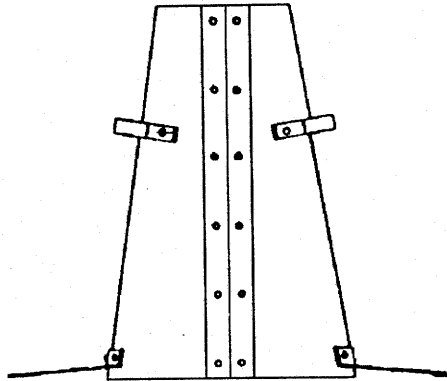
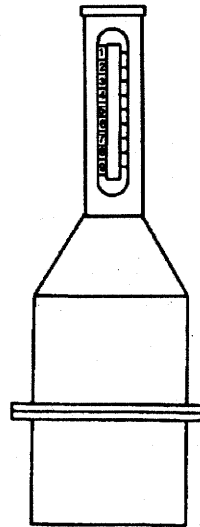


PORTLAND CEMENT CONCRETE TESTING MANUAL



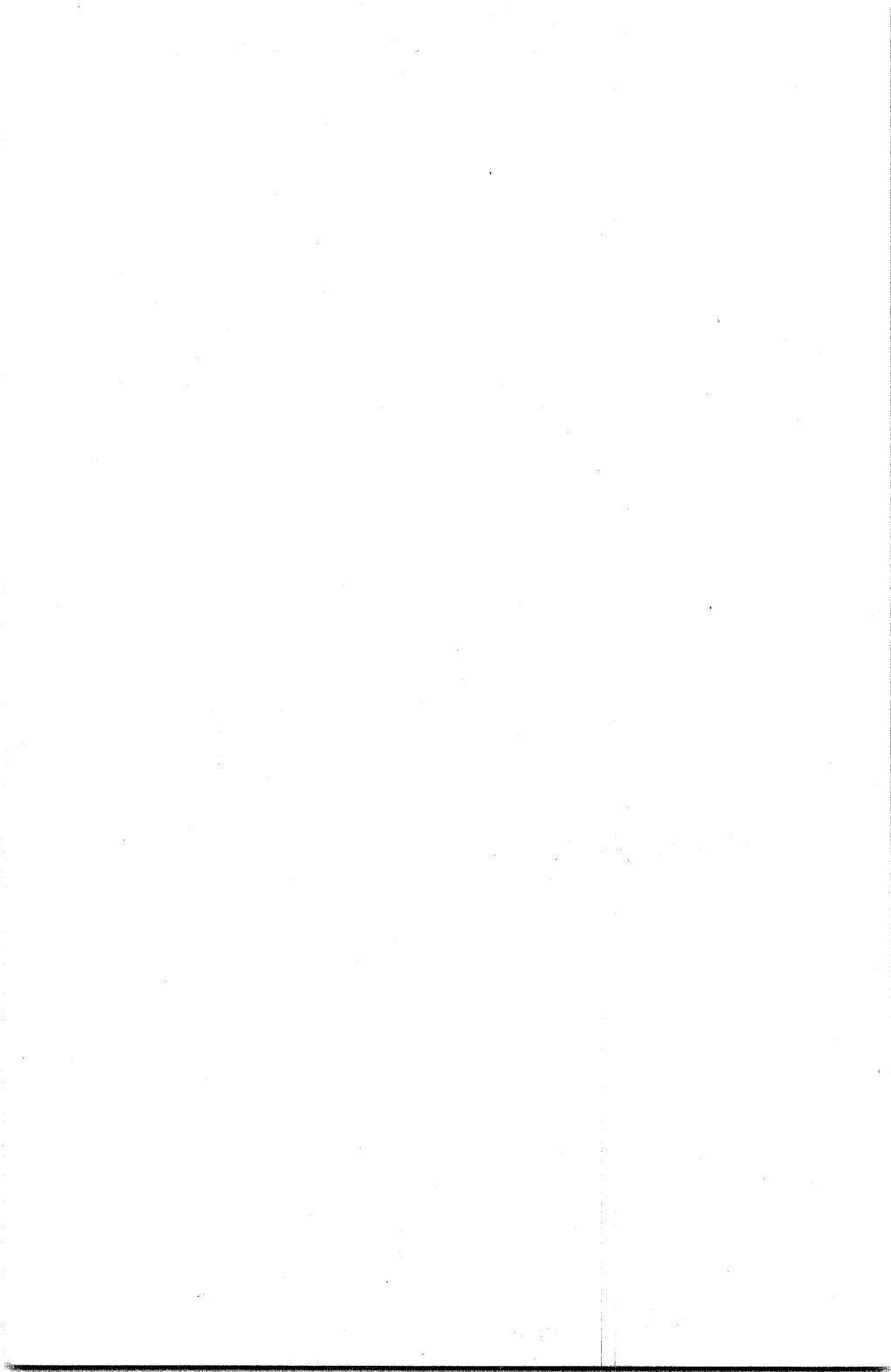
QUALITY

PERFORMANCE



U.S. Department
of Transportation
**Federal Highway
Administration**

**OFFICE OF ENGINEERING
CONSTRUCTION AND
MAINTENANCE DIVISION
MATERIALS BRANCH**



PORTLAND CEMENT CONCRETE TESTING

I. INTRODUCTION

This booklet is designed to be a quick reference to items that should be looked at in the field concerning the testing of portland cement concrete. It is meant to give some general background and discuss the significance of the field tests that are performed. The typical values which are indicated in the manual are for reference only and should not be considered as a standard. For convenience, space has been provided at the end of the manual to record the State specification requirements for several classes of concrete.

A more in-depth discussion of the test procedures can be found in the "Design and Control of Concrete Mixtures" published by the Portland Cement Association and the "Standard Specifications for Transportation Materials" and "Methods of Sampling and Testing" published by AASHTO.

II. MATERIALS - PROJECT DOCUMENTATION

The quality testing requirements for the component materials comprising the concrete may vary slightly from State-to-State but will generally follow the AASHTO requirements which are referenced. The quality tests on the component materials are generally performed in the central laboratory of the State. The project files should contain documentation of these tests.

A. Portland Cement

Materials Requirements

AASHTO M 85 - Portland Cements
AASHTO M 240 - Blended Cements

Portland cement is usually accepted on certification from the manufacturer. Verification samples are taken at the concrete plant and are tested by the central laboratory to confirm the certification. It should be noted that some States accept cement based on tests performed on acceptance samples taken at the concrete plant.

B. Aggregates

Materials Requirements

AASHTO M 6 - Fine Aggregates
AASHTO M 80 - Coarse Aggregates

Quality Requirements

Aggregates usually come from fixed sources that are approved by the State. The quality tests which are the basis of the approval are normally run on each source once a year or on a project by project basis. Quality tests on marginal material should be made more frequently. The quality tests consist of LA abrasion, soundness, sand equivalent, and deleterious substances.

