MIX DESIGN METHOD FOR SOIL-CEMENT MIXTURES

1.0 SCOPE

1.1 This Method is used in the laboratory mix design of soil-cement mixtures for sandy soils. This test method is for use with mixtures containing Portland cement, soil up to 40 mm maximum size and water. These design procedures are based on the Portland Cement Association method of design.

1.2 The purpose of this mix design method is to determine the quantity of Portland cement required to adequately harden the soil; the quantity of water that is needed for compaction; and the density to which the cement stabilized base course must be compacted. However, it is the optimum moisture content and maximum dry density obtained for each unit of production that govern field control.

1.3 This method is used to determine the lowest cement content that will provide acceptable performance characteristics, using natural aggregate.

2.0 APPLICABLE DOCUMENTS

2.1 ASTM C566 Total moisture content of aggregate by drying

2.2 ASTM D1632, D1633 Compressive strength of cylinders and cores

2.3 ASTM D2974 Organic matter content (loss on ignition)

2.4 ATT-25 Sieve analysis

2.5 ATT-26 Sieve analysis, 20 000 μm minus

2.6 ATT-57 Reducing samples to the testing size

2.7 Portland Cement Association, Soil-Cement Laboratory Handbook

2.8 Portland Cement Association, PCA Soil Primer

2.9 Portland Cement Association, Soil-Cement Construction Handbook

2.10 Portland Cement Association, Soil-Cement Inspector's Manual

2.11 TLT-113 Standard practice for identification and description of aggregate prospects (visual-manual procedure)

2.12 TLT-412 Atterberg limits, liquid limit, plastic limit, plasticity index

2.13 TLT-502 Moisture-density relation for soil-cement mixtures

2.14 TLT-503 Wet-dry test for soil-cement mixtures

2.15 TLT-504 Freeze-thaw test for soil-cement mixtures

2.16 TLT-649 Water analysis

3.0 OUTLINE OF METHOD

3.1 The procedures for the Soil-Cement design starts with the selection and preparation of the aggregate and test specimens. Preliminary to the operation it is required that:

3.1.1 the type of Portland cement for use in the mix design meets those specified in the contract;

3.1.2 the aggregate job mix formula meet the gradation requirements of the project.

4.0 APPARATUS

4.1 The equipment used are similar to those listed in the above mentioned publications.

5.0 TEST SPECIMENS

5.1 Aggregate Preparation (approximately 500 kg of material are required for a full design)

5.1.1 The samples are loaded on canvas covered wire mesh trays and placed in a drying room maintained at 37ºC.

5.1.2 After air drying, a small representative sample is taken from each tray to determine the gradation and soil classification. Additional small representative samples may be required to determine the presence of injurious compounds in the aggregate. The suitability of the source is assessed based on these preliminary results.

5.1.3 A sufficient number of samples are selected to do the design and their combined grading will approximate the average or design grading.

5.1.4 Unless the aggregate is to be modified (blend sand or flyash), the selected samples are combined and thoroughly mixed and blended.

5.1.5 A sample is obtained from the combined material and compared to the design grading.

6.0 PROCEDURE

There are two methods of cement stabilized mix design. Method A is used where all of the material passes the 5 000 μm sieve and Method B where there is material retained on the 5000 μm sieve. Both procedures use charts compiled by the Portland Cement Association (PCA) to aid in determining an approximate cement content to start the design. The maximum size of aggregate used is 20000 μm. Therefore, the material larger than 20000 μm is replaced by an equivalent weight of -20000 μm, +5000 μm material.

The procedures used are similar PCA Soil-Cement Laboratory Handbook Short Cut Test Procedures for Sandy Soil.

6.1 METHOD A: The estimated cement content is determined based on the gradation and density using PCA charts (see Method A charts attached).

6.1.1 The design grading of the aggregate is plotted on an aggregate gradation chart. The curve is extended to estimate the percentage of material that is smaller than 50 μm.

6.1.2 The percent of material smaller than 4.75 mm (Imperial sieve #4) and the 0.25 mm (Imperial sieve #60) are estimated and the difference between the two percentages is calculated.

6.1.3 The percentage of material between 4.75 mm and 0.25 mm is plotted versus the estimated percentage material smaller than 50 μm and the estimated maximum density is established.

