Transportation Technician Qualification Program

CONCRETE

Workbook

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Field Operating Procedures

PREFACE

This module is one of a set developed for the Western Alliance for Quality Transportation Construction (WAQTC). WAQTC is an alliance supported by the western state Transportation Departments, along with the Federal Highway Administration (FHWA) and the Western Federal Lands Highway Division (WFLHD) of FHWA. WAQTC's charter includes the following mission.

MISSION

Provide continuously improving quality in transportation construction.

Through our partnership, we will:

- Promote an atmosphere of trust, cooperation, and communication between government agencies and with the private sector.
- Assure personnel are qualified.
- Respond to the requirements of identified needs and new technologies that impact the products that we provide.

BACKGROUND

There are two significant driving forces behind the development of the WAQTC qualification program. One, there is a trend to the use of quality control/quality assurance (QC/QA) specifications. QC/QA specifications include qualification requirements for a contractor's QC personnel and will be requiring WAQTC qualified technicians. Two, Federal regulation on materials sampling and testing (23 CFR 637, *Quality Assurance Procedures for Construction*, published in June 1995) mandates that by June 29, 2000 all testing technicians whose results are used as part of the acceptance decision shall be qualified. In addition, the regulation allows the use of contractor test results to be used as part of the acceptance decision.

OBJECTIVES

WAQTC's objectives for its Transportation Technician Qualification Program include the following:

- To provide highly skilled, knowledgeable materials sampling and testing technicians.
- To promote uniformity and consistency in testing.
- To provide reciprocity for qualified testing technicians between states.
- To create a harmonious working atmosphere between public and private employees based upon trust, open communication, and equivalency of qualifications.

Training and qualification of transportation technicians is required for several reasons. It will increase the knowledge of laboratory, production, and field technicians – both industry and agency personnel – and increase the number of available, qualified testers. It will reduce problems associated with test result differences. Regional qualification eliminates the issue of reciprocity between states and allows qualified QC technicians to cross state lines without having the concern or need to be requalified by a different program.

The WAQTC Executive Board

FOREWORD

This module is one of seven developed to satisfy the training requirements prescribed by Western Alliance for Quality Transportation Construction (WAQTC) for technicians involved in transportation projects. The seven modules cover:

- Aggregate
- Concrete
- Asphalt I
- Asphalt II
- Embankment and Base
- In-place Density
- Embankment and Base/In-place Density
- Self-Consolidating Concrete

The modules are based upon AASHTO test methods along with procedures developed by WAQTC. They are narrative in style, illustrated, and include step-by-step instruction. There are review questions at the end of each test procedure, which are intended to reinforce the participants' understanding and help participants prepare for the final written and performance exams. Performance exam check lists are also included. The appendix includes WAQTC Field Operating Procedures (FOPs) in short form.

It is the technician's responsibility to stay current as changes are made to this living document.

The comments and suggestions of every participant are essential to the continued success and high standards of the Transportation Technician Qualification Program. Please take the time to fill out the Course Evaluation Form as the course progresses and hand it in on the last day of class. If you need additional room to fully convey your thoughts, please use the back of the form.

The WAQTC Executive Board

GUIDANCE FOR COURSE EVALUATION FORM

The Course Evaluation Form on the following page is very important to the continuing improvement and success of this course. The form is included in each Participant Workbook. During the course introduction, the Instructor will call the participants' attention to the form, its content, and the importance of its thoughtful completion at the end of the course. Participants will be encouraged to keep notes, or write down comments as the class progresses, in order to provide the best possible evaluation. The Instructor will direct participants to write down comments at the end of each day and to make use of the back of the form if more room is needed for comments.

On the last day of the course, just before the written examination, the Instructor will again refer to the form and instruct participants that completion of the form after their last examination is a requirement before leaving. Should the course have more than one Instructor, participants should be directed to list them as A, B, etc., with the Instructor's name beside the letter, and direct their answers in the Instructor Evaluation portion of the form accordingly.

WESTERN ALLIANCE FOR QUALITY TRANSPORTATION CONSTRUCTION COURSE EVALUATION FORM

The WAQTC Transportation Technician Qualification Program would appreciate your thoughtful completion of all items on this evaluation form. Your comments and constructive suggestions will be an asset in our continuing efforts to improve our course content and presentations.

Course Title: ____________________

Location: ____________________

Dates: ____________________

Your Name (Optional): ____________________

Employer: ____________________

Instructor(s) ____________________

COURSE CONTENT

Will the course help you perform your job better and with more understanding? Yes Maybe No

Explain: ____________________

____

Was there an adequate balance between theory, instruction, and hands-on application? Yes Maybe No

Explain: ____________________

____

Did the course prepare you to confidently complete both examinations? Yes Maybe No

Explain: ____________________

____

What was the most beneficial aspect of the course? ____________________

____

What was the least beneficial aspect of the course? ____________________

____

GENERAL COMMENTS

General comments on the course, content, materials, presentation method, facility, registration process, etc. Include suggestions for additional Tips!

INSTRUCTOR EVALUATION

Were the objectives of the course, and the instructional and exam approach, clearly explained? Yes Maybe No

Explain:

Was the information presented in a clear, understandable manner? Yes Maybe No

Explain:

Did the instructors demonstrate a good knowledge of the subject? Yes Maybe No

Explain:

Did the instructors create an atmosphere in which to ask questions and hold open discussion? Yes Maybe No

Explain:

COURSE OBJECTIVES AND SCHEDULE

Learning Objectives

Understanding:

- Quality Assurance (QA) concepts
- Measurements and calculations
- Highway materials terminology
- Respecting safety issues
- Random sampling techniques
- Understanding the basics of concrete
- Demonstrating proficiency in the following test procedures:

WAQTC TM 2
    Sampling Freshly Mixed Concrete
FOP for AASHTO T 309
    Test Method for Temperature of Freshly Mixed Portland Cement Concrete
FOP for AASHTO T 119
    Slump of Hydraulic Cement Concrete
FOP for AASHTO T 121
    Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
FOP for AASHTO T 152
    Air Content of Freshly Mixed Concrete by the Pressure Method
FOP for AASHTO R 100
    Making and Curing Concrete Test Specimens in the Field

The overall goals are to understand concrete and to be competent with specific quality control test procedures identified for the Transportation Technician Qualification Program (TTQP) of the Western Alliance for Quality Transportation Construction (WAQTC).