1. LA Abrasion

Test Procedure - AASHTO T 96

This test is used to determine an aggregate's resistance to abrasion. This test indicates the aggregates resistance to degradation during handling. The test results are reported as the percent loss of weight. States typically specify a maximum value between 30 and 50 percent.

2. Soundness

These tests are performed to predict the aggregate's resistance to freeze/thaw cycles. One of the following four tests is usually specified: sodium sulfate, magnesium sulfate, freeze/thaw testing of aggregate, or freeze thaw testing of concrete mixtures.

a. Sodium Sulfate - Magnesium Sulfate

Test Procedure - AASHTO T 104

Sodium sulfate and magnesium sulfate test results are reported as percent loss. The maximum values for sodium sulfate specifications are in the range of 8 to 18 percent. The maximum values for the magnesium sulfate specifications are in the range of 10 to 20 percent.

b. Freeze/Thaw Testing of Aggregates

Test Procedure - AASHTO T 103

The freeze/thaw aggregate test results are reported as percent loss.

c. Freeze/Thaw Testing of Mixtures

Test Procedure - AASHTO T 161

The test indicates the freeze/thaw resistance of aggregate in a concrete mix. Freeze/Thaw test results are reported as a durability factor and the typically specified minimum value is 90.

An expansion criterion of 0.035 percent in 350 cycles is often specified when freeze/thaw testing is used. This test is typically specified in States which have D-crack susceptible aggregates.

3. Sand Equivalent

Test Procedure - AASHTO T 161

This test is used as an indicator of the amount of clay size material in the in the fine aggregate. As the sand equivalent number increases it indicates less clay sized material in the sample.

States which use this test for portland cement concrete specify a minimum sand equivalent between 70 and 80.

4. Deleterious Substances

All States have different requirements in this area due to the variety of sources encountered. However, some of the items that are commonly limited are: clay lumps, organic material, shale, light weight and glass particles. These values are reported as a percent by weight of material.