6.1.4 The estimated maximum density and the percentage of material smaller than 50 μm is plotted to determine the starting cement content.

6.1.5 The PCA recommended starting cement content is highly conservative, therefore reduce it by 1%. This adjusted cement content is the percentage used for the moisture-density relation test and is the midpoint of the CSBC mix design.

6.2 METHOD B: The estimated cement content is determined based on the gradation and density using PCA charts (see Method B charts attached).

6.2.1 As for Method A, the gradation of the aggregate is plotted on an aggregate gradation chart and the percentage of aggregate smaller than 50 μm estimated. This percentage and the percentage of material retained on the 2000 μm sieve are plotted and the estimated maximum density established.

6.2.2 The estimated maximum density, the percent material smaller than 50 μm and the percentage of material larger than 4.75 mm are plotted to determine the starting cement content.

6.3 A five (5) point standard moisture-density relation test is carried out at the starting cement content (TLT-502).

6.3.1 Using the results obtained from TLT-502 the 42 mix design specimens are formed at the optimum moisture content.

6.3.2 Generally, with gravelly or clean aggregate, specimens are not formed at the optimum moisture content due to the fact that the optimum would introduce more water into the aggregate than it can hold. This would cause moisture to escape from the bottom of the sample during forming and would be detrimental in the field, i.e. wetting of the subgrade. In this case, a moisture content is selected slightly below optimum, so that all of the water introduced will be held by the aggregate.

6.4 For Method A, sets of 2000 g specimens (using a 4" x 4.6" mold as in TLT-502) are prepared in triplicate at the three different cement contents (i.e. at the recommended cement content, 2% less and 2% more) to be tested as follows:

6.4.1 one set of nine specimens for seven (7) day control compressive strength.

6.4.2 one set of nine specimens for twenty eight (28) day control compressive strength.

6.4.3 one set of nine specimens for seven (7) day wet-dry.

6.4.4 one set of fifteen specimens for seven (7) day freeze-thaw (includes cement content increments of ±1%).

6.4.5 The wetting down and mixing sequence is arranged so that each sample will sit for 5 to 10 minutes to facilitate complete moisture distribution before compaction.

6.5 For Method B the specimens are formed as described above with the following modifications:

6.5.1 the weight of the dry aggregate is 2000 g.

6.5.2 where there is greater than 5% material retained on the +5000 μm sieve, the +5000 μm material is kept separate from the -5000 μm material. The +5000 μm material is covered with water and allowed to soak for 24 hours. After 24 hours, the aggregate is brought to a saturated surface dry condition. The -5000 μm portion of the sample is dry mixed with the corresponding weight of cement and then the required water content by total weight is added and thoroughly mixed. The +5000 μm saturated surface dry aggregate is then added and the combined mixture is allowed to sit for the required time, then formed as previously specified.

6.6 7-Day Control Specimens

6.6.1 Immediately after forming, each set of specimens is placed in the moisture room and allowed to cure for seven (7) days at 21°C ±

1.5°C at 95% to 100% humidity.

6.6.2 At the end of the seven days, each specimen is weighed, measured, and immersed in water for not less than four (4) hours.

6.6.3 At the end of the soaking period, the specimens are weighed in water, then towel dried to the saturated surface dry condition and weighed again.

6.6.4 Each specimen is capped with a mixture of sulphur and fire clay and allowed to sit undisturbed for 0.5 hours, to permit the cap to harden.

6.6.5 The specimens are tested for compressive strength, and finally a representative moisture content sample is obtained from the broken pieces. This moisture content is corrected for losses due to hydration by adding approximately ¼ of the cement content to the moisture content obtained from the broken pieces (i.e. if cement content = 8%, add 2% to the moisture content).

6.7 28-Day Control Specimens

6.7.1 These specimens are handled in the same way as the 7-day control specimens, except that they are allowed to cure for 28 days before testing.

6.8 7-Day Wet-Dry Specimens and 7-Day Freeze-Thaw Specimens (TLT-503 and TLT-504)

6.8.1 After these specimens are formed and cured for the required period of time, they are subjected to weathering cycles of freezing and thawing and wetting and drying, which determines durability characteristics. This portion of the design takes from six (6) to eight (8) weeks to complete.