Course Outline and Suggested Schedule
Day One

Welcome
Introduction of Instructors
Introduction and Expectations of Participants

WAQTC Mission and TTQP Objectives
Instructional Objectives for the Course
Overview of the Course
Course Evaluation Form

Review of Quality Assurance Concepts

Background in Measurements and Calculations

Random Sampling

Basics of Concrete

Sampling Freshly Mixed Concrete
WAQTC TM 2

Temperature of Freshly Mixed Portland Cement Concrete
FOP for AASHTO T 309

Slump of Hydraulic Cement Concrete
FOP for AASHTO T 119

Review with Questions and Answers Forum

Afternoon Laboratory Practice

Day Two

Questions from the Previous Day

Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
FOP for AASHTO T 121

Air Content of Freshly Mixed Concrete by the Pressure Method
FOP for AASHTO T 152

Making and Curing Concrete Test Specimens in the Field
FOP for AASHTO R 100

Review with Questions and Answers Forum

Afternoon Laboratory Practice

Day Three

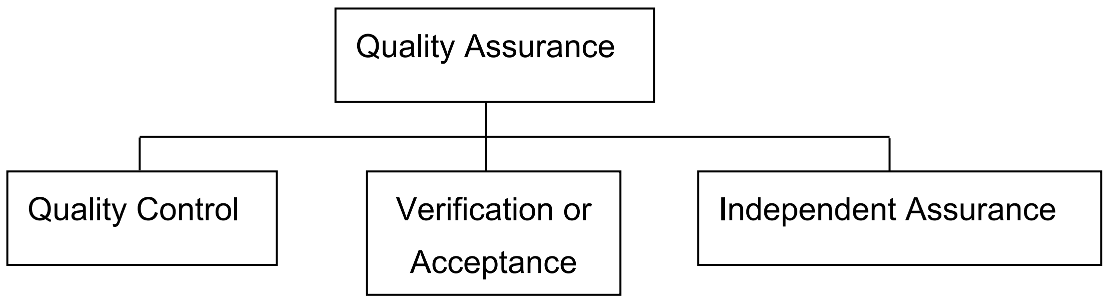
Start of Exams

Evaluation

QUALITY ASSURANCE CONCEPTS 02

The Federal Highway Administration (FHWA) has established requirements that each State
Transportation Department must develop a Quality Assurance (QA) Program that is
approved by the FHWA for projects on the National Highway System (NHS). In addition to
complying with this requirement, implementing QA specifications in a construction program 03
includes the benefit of improvement of overall quality of highway and bridge construction.

A QA Program may include three separate and distinct parts as illustrated below.



04

Quality Assurance (QA) are those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality.

Quality Control (QC) are those operational, process control techniques or activities that are
performed or conducted to fulfill contract requirements for material and equipment quality. 05
In some states, the constructor is responsible for providing QC sampling and testing, while in
other states the STD handles QC. Where the constructor is responsible for QC tests, the
results may be used for acceptance only if verified or accepted by additional tests performed 06
by an independent group.

Verification/Acceptance consists of the sampling and testing performed to validate QC sampling and testing and, thus, the quality of the product. Verification/Acceptance samples are obtained and tests are performed independently from those involved with QC. Samples taken for QC tests may not be used for Verification/Acceptance testing.

Independent Assurance (IA) are those activities that are an unbiased and independent 07
evaluation of all the sampling and testing procedures used in QC and
Verification/Acceptance. IA may use a combination of laboratory certification, technician
qualification or certification, proficiency samples, or split samples to assure that QC and
Verification/Acceptance activities are valid. Agencies may qualify or certify laboratories and
technicians, depending on the state in which the work is done.

BACKGROUND ON MEASUREMENTS AND CALCULATIONS

01
Introduction

This section provides a background in the mathematical rules and procedures used in making measurements and performing calculations. Topics include:

- Units: Metric vs. English
- Mass vs. Weight
- Balances and Scales
- Rounding
- Significant Figures
- Accuracy and Precision
- Tolerance

Also included is discussion of real-world applications in which the mathematical rules and procedures may not be followed.

02
Units: Metric vs. English

- Basic units in SI include:
- Length: meter, m
- Mass: kilogram, kg
- Time: second, s
-

SI units

Metric	English
25 mm	1 in.
1 kg	2.2 lb
1000 kg/m^3	62.4 lb/ft^3
25 MPa	3600 lb/in.^{2}

Some approximate conversions

03 The bulk of this document uses dual units. Metric units are followed by Imperial, more commonly known as English, units in parentheses. For example: 25 mm (1 in.). Exams are presented in metric or English.

04 Depending on the situation, some conversions are exact, and some are approximate. One inch is exactly 25.4 mm. If a procedure calls for measuring to the closest 1/4 in., however, 5 mm is close enough. We do not have to say 6.35 mm. That is because 1/4 in. is half way between 1/8 in. and 3/8 in. – or half way between 3.2 and 9.5 mm. Additionally, the tape measure or rule used may have 5 mm marks, but may not have 1 mm marks and certainly will not be graduated in 6 mm increments.

In SI (Le Systeme International d'Unites), the basic unit of mass is the kilogram (kg) and the basic unit of force, which includes weight, is the Newton (N).

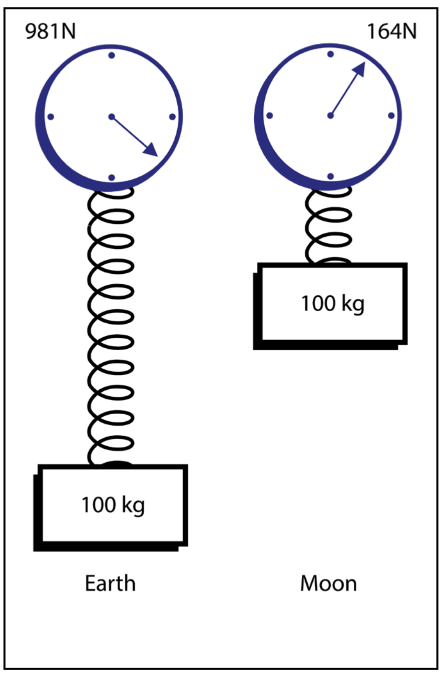
Mass in this document is given in grams (g) or kg. See the section below on "Mass vs. Weight" for further discussion of this topic.