C. Admixtures

Materials Requirements

AASHTO M 154 - Air Entraining Agents
AASHTO M 194 - Chemical Admixtures for
Concrete (retarders, accelerators, water
reducers, and superplasticizers)

AASHTO M 295 - Fly Ash and Raw or Calcinated
Natural Pozzolan for Use as a Mineral
Admixture in Portland Cement
Concrete

These materials are usually accepted by a certification program. This procedure would include the establishment of an approved list by trade name along with verification sampling and testing. The specific admixtures should appear on the mix design approval. It is important for the admixture trade name to appear on the mix design since there can be an adverse chemical reaction by substitution of admixtures not specifically designed into the mix. These adverse reactions can lead to poor strength, quick set, and/or no set. The proper entraining of air can also be affected by any of the admixtures and proper mixing and batching.

Compatibility of admixtures is a large concern. In all cases, trial batches should be performed when multiple admixtures are used to ensure compatibility. In no case should two admixtures be mixed together.

D. Water Cementitious Ratio (W/C).

The W/C ratio is the ratio by weight of water to the weight of cement plus fly ash. The compressive strength is inversely proportional to the w/c ratio within the normal ranges of w/c ratios. A low w/c ratio will result in a durable, high strength, impermeable concrete. However, the mix must still retain its workability.

Typical w/c ratios used in highway work range from 0.35 to 0.50. The lower w/c ratios require admixtures to maintain workability of the mixtures. The maximum w/c ratio should be indicated on the mix design approval. There should also be a system

of controlling water to insure that the maximum w/c ratio is not exceeded.

III. PLANT TESTS

A. Gradation

Test Procedures

AASHTO T 11 - Amount of Material Passing the
No. 200 Sieve

AASHTO T 27 - Sieve Analysis

Purpose of Procedure

There are several reasons for specifying grading limits and maximum aggregates size. Excessive amounts of fine aggregate will result in an increase in surface area which will increase the demand for cement, increase the water demand, lower the strength, and increase the rate of shrinkage. A gap graded material will impair workability. In addition, variations in grading can seriously affect the uniformity of concrete from batch-to-batch.

An increase in the material passing the No. 100 sieve will decrease the air content while an increase in the material passing the No. 30 sieve and retained on the 100 sieve will increase the air content.

Description of Procedure

The material is dried to a constant weight and washed over a No. 200 sieve to remove the minus 200 material from the coarse aggregate (AASHTO T 11). The material retained on the 200 sieve is then dried. The gradation of this material is then determined by running the aggregates over a series of predetermined wire mesh sieves

(AASHTO T 27). Limits are usually specified for the percentage of material passing each sieve. A gradation test at the plant is typically run once a day.

Aggregate samples for gradation should be obtained as close as possible to the point where they are incorporated into the mix.

Precautions

1. The sieves should be checked for wear and material "blinding" the sieve. Blinding is caused by aggregate clogging the mesh. Equipment should be checked annually and when the results from the independent assurance program indicate a potential problem.
2. Overloading a sieve will also affect the results.

B. Fineness Modulus

Purpose of Procedure

The fineness modulus is an indicator of the fineness of the fine aggregate. As the fineness modulus increases the material will tend to be coarser. The fineness modulus is also used to monitor the uniformity of the fine aggregates. For the purposes of this test fine aggregate is defined as that material that passes the 3/8 inch sieve. It is important the fineness modulus is within the acceptable range of the material used in the mix design since a finer sand would increase the water demand and possibly reduce strength. A coarser sand would increase bleed water and may impair finishing.

Description of Procedure

This procedure is outlined in the material requirements of AASHTO M 6. The value is computed by adding the cumulative percentage by weight retained on the following sieves and dividing by 100: 3/8 inch, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100. These values are obtained from the gradation analysis.

Typical Values

Typical values for FM range from 2.3 to 3.1. The value should not change more than ± 0.20 from the value that was approved in the mix design. A change greater than this may require a new mix design.

C. Moisture Content

Test Procedures

AASHTO T 217 - Determination of Moisture in Soil by Means of a Calcium Carbide Gas Pressure Tester (Speedy Moisture Meter)

AASHTO T 255 - Total Moisture Content of Aggregate by Drying

Purpose of Procedures

The batch weights of the aggregates are usually based on the saturated surface dry condition (all aggregate surface pores are full of water). An adjustment must be made to the batch weights to account for the amount of moisture required to bring the aggregate to the saturated surface dry (SSD) conditions. This is done to insure that specified water cement ratio is not exceeded and that workability is maintained. The moisture

content of the fine aggregate should be performed at least twice a day. Since the moisture content varies in the stockpile, a rain storm will increase the variability of the moisture content in stockpiles. The following method determines total moisture content. The adjustment to SSD is made using the absorption that was found in the laboratory.

