements of M 231, Class G 20. Also, a balance conforming to the requirements of M 231, Class G 2.

2.2 Molds. Calibrated cylindrical molds, split sided, approximately 6.0 inches in diameter and 6.0 inches in height and having a volume of approximately 0.10 ft^3. The molds shall be equipped with a removable top collar and a removable base plate.

NOTE: A suitable sealant; such as heavy grease, molding clay, or microcrystalline wax shall be used where necessary to ensure that the molds are water tight when used for fabricating specimens. Molds shall be water tight when assembled as judged by their ability to hold water poured into them.

2.3 Rammer. A sleeveless rammer, per USACE EM 1110-2-1906, Appendix VI, shall be used for specimen consolidation (compaction), rather than rodding or vibration. A standard Proctor rammer (AASHTO T 99) may be used for specimen consolidation but use care to ensure the free fall of the rammer weight is not obstructed.

2.4 Straightedge. A hardened steel straightedge at least 10 inches in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 in. per 10 in. (0.1 percent) of length within the portion used for trimming the mixture.

NOTE: The straightedge shall not be so flexible that trimming the sample with the cutting edge will cause a concave or convex sample surface.

2.5 Mixing Tools. Miscellaneous tools such as mixing pan, spoon, trowel, spatula, scoop, or a suitable mechanical device for thoroughly mixing the sample of aggregate with cement and/or fly ash and with increments of water.

2.6 Testing Machine. The compression testing machine should have sufficient capacity, readability, and capable of providing the prescribed rates of loading. Since the compressive strength of CTB cylinders will typically be 600 to 2000 psi, the testing machine must have a loading range such that valid values of compressive strength can be obtained.

3 MATERIALS

3.1 Aggregate, mixing water, cement, and fly ash shall come from sources proposed for use on the project, and conform to applicable ODOT Specifications and Special Provisions.

3.2 Approximately 400 lbs of aggregate, 10 gallons of water, 30 lbs of cement and flyash are required for mix design.

4 PROCEDURE

4.1 Design Criteria. The design criteria for CTB shall be the average compressive strength of compacted and cured specimens is no less than 600 psi and no greater than 1200 psi. The target strength range should be 800 to 1000 psi. The workability of the mix is such that it may be placed and compacted in the field with minimal segregation and deformation. This will be a no-slump mix, with consistency in the very stiff to extremely dry range.

NOTE: Cement-treated bases with compressive strengths in this range are prone to shrinkage cracking, which may reflect through surface layers. This is currently being addressed with a bond-breaking layer between the CTB and surface layer.

4.2 Mix Proportions. Proportions of aggregate, cement, and water may be determined by experience, or by one of the two following methods. In any case, trial mixes are required and specimens are mixed, compacted, cured, and tested in the same manner.

NOTE: Acceptable mix designs have contained 3 to 5 % cement and fly ash with water/cement ratios of 0.75 to 1.25. Mixtures should contain sufficient mortar to just fill the voids between the coarse aggregate. Too much mortar will push the coarse aggregate particles apart, too little mortar will leave large voids in the concrete, both reduce the strength of the mixture.

4.3 Absolute Volume Method. Mix proportions are determined in the same manner as Portland cement concrete using the methods described in ACI 211.3R-02, "Guide for Selecting Proportions for No-Slump Concrete," Appendix 3, "Roller-Compacted Concrete Mixture Proportioning. Typically, given an aggregate gradation, design strength, and design consistency:

- an initial water/cement ratio and paste/mortar ratio to obtain the design strength are determined by testing mortar cubes, or from design curves and tables (or software based on these design curves and tables);

- an initial proportion of coarse aggregate to mortar to achieve the design consistency is determined by testing trial batches by the modified Vebe method (ASTM C 1170), or from design curves and tables or software;

- specimens of the trial mix are compacted, cured and tested for compressive strength;

- if necessary, adjustments are made to the proportions of the initial trial mix to better match the design strength and consistency.