6.9 The compressive strength of each moisture-density relation specimen is plotted against the formed moisture content.

6.10 The compressive strength and % weight loss of each 7-day freeze-thaw specimen is plotted against the formed cement content.

6.11 The % weight loss of each 7-day wet-dry specimen is plotted against the formed cement content. Compressive strengths are not determined on wet-dry specimens.

Note: The % weight loss for both the freeze-thaw and wet-dry specimens is determined by brushing after the twelfth cycle using a 5 kg force.

6.12 Interpretation of Test Data

6.12.1 An average compressive strength value at each cement content for a given set of specimens is determined. In addition, for the freeze-thaw and wet-dry specimens, an average % loss is calculated for each cement content. This data is summarized graphically. In selecting the design cement content, several factors must be considered.

6.12.2 The compressive strength of the 28-day control specimens are compared to those of the 7-day control group. The primary concern here is the degree of strength gain with time. Cement stabilized mixtures will gain strength in moderation almost indefinitely, providing a moist environment is maintained. The 28-day strengths therefore should be well above 7-day strengths. However, the aggregate reaction to the cement over prolonged curing is not as critical as the reaction within the first 28-days of curing.

6.12.3 The compressive strengths of the 7-day freeze-thaw specimens should normally plot between the 7-day and 28-day control groups. These specimens cure longer than 7-day control samples, but not as long as the 28-day control samples. In this respect this group serves as a check on the results obtained from the other two.

6.12.4 The % weight loss during the freeze-thaw cycles is the primary means of evaluating the durability of the cement stabilized mix. A high loss at any cement content is a critical factor in the selecting a design cement content. A high % loss indicates disintegration of the sample and shows that there is insufficient cement for the aggregate at that point. The design cement content, therefore, must be selected well above the critical value. In practice, the maximum allowable % loss is 3%.

6.12.5 The wet-dry test provides similar data as the freeze-thaw test. For normal aggregates, the freeze-thaw does more damage than the wet-dry. However, if the aggregate contains a significant amount of silt and clay, the wet-dry test is more destructive, and gives a better indicator of the susceptibility of these aggregates to shrinkage and swelling stresses that they are likely to encounter in service.

6.12.6 The 7-day compressive strength of the moisture-density relation specimens give some indication of the strength of the mixture under varying conditions of moisture and density which may be encountered during construction.

6.13 Determination of Design Cement Content

6.13.1 After reviewing and evaluating all the test data, a design cement content is selected. Half a percent is normally added to account for variations within the mixture caused by field mixing.

7.0 REPORT

7.1 The weights and measures for the 7 and 28 day control tests are recorded.

7.2 The recommended cement content, optimum moisture content and maximum dry density are reported along with the results of all other tests.

7.3 A graphical representation of the compressive strengths and % weight loss are also provided to show strength and durability patterns and trends.