Mass vs. Weight

The terms mass, force, and weight are often
05 confused. Mass, m, is a measure of an object's material makeup, and has no direction. Force, F, is a measure of a push or pull, and has the direction of the push or pull. Force is equal to mass times acceleration, a.

$$F = ma$$

06 Weight, W, is a special kind of force, caused by gravitational acceleration. It is the force required to suspend or lift a mass against gravity. Weight is equal to mass times the acceleration due to gravity, g, and is directed toward the center of the earth.



Comparison of mass and weight

$$W = mg$$

In SI, the basic unit of mass is the kilogram (kg), the units of acceleration are meters per square second (m/s^2), and the unit of force is the Newton (N). Thus a person having a mass of 84 kg subject to the standard acceleration due to gravity, on earth, of 9.81 m/s^2 would have a weight of:

$$W = (84.0\ kg)(9.81\ m/s^2) = 824\ kg\text{-}m/s^2 = 824\ N$$

In the English system, mass can be measured in pounds-mass (lb_m), while acceleration is in feet per square second (ft/s^2), and force is in pounds-force (lb_f). A person weighing 185 lb_f on a scale has a mass of 185 lb_m when subjected to the earth's standard gravitational pull. If this person were to go to the moon, where the acceleration due to gravity is about one-sixth of what it is on earth, the person's weight would be about 31 lb_f, while his or
07 her mass would remain 185 lb_m. Mass does not depend on location, but weight does.

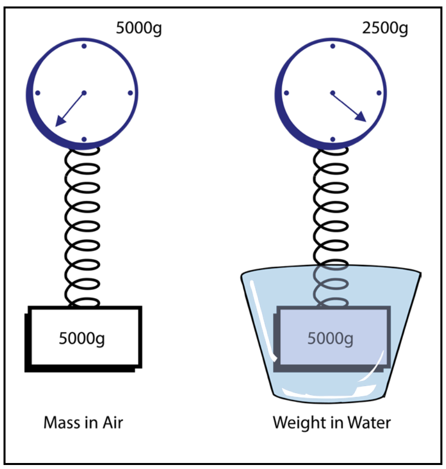
08

While the acceleration due to gravity does vary with position on the earth (latitude and elevation), the variation is not significant except for extremely precise work – the manufacture of electronic memory chips, for example.

As discussed above, there are two kinds of pounds, lb_m and lb_f. In laboratory measurements of mass, the gram or kilogram is the unit of choice. But, is this mass or force?

09

Technically, it depends on the instrument used, but practically speaking, mass is the result of the measurement. When using a scale, force is being measured – either electronically by the stretching of strain gauges or mechanically by the stretching of a spring or other device. When using a balance, mass is being measured, because the mass of the object is being compared to a known mass built into the balance.



Submerged weight

In this document, mass, not weight, is used in test procedures except when determining "weight" in water. When an object is submerged in water (as is done in specific gravity tests), the term weight is used. Technically, what is being measured is the force the object exerts on the balance or scale while the object is submerged in water (or the submerged weight). This force is actually the weight of the object less the weight of the volume of water

10 displaced.

11 In summary, whenever the common terms "weight" and "weighing" are used, the more appropriate terms "mass" and "determining mass" are usually implied, except in the case of weighing an object

12 submerged in water.

Balances and Scales

Balances, technically used for mass determinations, and scales, used to weigh items, were discussed briefly above in the section on "Mass vs. Weight." In field operating procedures, we usually do not differentiate between the two types of instruments. When using either one for a material or object in air, we are determining <u>mass</u>. For those procedures in which the material or object is suspended in water, we are determining <u>weight</u> in water.

13

AASHTO recognizes two general categories of instruments. Standard analytical balances are used in laboratories. For most field operations, general purpose balances and scales are specified. Specifications for both categories are shown in Tables 1 and 2.

14

Table 1
Standard Analytical Balances

Class	Capacity	Readability and Sensitivity	Accuracy
A	200 g	0.0001 g	0.0002 g
B	200 g	0.001 g	0.002 g
C	1200 g	0.01 g	0.02 g

Table 2
General Purpose Balances and Scales

Class	Principal Sample Mass	Readability and Sensitivity	Accuracy
G2	2 kg or less	0.1 g	0.1 g or 0.1 percent
G5	2 kg to 5 kg	1 g	1 g or 0.1 percent
G20	5 kg to 20 kg	5 g	5 g or 0.1 percent
G100	Over 20 kg	20 g	20 g or 0.1 percent

Rounding

Numbers are commonly rounded up or down after measurement or calculation. For example, 53.67 would be rounded to 53.7 and 53.43 would be rounded to 53.4, if rounding were required. The first number was rounded up because 53.67 is closer to 53.7 than to 53.6. Likewise, the second number was rounded down because 53.43 is closer to 53.4 than to 53.5. The reasons for rounding are covered in the next section on "Significant Figures."

If the number being rounded is followed by exactly 5, followed by only zeroes, two possibilities exist. In the more mathematically sound approach, numbers are rounded up or down depending on whether the number to the left of the 5 is odd or even. Thus, 102.25 would be rounded down to 102.2, while 102.35 would be rounded up to 102.4. This procedure avoids the bias that would exist if all numbers ending in 5 were rounded up or all numbers were rounded down. In some calculators, however, all rounding is up. This does result in some bias, or skewing of data, but the significance of the bias may or may not be significant to the calculations at hand.

When rounding numbers that are followed by exactly 5, follow agency guidelines. For the purpose of WAQTC training, if the number being rounded is followed by a 5, the number is increased by 1.

Significant Figures

- General

  A general-purpose balance or scale, classified as G20 in AASHTO M 231, has a capacity of
16 20,000 g and an accuracy requirement of ±5 g. A mass of 18,285 g determined with such an instrument could actually range from 18,280 g to 18,290 g. Only <u>four</u> places in the measurement are significant. The fifth (last) place is <u>not</u> significant since it may change.