1. Description of Procedure - Total Moisture Content of Aggregate by Drying

A sample of aggregate is dried in an oven, hot plate, or microwave. The sample is considered dry when further heating will cause less than a 0.1 percent additional weight loss.

Precautions in Using the Microwave

Aggregates with metallic elements such as iron oxides will cause arcing in the microwave. This alters the aggregate properties and will also damage the microwave. Before using the microwave, the minimum dry time should also be determined since excessive time in a microwave may also alter aggregate properties.

2. Description of Procedure - Speedy Moisture Meter

A measured amount of calcium carbide and steel balls are placed inside the chamber of the tester. The sample is placed in the cap and the tester is closed taking care that no calcium carbide comes in contact with the aggregate until a complete seal is achieved. The apparatus is then shaken vigorously. When the needle on the pressure meter stops moving, the dial is read.

Precautions

The dial reading is the percent moisture by wet mass and must be converted to dry mass. This is done by using the graph that accompanies the meter. The sample should also be examined for lumps when it is removed from the tester. If lumps exist, the reading will be wrong and it is necessary to retest with a new sample.

Typical Values

The moisture content of normal weight coarse aggregate will typically run from 1/2 to 3 percent. The moisture content of fine aggregate will typically run from 3 to 8 percent.

IV. FIELD TESTS

A. Fresh Concrete Sampling

Test Procedure - AASHTO T 141

Purpose of the procedure is to obtain a representative sample of plastic concrete.

Description of Procedure

At least two samples are obtained from the middle third of the load of concrete. The combined sample should be large enough to perform all required test but should not be less than 1 cubic foot. The portions of the sample are combined.

Precautions

The portions of the sample must be taken within 15 minutes of each other.

B. Slump Test

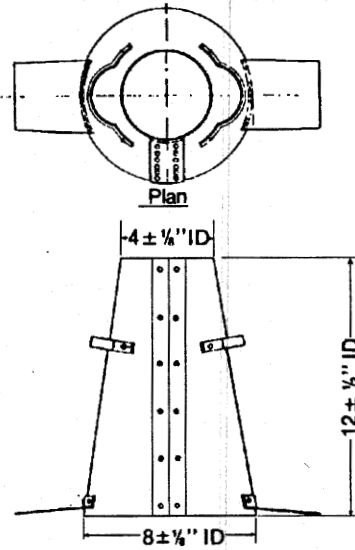


FIGURE 1 - Slump Cone

Test Procedure - AASHTO T 119

Purpose of Test Procedure

This test is a measure of the consistency of the concrete. A change in the slump indicates that something in the manufacturing of the concrete has changed.

Description of Procedure

The slump test is performed by:

1. Dampening the slump cone and a nonabsorbent flat surface;

2. filling the slump cone with three equal volumes, the 1/3 volume is obtained at a depth of 2 5/8 inches, the 2/3 volume is obtained at a depth of 6 1/8 inches;
3. rodding each lift 25 times, approximately 1 inch into the preceding layer;
4. raising the mold steadily without twisting; and
5. measuring the slump to the displaced original center of the top of the specimen. The test value is reported to the nearest 1/4 inch.

Typical Values

The maximum slump specified varies with the intended purpose of the concrete. The maximum slump for slip form paving is typically 1 1/2 inches. The typical maximum slump for form paving and structural concrete is 3 to 4 inches.

Precautions

1. The test must be started within 5 minutes of obtaining the last sample of concrete.
2. The test must be completed in 2 1/2 minutes.
3. The test should be performed in an area without any vibrations.
4. The test must be performed on a level area.
5. The cone should be lifted straight up without twisting in 3 to 7 seconds.

Factors Affecting Slump

If there is a change in slump, the following items may have changed:

1. Amount of Water, any increase in water from these sources will increase slump:
 - a. Moisture content of the aggregate
 - b. Wash water left in trucks
 - c. Water added at the plant or site
 - d. Incorrect weight of bagged ice;
2. aggregate gradation;
3. fineness modules;
4. air content, an increase in air content will increase slump;
5. ambient temperature and concrete temperature, as the temperature increases the slump will decrease;
6. texture of aggregate, smoother, rounder aggregate will increase slump;
7. source of any material.
8. haul time, an increase in haul time will decrease slump.