7.4 A covering memorandum with comments, instructions and recommendations completes the report package.

8.0 DESIGN CRITERIA

8.1 Minimum compressive strength 2.07 MPa.

8.2 Maximum allowable % weight loss 3% (freeze-thaw or wet-dry)

Method A charts

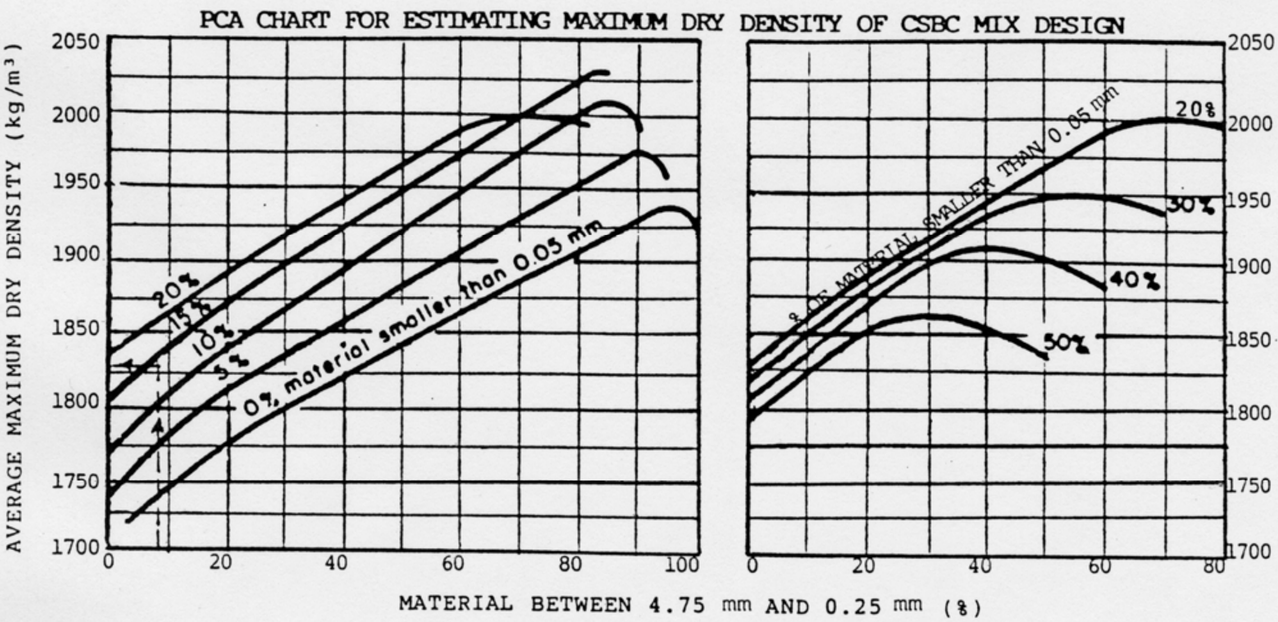
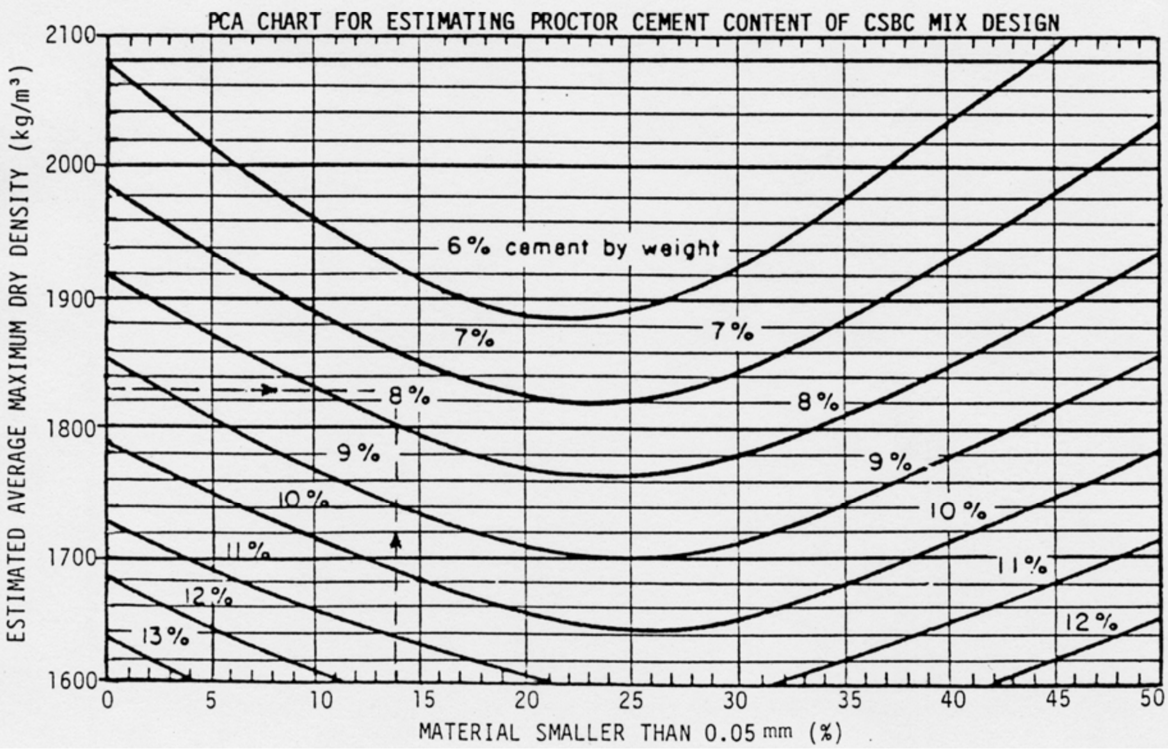


FIGURE 5.2



Method B charts