17 Mathematical rules exist for handling significant figures in different situations.

  An example in Metric (**m**) or English(**ft**), when performing addition and subtraction, the number of significant figures in the sum or difference is determined by the least precise input. Consider the three situations shown below:

Situation 1	Situation 2	Situation 3
35.67	143.903	162
+ 423.938	- 23.6	+33.546
		- .022
= 459.61	= 120.3	= 196
not 459.608	not 120.303	not 195.524

Rules also exist for multiplication and division. These rules, and the rules for mixed operations involving addition, subtraction, multiplication, and/or division, are beyond the scope of these materials. AASHTO covers this topic to a certain extent in the section called "Precision" or "Precision and Bias" included in many test methods, and the reader is directed to those sections if more detail is desired.

18 • Real World Limitations

While the mathematical rules of significant digits have been established, they are not always followed. For example, AASHTO T 176, *Plastic Fines in Graded Aggregates and Soils by the Use of the Sand Equivalent Test*, prescribes a method for rounding and significant digits in conflict with the mathematical rules.

In this procedure, readings and calculated values are always rounded up. A clay reading of 7.94 would be rounded to 8.0 and a sand reading of 3.21 would be rounded to 3.3. The rounded numbers are then used to calculate the Sand Equivalent, which is the ratio of the two numbers multiplied by 100. In this case:

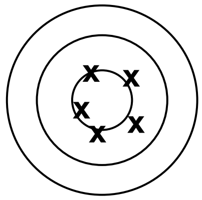
$$\frac{3.3}{8.0} \times 100 = 41.250 \ldots$$

rounded to 41.3 and reported as 42

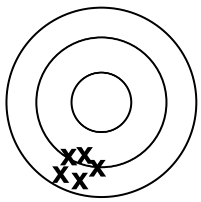
$$Not\colon \; \frac{3.21}{7.94} \times 100 = 40.428 \ldots$$

rounded to 40.0 and reported as 40

It is extremely important that engineers and technicians understand the rules of rounding and significant digits just as well as they know procedures called for in standard test methods.



ACCURATE BUT NOT PRECISE, SCATTERED



PRECISE BUT NOT ACCURATE, BIASED

Accuracy and Precision

Although often used interchangeably, the terms
19 accuracy and precision do not mean the same thing.
In an engineering sense, accuracy denotes nearness
to the truth or some value accepted as the truth,
while precision relates to the degree of refinement
or repeatability of a measurement.

20 Two bulls-eye targets are shown to the left. The upper one indicates hits that are scattered and, yet, are very close to the center. The lower one has a tight pattern, but all the shots are biased from the center. The upper one is more accurate, while the lower one is more precise. A biased, but precise, instrument can often be adjusted physically or mathematically to provide reliable single measurements. A scattered, but accurate, instrument can be used if enough measurements are made to provide a valid average.

Consider the measurement of the temperature of
boiling water at standard atmospheric pressure by
21 two thermometers. Five readings were taken with
each, and the values were averaged.

Thermometer No. 1		**Thermometer No. 2**	
101.2°	214.2°	100.6°	213.1°
101.1°	214.0°	99.2°	210.6°
101.2°	214.2°	98.9°	210.0°
101.1°	214.0°	101.0°	213.8°
101.2°	214.2°	100.3°	212.5°
AVG = 101.2°	214.2°	AVG = 100.0°	212.0°

No. 1 shows very little fluctuation, but is off the
22 known boiling point (100°C or 212°F) by 1.2°C or
2.2°F. No. 2 has an average value equal to the
known boiling point, but shows quite a bit of
fluctuation. While it might be preferable to use
neither thermometer, thermometer No. 1 could be
employed if 1.2°C or 2.2°F were subtracted from
each measurement. Thermometer No. 2 could be
used if enough measurements were made to provide
23 a valid average.

24 Engineering and scientific instruments should be calibrated and compared against reference standards periodically to assure that measurements are accurate. If such checks are not performed, the accuracy is uncertain, no matter what the precision. Calibration of an instrument removes fixed error,
25 leaving only random error for concern.

Tolerance

Dimensions of constructed or manufactured objects, including laboratory test equipment, cannot be
26 specified exactly. Some tolerance must be allowed. Thus, procedures for including tolerance in addition/subtraction and multiplication/division operations must be understood.

- Addition and Subtraction

  When adding or subtracting two numbers that individually have a tolerance, the tolerance of
  27 the sum or difference is equal to the sum of the individual tolerances.

  An example in Metric (**m**) or English (**ft**), if the distance between two points is made up of two parts, one being 113.361 ±0.006 and the other being 87.242 ±0.005 then the tolerance of the sum (or the difference) is:

  $$(0.006) + (0.005) = 0.011$$

  and the sum would be 200.603 ±0.011.

- Multiplication and Division

  To demonstrate the determination of tolerance
  28 again in either Metric (**m**) or English (**ft**) for the product of two numbers, consider determining the area of a rectangle having sides of 76.254 ±0.009 and 34.972 ±0.007. The percentage variations of the two dimensions are:

$$\frac{0.009}{76.254} \times 100 = 0.01\% \quad \frac{0.007}{34.972} \times 100 = 0.02\%$$

  The sum of the percentage variations is 0.03 percent – the variation that is employed in the area of the rectangle:

Area =

$$266.8\ (m^2 or\ ft^2) = \pm 0.03\%$$
$$= 2666.8 \pm 0.8\ (m^2 or\ ft^2)$$

- Real World Applications

29 Tolerances are used whenever a product is manufactured. For example, the mold used for determining soil density in AASHTO T 99 has a diameter of 101.60 ±0.41 mm(4.000 ±0.016 in) and a height of 116.43 ±0.13 mm(4.584 ±0.005 in).