C. Air Content Determination

There are three methods to determine air content in portland cement concrete in the field; the volumetric method (rollometer), the pressure meter, and the Chace air indicator.

Test Procedures

AASHTO T 152 - Air Content by Pressure Meter

AASHTO T 196 - Air Content by Volumetric
Method

AASHTO T 199 - Air Content by Chace Air
Indicator

Purpose of Test

The purpose of the test is to determine the air content of the mixture. Air entrainment is used in portland cement concrete to increase its durability to freeze/thaw cycles. It also has an added advantage because it increases the workability of the mix.

If there is not enough entrained air, scaling of the concrete will result. If too much air is entrained, the concrete will have lower strength. The volumetric and Chace procedure are based on measuring the air content by displacing the air with fluid. The pressure meter methods are based on pressure volume relationships. The air content test should be started within 5 minutes after the last sample of concrete is obtained.

1. Description of Procedure - Pressure Meter

There are two types of pressure meters, Type A and Type B.

Both tests require a clean damp bowl and top seal. The bowl is filled in three equal lifts; rodded 25 times per lift, penetrating approximately 1 inch into the previous layer; and tapped 10 to 15 times with a mallet for each lift.

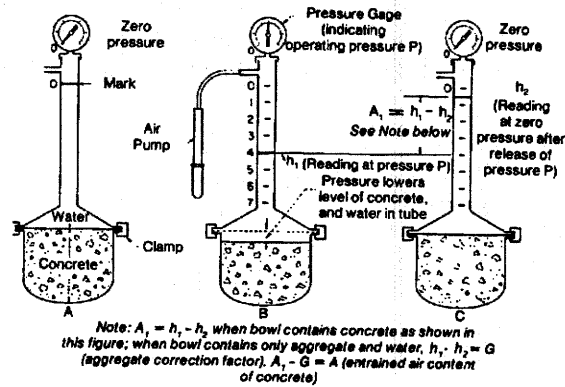


FIGURE 2 - Type A Pressure Meter

The procedure with the Type A meter is as follows:

- Water is added to the 4 percent mark. The meter is tilted and rapped to remove all air bubbles.
- The water column is filled until the water comes out of the top valve. Then the water level is brought down to the initial fill line.
- The vents at the top of the gauge are closed and slightly more than the desired test pressure is applied. The test pressure is determined from the calibration procedure and accompanies the particular gauge.
- The gauge is tapped to remove air bubbles. The air content is read from the water column and reported to the nearest 0.1 percent.

- e. The pressure is released and the water column should return to the initial test mark. If this does not occur the test result is not valid.

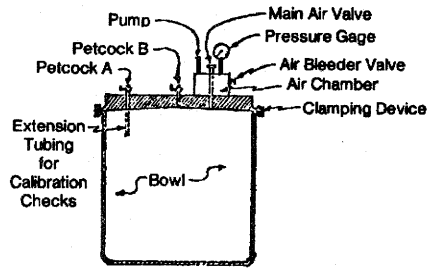


FIGURE 3 - Type B Pressure Meter

The procedure with the Type B meter is as follows:

- a. Close the main air valve.
- b. Open both pet cocks and inject water with a syringe into one pet cock until water comes out of the other. Alternate the procedure between the two pet cocks until the stream of water is free from air bubbles.
- c. Jar meter to remove air.
- d. Close pet cocks.
- e. Close the air bleeder valve on the air chamber and pump air into the chamber to the initial pressure. The initial pressure is determined by the calibration procedure and accompanies the gauge.

- f. Open the air valve between the air chamber and bowl.
- g. Read the percent air on the pressure meters and report to the nearest 0.1 percent.

Precautions with Pressure Meters

It should be noted that the pressure meter should not be used on porous aggregates, such as slag. It is also necessary that the meter be calibrated on a regular basis.

The meters must be recalibrated when significant changes in altitude occur between the site of calibration and the project site. Leaks in the meter will also affect the test results.

It is important that the top and bottom of the meter were the ones used during calibration.