NOTE: The mix proportion curves in ACI 211.3R-02 have a lower limit of 2000 psi compressive strength. Below this, proportions must be estimated and verified with trial mixes.

4.4 Soil Compaction Method. Water content is the amount required for compaction to maximum standard density. Cement content is the minimum amount required to meet the design criteria.

- Assume an initial cement content and prepare and compact specimens over a range of water contents to determine an initial optimum moisture.

- Trial specimens are compacted, cured, and tested over a range of cement contents using the initial optimum moisture content.

- The design cement content is selected from test results.

- A final mix at the design cement content is made to refine the estimate of maximum standard density and optimum moisture.

4.5 Mixing and Compaction of Material. Prepare materials and mix in accordance with AASHTO R 39. Do not reuse materials; use new materials for each trial batch.

4.5.1 Mold specimens as close as practical to the place where they are to be stored during the first 24 hours. If it is not practical to mold the specimens where they will be stored, move them to the place of storage immediately after being struck off.

4.5.2 Place the mix in a lightly oiled mold using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of mix from the mixing pan to ensure that it is representative of the batch. It may be necessary to remix with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop or trowel around the top edge of the mold as the mix is discharged in order to ensure a symmetrical distribution of the mix and to minimize segregation of coarse aggregate within the mold. Further distribute the mix by use of a spatula prior to the start of compaction. In placing the final layer, the operator shall attempt to add an amount of mix that will exactly fill the mold after compaction. Do not add nonrepresentative samples of mix to an underfilled mold.

4.5.3 Form a specimen by compacting the prepared mixture in four approximately equal layers. Compact each layer with 56 blows from the rammer dropping free from a height of 12 inches. Distribute the 56 blows of the rammer uniformly over the surface area of each layer. During compaction, the mold shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process.

NOTE: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the mix: a block of concrete with a mass not less than 200 lb supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges, and pavements.

4.5.4 Upon completion of compaction of the final layer, remove the extension collar and using the straightedge carefully strike off the specimen level with the top edge of the mold. Using the same straightedge at a slight incline, smooth off the material so that the surface is plane with no depressions or projections greater than 1/8" and the material is level with the top of the mold. Fill small depressions in the top surface with fines from the same sample immediately after striking off. If necessary, the top surface may be smoothed again.

4.5.5 Density Determination. After each specimen is molded and struck off to the required smoothness, weigh the specimen on a scale or balance to the nearest 0.1% of the sample mass or better. Prior to compacting, the weight of each mold and base plate shall be determined. Calculate the wet density. Calculate the dry density using the batch moisture content.

4.5.6 If the specimen is intended for compression strength testing, cure as described below. Note that three replicate specimens and tests are required to determine average strength.

4.5.7 If the specimen is intended for determination of the moisture-density curve, discard the compacted material and repeat the batching and molding with separate samples over a range of moisture contents, in the same manner as AASHTO T 99. Determine the optimum moisture and maximum density, using the batch moisture content (instead of a moisture content determined from a sample).

NOTE: The batch moisture is considered a more accurate estimate of the moisture content needed for compaction than could be obtained from a moisture sample, due to cement hydration.

4.6 Curing. Once the specimen has been struck off to the required smoothness and weighed, cover the top of the mold with plastic, such as plastic cut from sample bags, and then place the compaction collar back on the mold and plastic. Tighten the collar so that the plastic will make an airtight seal around the rim of the mold and the surface of the specimen. This shall be done in order to prevent moisture loss from the specimen during the initial curing. Unless otherwise specified, all specimens shall be moist cured at 73 ± 3ºF from the time of molding until the moment of test. Storage during the first 48 hours of curing shall be in a vibration-free environment.

4.6.1 Initial Curing. Once all specimens have been molded and sealed with plastic, cure the specimens in the molds, covered in tough, durable, impervious plastic sheeting or plastic bags, in the moisture room for 24 ± 8 hours.