Using the smaller of each dimension results in a volume of:

$$\left(\frac{\pi}{4}\right)(101.19\ mm)^2(116.30\ mm)$$
$$= 935{,}287\ mm^3 or\ 0.000935\ m^3$$

$$\left(\frac{\pi}{4}\right)(3.984\ in)^2(4.579\ in)$$
$$= 57.082\ in^3 or\ 0.0330\ ft^3$$

Using the larger of each dimension results in a volume of:

$$\left(\frac{\pi}{4}\right)(102.01\ mm)^2(116.56\ mm)$$
$$= 952.631\ mm^3 or\ 0.000953\ m^3$$

$$\left(\frac{\pi}{4}\right)(4.016\ in)^2(4.589\ in)$$
$$= 58.130\ in^3 or\ 0.0336\ ft^3$$

The average value is 0.000944 m^3 (0.0333), and AASHTO T 99 specifies a volume of:

0.000943 ±0.000008 m^3

or a range of

0.000935 to 0.000951 m^3

0.0333 ±0.0003 ft^3

or a range of

0.0330 to 0.0336 ft^3

Because of the variation that can occur, some agencies periodically standardize molds, and make adjustments to calculated density based on those calculations.

Summary

Mathematics has certain rules and procedures for making measurements and performing calculations that are well established. So are standardized test procedures. Sometimes these agree, but occasionally, they do not. Engineers and technicians must be familiar with both but must follow test procedures in order to obtain valid, comparable results.

TERMINOLOGY

Many of the terms listed below are defined differently by various agencies or organizations. The definitions of the American Association of State Highway and Transportation Officials (AASHTO) are the ones most commonly used in this document.

Absorbed water – Water drawn into a solid by absorption and having physical properties similar to ordinary water.

Absorption – The increase in the mass of aggregate due to water being absorbed into the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

Acceptance – See verification.

Acceptance program – All factors that comprise the State Transportation Department's (STD) determination of the quality of the product as specified in the contract requirements. These factors include verification sampling, testing, and inspection and may include results of quality control sampling and testing.

Admixture – Material other than water, cement, and aggregates in Portland cement concrete (PCC).

Adsorbed water – Water attached to the surface of a solid by electrochemical forces and having physical properties substantially different from ordinary water.

Aggregate – Hard granular material of mineral composition, including sand, gravel, slag, or crushed stone, used in roadway base and in Portland cement concrete (PCC) and asphalt mixtures.

- **Coarse aggregate** – Aggregate retained on or above the No. 4 (4.75 mm) sieve.
- **Coarse-graded aggregate** – Aggregate having a predominance of coarse sizes.
- **Dense-graded aggregate –** Aggregate having a particle size distribution such that voids occupy a relatively small percentage of the total volume.
- **Fine aggregate** – Aggregate passing the No. 4 (4.75 mm) sieve.
- **Fine-graded aggregate** – Aggregate having a predominance of fine sizes.
- **Mineral filler** – A fine mineral product at least 70 percent of which passes a No. 200 (75 µm) sieve.
- **Open-graded gap-graded aggregate** – Aggregate having a particle size distribution such that voids occupy a relatively large percentage of the total volume.
- **Well-Graded Aggregate** – Aggregate having an even distribution of particle sizes.

Aggregate storage bins – Bins that store aggregate for feeding material to the dryer in a hot mix asphalt (HMA) plant in substantially the same proportion as required in the finished mix.

Agitation – Provision of gentle motion in Portland cement concrete (PCC) sufficient to prevent segregation and loss of plasticity.

Air voids (V_a) – Total volume of the small air pockets between coated aggregate particles in asphalt mixtures; expressed as a percentage of the bulk volume of the compacted paving mixture.

Ambient temperature – Temperature of the surrounding air

Angular aggregate – Aggregate possessing well-defined edges at the intersection of roughly planar faces.

Apparent specific gravity (G_{sa}) – The ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of water at a stated temperature.

Asphalt – A dark brown to black cementitious material in which the predominate constituents are bitumens occurring in nature or obtained through petroleum processing. Asphalt is a constituent of most crude petroleums.

Asphalt emulsion – A mixture of asphalt binder and water.

Asphalt binder – An asphalt specially prepared in quality and consistency for use in the manufacture of asphalt mixtures.

Asphalt mixtures – High quality, thoroughly controlled mix of aggregate and asphalt binder.

- **Hot mix asphalt (HMA)** – Asphalt mixtures of well-graded aggregate and asphalt binder that are mixed and placed at high temperatures.
- **Stone matrix asphalt (SMA) –** A gap-graded hot asphalt mixture that is designed to maximize deformation (rutting) resistance and durability by using a structural basis of stone-on-stone contact.
- **Warm mix asphalt (WMA) –** Asphalt mixtures that, due to a variety of technologies, are mixed and placed at relatively lower temperatures than HMA.

Automatic cycling control – A control system in which the opening and closing of the weigh hopper discharge gate, the bituminous discharge valve, and the pugmill discharge gate are actuated by means of automatic mechanical or electronic devices without manual control. The system includes preset timing of dry and wet mixing cycles.

Automatic dryer control – A control system that automatically maintains the temperature of aggregates discharged from the dryer.

Automatic proportioning control – A control system in which proportions of the aggregate and asphalt binder fractions are controlled by means of gates or valves that are opened and closed by means of automatic mechanical or electronic devices without manual control.

Bag (of cement) – 94 lb of Portland cement (Approximately 1 ft^3 of bulk cement)

Base – A layer of selected material constructed on top of subgrade or subbase and below the paving on a roadway.

Bias – The offset or skewing of data or information away from its true or accurate position as the result of systematic error.

Binder – Asphalt binder or modified asphalt binder that binds the aggregate particles into a dense mass.

Boulders – Rock fragment, often rounded, with an average dimension larger than 300 mm (12 in.).

Bulk specific gravity– The ratio of the mass, in air, of a volume of aggregate (G_{sa}) or compacted HMA mix (G_{mb}) (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of water at a stated temperature.

Bulk specific gravity (SSD) – The ratio of the mass, in air, of a volume of aggregate (G_{sa} *SSD*) or compacted asphalt mixtures (G_{mb} *SSD*), including the mass of water within the voids (but not including the voids between particles), to the mass of an equal volume of water at a stated temperature. (See saturated surface dry.)

Cementitious Materials – cement and pozzolans used in concrete such as: Portland cement, fly ash, silica fume, and blast-furnace slag.

Clay – Fine-grained soil that exhibits plasticity over a range of water contents, and that exhibits considerable strength when dry, also, that portion of the soil finer than 2 µm.

Cobble – Rock fragment, often rounded, with an average dimension between 75 and 300 mm (3 and 12 in.).