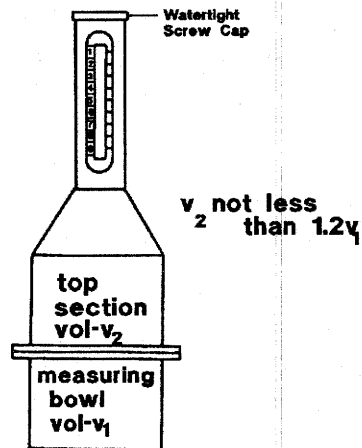


FIGURE 4 - Volumetric Meter - Rollometer

2. Description of Procedure - Volumetric Method

The volumetric method is performed as follows:

- a. The bowl is filled in three lifts.
- b. Each lift is rodded 25 times, penetrating the previous layer approximately 1 inch.
- c. The bowl is tapped 10 to 15 times with a mallet after each lift.
- d. Water is added to the zero mark and agitated. The meter is allowed to settle and agitation is repeated until there is no further drop in water elevation.
- e. Alcohol is added with the cup provided to dispel the foam. The cup equates to 1 percent of the volume of the bowl.
- f. The percent air content is read directly and corrected for the amount of alcohol added. The value is reported to the nearest 0.1 percent.

Precautions with Volumetric Meters

All of the concrete must be loosened from the bottom of air meter and be in complete suspension in the water. If this does not occur low air content readings will result.

This method is accurate for concrete made with all types of aggregates.

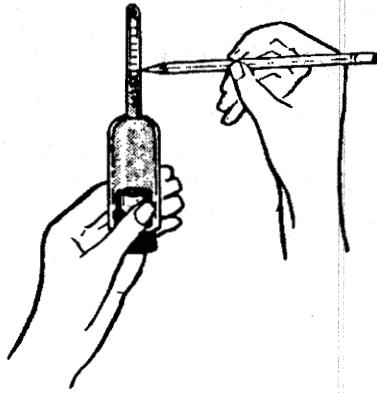


FIGURE 5 - Chace Air Indicator

3. Description of Procedure - Chace Air Indicator

The method consists of the following:

- a. The brass cup is filled with mortar that passes the No. 10 sieve and rodded with a stiff piece of wire;
- b. A finger is placed over the small end of the tube and the tube is filled with alcohol to the reference line;
- c. The stopper/brass cup is inserted. The indicator is inverted and alcohol is added to reach the top mark;
- d. The device is agitated and a reading is made to the nearest half graduation;

- e. It is necessary to use the nomograph in Figure 6 to obtain the air content based on the percent of mortar in the mix and the Chace factor for the particular indicator. The mortar content of the mix being the total percent of the portland cement, water, and fine aggregate in the mix.

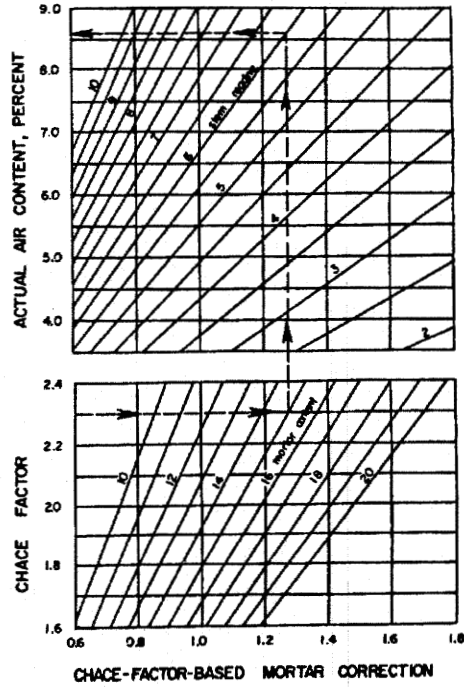


Figure 6 - Chace Conversion Nomograph

The nomograph is used by starting with the Chace factor and going horizontally to the mortar content, then going vertically to the stem reading and going horizontally to the actual air content.

Precaution with Procedure

The Chace air indicator is not an accurate method of determining air content but it is quick and can be used to screen trucks in between the use of volumetric or pressure meters. The average of two tests is taken as one test result. It should be noted that the results of this test should not be used to reject a load of concrete.

Typical Values

A mix which contains aggregate with a 1 inch maximum size should have an air content of 6.5 percent with a tolerance of $\pm 1\frac{1}{2}$ percent. The amount of air required is based on the maximum size of the coarse aggregate.

Factors Affecting Air Content

Factors affecting air content:

- a. A change in the fine aggregate proportion will change the air content of the mix. Less air is entrained as the amount of material passing the No. 100 sieve increases. The air content will increase as the amount of material passing the No. 30 sieve and retained on the No. 100 sieve increases.

- b. As slump increases; the air content increases.
- c. As the concrete temperature and ambient air temperature increases, air content decreases.
- d. Over mixing will drive entrained air out of the mix.
- e. Any change in material.