4.6.2 Final Curing. Remove from the molds and return the specimens to the moisture room. Protect from dripping, spraying, or pooled water for the remainder of the 7-day moist curing period. Alternatively, the specimens may be wrapped in plastic, covered with wet cloths, and placed in an ice chest in a controlled temperature room (heated and air-conditioned).

4.7 Compressive strength determination. Determine the diameter using two diameter measurements to the nearest 0.01 inches taken at 90 degrees to one another near the mid height of the specimen. Prior to placing compressive strength specimens in the compression machine, verify that both ends of the specimen are plane to within 0.002 in. If an end of the specimen is outside of the 0.002 in. tolerance, that end of the specimen shall be capped in accordance with AASHTO T 231.

NOTE: Due to the irregular surface of the ends, it is highly recommended to cap both ends of all specimens.

4.7.1 Determine the 7 day unconfined compressive strength in accordance with AASHTO T 22 except as modified herein. The requirement for immersing cured specimens in water for 4 hours prior to testing shall be omitted. The specimen will be the 6.0-inch size.

4.7.2 Maintain free moisture on the outsides of specimens to prevent drying until testing is complete (except for the ends of the specimens when sulfur capping). When capping with sulfur, be certain that the ends of the specimen are dry enough to prevent small pockets of steam from forming within the capping compound.

4.7.3 Apply the load continuously and without shock. The rate of loading shall be within 10 ± 5 psi per second. Continue applying the load until the maximum possible load has been attained and the specimen shows a well defined fracture. Read and record the load to the nearest 10 lbf.

NOTE: For purposes of this method, strength determined for specimens at a height divided by diameter ratio (uncapped) of 1.0 is considered to be standard, and is not corrected by a length to diameter correction factor.

4.7.4 Calculate the compressive strength for the specimen. Calculate the average strength for each cement content. Use ASTM E178 for determination of outliers at an upper significance level of 10%.

5 DESIGN CEMENT CONTENT

5.1 The design cement content is defined as the cement content required to achieve the target unconfined compressive strength of 800 to 1000 psi. Select a design cement content that achieves the required strength.

5.2 Determine the optimum moisture content and maximum standard density at the design cement content. This is not necessary if the design cement content is the same as the cement content used in the initial optimum moisture and density determination.

6 REPORT

6.1 The report shall include:

- the project number or contract number.
- identification of the aggregate material and cementitious materials including the Department's Producer/supplier code and naming convention shown on the Department's website.
- gradations for the aggregates, the optimum moisture content, maximum density, design cement content, and average unconfined compressive strength at design values.
- include a single-point gradation for the combined aggregates for each sieve within the specification limits. The allowed tolerances from the single point gradation are:
    - 1-1/2" Sieve +/- 0 %
    - 1", 1/2", #4 Sieves +/- 8 %
    - #40 Sieve +/- 5 %
    - #200 Sieve +/- 3 %

6.2 The report shall reference the procedures used and satisfy the reporting requirements of the referenced procedures.

Revision Date	**Revision Description**
08/22/2008	Original published.
3/19/2009	Editorial and format changes throughout: In Section 3, added notes 1 and 2 and renumbered remaining notes. In Section 5.5.5, changed curing time from 12 hrs to 16 hrs. In Section 5.6.4, removed correction factors for specified CTB mold sizes and added Note 9 explaining the change to improve agreement with ASTM D 1633. In Section 6.2, added interpolation between test results. Combined Sections 6 and 7 and renumbered following sections. In Section 7.3, added requirement for single point gradation submittal.
7/24/2009	In Section 5.1, added note 3 to reference Appendix 2 and renumbered following notes. In Section 5.6, added note 8 to omit immersion of specimens and renumbered following notes. In Section 5.6.1, added requirement to minimize moisture changes during testing. Added Appendix 2 to address constructability/gradation issues.
1/24/2013	Extensively rewritten to remove reference to “soil-aggregate” and move away from soil cement more towards low-strength roller-compacted concrete and included option for “absolute volume” proportioning. Moisture contents based on batch moisture, rather than moisture samples.