Cohesionless soil – Soil with little or no strength when dry and unconfined or when submerged, such as sand

Cohesive soil – Soil with considerable strength when dry and that has significant cohesion when unconfined or submerged.

Compaction – Densification of a soil or asphalt mixtures by mechanical means.

Compaction curve (Proctor curve or moisture-density curve) – The curve showing the relationship between the dry unit weight or density and the water content of a soil for a given compactive effort.

Compaction test (moisture-density test) – Laboratory compaction procedure in which a soil of known water content is placed in a specified manner into a mold of given dimensions, subjected to a compactive effort of controlled magnitude, and the resulting density determined.

Compressibility – Property of a soil or rock relating to susceptibility to decrease in volume when subject to load.

Constant mass – The state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Constructor – The builder of a project. The individual or entity responsible for performing and completing the construction of a project required by the contract documents. Often called a contractor, since this individual or entity contracts with the owner.

Cutback asphalt – Asphalt binder that has been modified by blending with a chemical solvent.

Crusher-run – The total unscreened product of a stone crusher.

Delivery tolerances – Permissible variations from the desired proportions of aggregate and asphalt binder delivered to the pugmill.

Density – The ratio of mass to volume of a substance. Usually expressed in lb/ft^3 (kg/m^3).

Design professional – The designer of a project. This individual or entity may provide services relating to the planning, design, and construction of a project, possibly including materials testing and construction inspection. Sometimes called a "contractor," since this individual or entity contracts with the owner.

Dryer – An apparatus that dries aggregate and heats it to specified temperatures.

Dry mix time – The time interval between introduction of aggregate into the pugmill and the addition of asphalt binder.

Durability – The property of concrete that describes its ability to resist disintegration by weathering and traffic. Included under weathering are changes in the pavement and aggregate due to the action of water, including freezing and thawing.

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio) – The percent passing the No. 200 sieve divided by the percent of effective asphalt binder.

Effective specific gravity (G_{se}) – The ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt binder) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.

Effective diameter (effective size) – D_{10}, particle diameter corresponding to 10 percent finer or passing.

Embankment – Controlled, compacted material between the subgrade and subbase or base in a roadway.

End-result specifications – Specifications that require the Constructor to take the entire responsibility for supplying a product or an item of construction. The Owner's (the highway agency's) responsibility is to either accept or reject the final product or to apply a price adjustment that is commensurate with the degree of compliance with the specifications. Sometimes called performance specifications, although considered differently in highway work. (See performance specifications.)

Family of curves – a group of soil moisture-density relationships (curves) determined using AASHTO T 99 or T 180, which reveal certain similarities and trends characteristic of the soil type and source.

Field operating procedure (FOP) – Procedure used in field testing on a construction site or in a field laboratory. (Based on AASHTO or NAQTC test methods.)

Fineness modulus – A factor equal to the sum of the cumulative percentages of aggregate retained on certain sieves divided by 100; the sieves are 150, 75, 37.5, 19.0, 9.5, 4.75, 2.36, 1.18, 0.60, 0.30, and 0.15 mm. Used in the design of concrete mixes. The lower the fineness modulus, the more water/cement paste that is needed to coat the aggregate.

Fines – Portion of a soil or aggregate finer than a 75 μm (No. 200) sieve. Also silts and clays.

Fractured criteria – The specified requirement for fractured particles determined by each agency.

Fractured face – An angular, rough, or broken surface of an aggregate particle created by crushing or by other means. A face is considered a "fractured face" whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well-defined edges. This excludes small nicks.

Fractured particle – A particle of aggregate having at least the minimum number of fractured faces specified.

Free water – Water on aggregate available for reaction with hydraulic cement. Mathematically, the difference between total moisture content and absorbed moisture content.

Glacial till – Material deposited by glaciation, usually composed of a wide range of particle sizes, which has not been subjected to the sorting action of water.

Gradation (grain-size distribution) – The proportions by mass of a soil or fragmented rock distributed by particle size.

Gradation analysis (grain size analysis or sieve analysis) – The process of determining grain-size distribution by separation of sieves with different size openings.

Hot aggregate storage bins – Bins that store heated and separated aggregate before final proportioning into the mixer.

Hot Mix Asphalt (HMA) batch plant – A manufacturing facility for producing hot mix asphalt (HMA) that proportions aggregate by weight and asphalt by weight or volume.

HMA continuous mix plant – A manufacturing facility for producing HMA that proportions aggregate and asphalt binder by a continuous volumetric proportioning system without specific batch intervals.

Hydraulic cement – Cement that sets and hardens by chemical reaction with water.

Independent assurance – Unbiased and independent evaluation of all the sampling and testing procedures, equipment, and technicians involved with Quality Control (QC) and Verification/Acceptance.

In situ – Rock or soil in its natural formation or deposit.

J-Ring – a rigid ring made of steel connecting 100 mm (4 in.) vertical smooth bars used in testing the passing ability of SCC.

Liquid limit – Moisture content corresponding to the boundary between the liquid and plastic states.

Loam – A mixture of sand, silt or clay, or a combination thereof, with organic matter.

Lot – A quantity of material to be controlled. It may represent a specified mass, a specified number of truckloads, or a specified time period during production.

Manual proportioning control – A control system in which proportions of the aggregate and asphalt binder fractions are controlled by means of gates or valves that are opened and closed by manual means. The system may or may not include power assisted devices in the actuation of gate and valve opening and closing.

Materials and methods specifications – Also called prescriptive specifications. Specifications that direct the Constructor to use specified materials in definite proportions and specific types of equipment and methods to place the material.

Maximum size – One sieve larger than nominal maximum size.

Mesh – The square opening of a sieve.

Moisture content – The ratio, expressed as a percentage, of the mass of water in a material to the dry mass of the material.

Nominal maximum size – One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Note: The first sieve to normally retain more than 10 percent of the material usually is the second sieve in the stack but may be the third sieve.

Nuclear gauge – Instruments used to measure in-place density, moisture content, or asphalt binder content through the measurement of nuclear emissions.

Optimum moisture content (optimum water content) – The water content at which a soil can be compacted to a maximum dry density by a given compactive effort.

Organic soil – Soil with a high organic content.