D. Strength Tests

There are two common tests that are performed to determine strength of Portland cement concrete. Flexural strength tests are typically used for concrete paving; and compressive strength tests are typically used for structures.

Test Procedures

AASHTO T 23 - Making and curing concrete test specimens in the field.

Purpose of Procedure

The tests are performed to determine if the material is capable of attaining design strength values, and/or to determine if the element the test specimen represents may be put into service.

1. Description of Procedure - Compressive Strength

Compressive strength tests are performed on cured concrete cylinders from production mixes. The dimensions of a standard cylinder are 6 inches X 12 inches. 4 X 8 inch cylinder molds can be used on concrete with aggregate which has a maximum aggregate size of 1 inch.

The cylinders are made by filling the molds in three equal lifts and rodding each lift 25 times. If voids are left after rodding it is necessary to tap the side of the mold 10 to 15 times with a rubber mallet. For testing and curing of samples, see precautions to be taken for all strength tests.

Typical Values

The typical specified compressive strength for structural concrete is 4000 to 4500 PSI after curing for 28 days. The compressive strength of concrete paving is typically specified from 3000 PSI to 3500 PSI after curing for 28 days. It should be noted that the mix design strengths should be higher than the minimum specified strength to account for material variability. For good construction in the strength ranges which are used in highway construction, the mix designs strengths should be 1000 PSI higher than the minimum specified strength.

2. Description of Procedure - Flexural Strength

Flexural tests are performed on concrete beams produced from production mixes. The dimensions of a standard beam are 6 inches X 6 inches X 20 inches. These can be tested by center point loading or third point loading.

The beams are made by filling the molds in two equal layers and rodding each lift once per two square inches (60 times for the standard beam). If voids are left after rodding it is necessary to tap the side of the mold 10

to 15 times with a rubber mallet. The sides of the mold should be spaded after each lift is rodded.

Beams may also be cast by placing the concrete in one layer and vibrating the concrete in three locations along the beam.

Typical Values

The specified flexural strength is typically 500 to 550 PSI after curing for 7 days. There are differences in the values that will be obtained by testing a concrete by third and center point loading.

Precautions to be Taken with all Strength Tests

1. Molding strength test specimens must be started within 15 minutes of obtaining the last sample of concrete.
2. Curing Test Samples.

If the specimens are to be used to determine the date for opening the road to traffic or for form removal, the specimens should be stored as close to the structure as possible and cured under the same conditions.

Samples that are used for acceptance testing should have the molds stripped in 24 ± 8 hours and stored at 60° to 80° F in a moist room, immersed in lime saturated water, or moist sand beds.

3. Transporting Specimens

Specimens less than 48 hours old may be transported in the mold. in all cases the

specimens must be properly cushioned and protected from moisture loss during transportation.

4. Testing of Samples

The equipment used for testing compressive or flexural samples should be capable of applying loads at a uniform rate.

E. Unit Weight

Test Procedure - AASHTO T 121

Purpose of Procedure

This test is used to determine the amount of concrete produced in each batch. The unit weight as determined in the field is compared to the theoretical unit weight based on the batch weights. A difference in the unit weights indicates a change in air content or improper batching.

Description of Procedure

The test is performed with calibrated container with a known volume. The concrete should be rodded if the slump is greater than 3 inches or vibrated if the slump is less than 1 inch. Either method can be used if the slump is between 1 and 3 inches.

In the rodding procedure, the container is filled in three equal lifts and rodded 25 times per lift for the 1/2 cubic foot container or 50 times per lift for the 1 cubic foot container. The container is rapped 10 to 15 times after each lift is rodded.

In the vibrating procedure the container is filled in two equal lifts and vibrated 3 times per lift taking care not to over vibrate.

The container is then struck level with the top of the container with a plate. The container is weighted and the unit weight is calculated. The container should be calibrated on a regular basis.

Typical Value

The unit weight of concrete made from normal weight aggregate runs from 140 PCF to 150 PCF.

F. Temperature

Test Procedure ASTM C 1064

Purpose of Test

As the temperature increases the rate of hydration increases. As a result the slump decreases and the setting time is reduced. In addition, high concrete temperatures causes variability in the air content and there is a loss in strength.

Description of Test

The thermometer should be accurate to $\pm 1^\circ$ F. The thermometer should remain in place for a minimum of two minutes or until the reading becomes stable. The test should be completed within 5 minutes after the sample is taken.

Temperature of the mix should be taken throughout the day.