Owner – The organization that conceives of and eventually operates and maintains a project. A State Transportation Departments (STD) is an Owner.

Passing ability – An indication of the ability of the SCC to flow around and between reinforcement without blocking.

Paste – Mix of water and hydraulic cement that binds aggregate in Portland cement concrete (PCC).

Penetration – The consistency of a bituminous material, expressed as the distance in tenths of a millimeter (0.1 mm) that a standard needle vertically penetrates a sample of the material under specified conditions of loading, time, and temperature.

Percent of Absorbed (asphalt) Binder (P_{ba}) – The total percent of the asphalt binder that is absorbed into the aggregate, expressed as a percentage of the mass of aggregate rather than as a percentage of the total mass of the mixture. This portion of the asphalt binder content does not contribute to the performance of the mix.

Percent aggregate (stone) (P_s) – The percent aggregate (stone) content, expressed as a percentage of the total mass of the sample.

Percent of Effective (asphalt) Binder (P_{be}) – The total asphalt binder content of a paving mixture minus the portion of asphalt binder that is lost by absorption into the aggregate particles, expressed as a percentage of the mass of aggregate. It is the portion of the asphalt binder content that remains as a coating on the outside of the aggregate particles.

Percent compaction – The ratio of density of a soil, aggregate, or asphalt mixtures in the field to a maximum density determined by a standard compaction test, expressed as a percentage.

Performance specifications – Specifications that describe how the finished product should perform. For highways, performance is typically described in terms of changes over time in physical condition of the surface and its response to load, or in terms of the cumulative traffic required to bring the pavement to a condition defined as "failure." Specifications containing warranty/guarantee clauses are a form of performance specifications.

Plant screens – Screens located between the dryer and hot aggregate storage bins that separate the heated aggregates by size.

Plastic limit – Moisture content corresponding to the boundary between the plastic and the semisolid states.

Plasticity – Property of a material to continue to deform indefinitely while sustaining a constant stress.

Plasticity index – Numerical difference between the liquid limit and the plastic limit and, thus, the range of water content over which the soil is plastic.

Portland cement – Hydraulic cement produced by pulverizing Portland cement clinker.

Portland cement concrete (PCC) – A controlled mix of aggregate, Portland cement, and water, and possibly other admixtures.

PCC batch plant – A manufacturing facility for producing Portland cement concrete.

Prescriptive specifications – See Materials and Methods specification.

Proficiency samples – Homogeneous samples that are distributed and tested by two or more laboratories. The test results are compared to assure that the laboratories are obtaining the same results.

Pugmill – A shaft mixer designed to mix aggregate and cement.

Quality assurance – Planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality. The overall system for providing quality in a constructed project, including Quality Control (QC), Verification/Acceptance, and Independent Assurance (IA).

Quality assurance specifications – Also called QC/QA specifications. A combination of end-result (performance) specifications and materials and methods (prescriptive) specifications. The Constructor is responsible for quality control, and the Owner (highway agency) is responsible for acceptance of the product.

Quality control (QC) – Operational, process control techniques or activities that are performed or conducted to fulfill contract requirements for material or equipment quality.

Random sampling – Procedure for obtaining non-biased, representative samples.

Recycled (reclaimed) asphalt materials – Recycled asphalt pavement (RAP) and recycled asphalt shingles (RAS) used as a component in asphalt mixtures.

Sand – Particles of rock passing the No. 4 (4.75 mm) sieve and retained on the No. 200 (75 µm) sieve.

Saturated surface dry (SSD) – Condition of an aggregate particle, asphalt mixtures or Portland cement concrete (PCC) core, or other porous solid when the permeable voids are filled with water, but no water is present on exposed surfaces. (See bulk specific gravity.)

Self-Consolidating Concrete (SCC) – A highly flowable non-segregating concrete mix that spreads into place and is able to flow and fill all corners of the formwork, even in the presence of congested reinforcement by means of its own mass with no mechanical vibration.

Segregation – The separation of aggregate by size resulting in a non-uniform material.

Sieve – Laboratory apparatus consisting of wire mesh with square openings, usually in circular or rectangular frames.

Silt – Material passing the (75 µm) sieve that is non-plastic or very slightly plastic, and that exhibits little or no strength when dry and unconfined. Also, that portion of the soil finer than 75 µm and coarser than 2 µm.

Slump – Measurement related to the workability of concrete.

Slump flow – Assesses the horizontal free flow, filling ability of self-compacting concrete in the absence of obstructions and may give some indication of resistance to segregation. It does not indicate the ability of the SCC to pass between reinforcement without blocking.

Soil – Sediments or unconsolidated accumulations of solid particles produced by the physical and chemical disintegration or rocks, and which may or may not contain organic matter.

Specific gravity – The ratio of the mass of a volume of a material to the mass of an equal volume of water at a stated temperature.

- $\mathbf{G_{mm}}$ – theoretical maximum specific gravity (Gravity $_{\text{mix max}}$)
  The ratio of the mass of a given volume of asphalt mixtures with no air voids to the mass of an equal volume of water, both at a stated temperature.

- $\mathbf{G_{mb}}$ – measured bulk specific gravity (Gravity $_{\text{mix bulk}}$)
  The ratio of the mass, in air, of a volume of compacted HMA mix (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of water at a stated temperature.

- $\mathbf{G_{sb}}$ – oven-dry bulk specific gravity of aggregate (Gravity $_{\text{stone bulk}}$)
  The ratio of the mass, in air, of a volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of water at a stated temperature.

- **G_{sa}** – apparent specific gravity of aggregate (Gravity $_{\text{stone apparent}}$)
  The ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of water at a stated temperature.

- **G_{se}** – effective specific gravity of aggregate (Gravity $_{\text{stone effective}}$)
  The ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt binder) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.

- **G_b** – specific gravity of the binder (Gravity $_{\text{binder}}$)
  The ratio of the mass of a volume of asphalt binder to the mass of an equal volume of water at a stated temperature.

Spine – smooth line extending through the point of maximum density and optimum moisture content of a family of moisture-density curves.

Stability – The ability of an asphalt mixture to resist deformation from imposed loads. Stability is dependent upon internal friction, cohesion, temperature, and rate of loading.