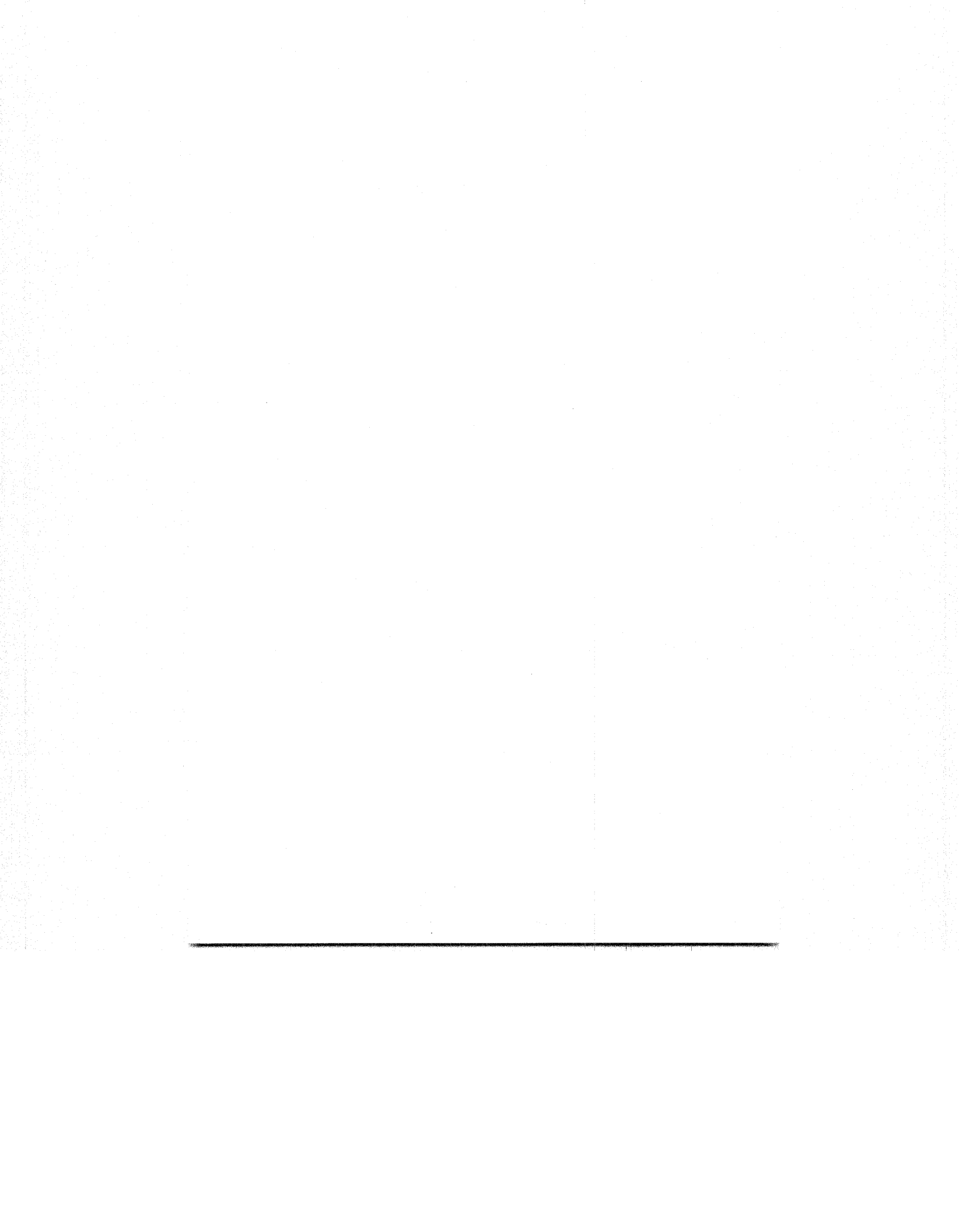
Typical Values

A typical requirement is to limit the temperature of concrete to 90 degrees F. Since water has the largest specific heat of all the materials replacing mixing water with ice is typically used to control concrete temperature. Controlling the aggregate

temperature by sprinkling the aggregate stock pile with water can also be used to lower the temperature of the aggregate.

STATE SPECIFICATIONS

	DECK	STRUCTURAL	PAVING
Class	_____	_____	_____
Maximum aggr. size	_____	_____	_____
Cement content	_____	_____	_____
W/C	_____	_____	_____
Slump	_____	_____	_____
Air content	_____	_____	_____
Strength	_____	_____	_____
Concrete temperature	_____	_____	_____





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