Static segregation - The tendency for coarse aggregate to separate from the sand-cement mortar in SCC.

Stratified random sampling – Procedure for obtaining non-biased, representative samples in which the established lot size is divided into equally-sized sublots.

Subbase – A layer of selected material constructed between the subgrade and the base coarse in a flexible HMA roadway, or between the subgrade and Portland cement concrete (PCC) pavement in a rigid PCC roadway.

Subgrade – Natural soil prepared and compacted to support a structure or roadway pavement.

Sublot – A segment of a lot chosen to represent the total lot.

Superpave™ – Superpave™ (Superior Performing Asphalt Pavement) is a trademark of the Strategic Highway Research Program (SHRP). Superpave™ is a product of the SHRP asphalt research. The Superpave™ system incorporates performance-based asphalt materials characterization with design environmental conditions to improve performance by controlling rutting, low temperature cracking and fatigue cracking. The three major components of Superpave™ are the asphalt binder specification, the mix design and analysis system, and a computer software system.

Theoretical maximum specific gravity (G_{mm}) – The ratio of the mass of a given volume of asphalt mixtures with no air voids to the mass of an equal volume of water, both at a stated temperature.

Topsoil – Surface soil, usually containing organic matter.

Uniformity coefficient – C_u, a value employed to quantify how uniform or well-graded an aggregate is: $C_u = D_{60}/D_{10}$. 60 percent of the aggregate, by mass, has a diameter smaller than D_{60} and 10 percent of the aggregate, by mass, has a diameter smaller than D_{10}.

Unit weight – The ratio of weight to volume of a substance. The term "density" is more commonly used.

µm – Micro millimeter (micron) Used as measurement for sieve size.

Vendor – Supplier of project-produced material that is other than the constructor.

Verification – Process of sampling and testing performed to validate Quality Control (QC) sampling and testing and, thus, the quality of the product. Sometimes called Acceptance.

Visual stability index (VSI) – The Visual Stability Index (VSI) is used to assess the stability of SCC. The stability (or segregation resistance) of an SCC mixture is the ability of the mixture to remain homogeneous during transport, during placement, and after placement. The VSI determination is useful for quality control and consistency testing.

Void in the mineral aggregate (VMA) – The volume of inter-granular void space between aggregate particles of compacted asphalt mixtures that includes air and asphalt binder; expressed as a percentage of the bulk volume of the compacted paving mixture.

Voids filled with asphalt (VFA) – The portion of the void in the mineral aggregate (VMA) that contains asphalt binder; expressed as a percentage of the bulk volume of mix or the VMA.

Wet mixing period – The time interval between the beginning of application of asphalt binder and the opening of the mixer gate.

Zero air voids curve (saturation curve) – Curve showing the zero air voids density as a function of water content.

SAFETY

The procedures included in this manual may involve hazardous materials, operations, and equipment. The procedures do not address all of the safety issues associated with their use. It is the responsibility of the employer to assess workplace hazards and to determine whether personal protective equipment (PPE) must be used. PPE must meet applicable American National Standards Institute (ANSI) standards and be properly used and maintained. The employer must establish appropriate safety and health practices, in compliance with applicable state and federal laws, for these procedures and associated job site hazards. Hazardous materials must be addressed in a Hazard Communication program, and Material Safety Data Sheets (MSDS) must be obtained and available to workers. Supervisors and employees should be aware of job site hazards and comply with their employer's safety and health program. The following table identifies some areas that may affect individuals performing the procedures in this manual.

Body Part Affected	Potential Hazards	PPE/Procedures That May Be Appropriate
Head	Falling or fixed overhead objects; electrical shock	Hard hat or other protective helmet
Eyes and Face	Flying objects, radiation, molten metal, chemicals	Safety glasses, goggles, face shields; prescription or filter lenses
Ears	Noise	Ear plugs, earmuffs
Respiratory System	Inhalation of dusts, chemicals; O_2 deficiency	Properly fit and used respiratory protection consistent with the hazard
Skin	Chemicals including cement; heat	Appropriate chemical or heat resistant gloves, long-sleeve shirts, coveralls
Mouth, digestive system	Ingestion of toxic materials	Disposable or washable gloves, coveralls; personal hygiene
Hands	Physical injury (pinch, cut, puncture), chemicals	Appropriate gloves for physical hazards and compatible with chemicals present
Feet	Falling, sharp objects; slippery surfaces, chemicals	Safety shoes or boots (steel toed, steel shank); traction soles; rubber boots – chemicals, wet conditions
Joints, muscles, tendons	Lifting, bending, twisting, repetitive motions	Proper training and procedures; procedure modifications
Body/Torso	Falls; Burial	Fall protection; trench sloping or shoring
Miscellaneous	Traffic	Visibility, awareness, communication; driver training, safety awareness
Whole body	Radiation	Radiation safety training

RANDOM SAMPLING OF CONSTRUCTION MATERIALS

01

Significance

Sampling and testing are two of the most important functions in quality control (QC). Data from the tests are the tools with which the quality of product is controlled. For this reason, great care must be used in following standardized sampling and testing procedures.

In controlling operations, it is necessary to obtain numerous samples at various points along the production line. Unless precautions are taken, sampling can occur in patterns that can create a bias to the data gathered. Sampling at the same time, say noon, each day may jeopardize the effectiveness of any quality program. This might
02 occur, for example, because a material producer does certain operations, such as cleaning screens at an aggregate plant, late in the morning each day. To obtain a representative sample, a reliable system of random sampling must be employed.

Scope

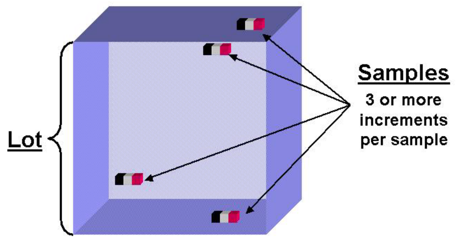
The procedure presented here eliminates bias in sampling materials. Randomly selecting a set of numbers from a table or calculator will eliminate the possibility for bias. Random numbers are used to identify sampling times, locations, or points within a lot or sublot. This method does not cover how to sample, but rather how to determine sampling times, locations, or points.

Sampling Concepts

03
04 A lot is the quantity of material evaluated by QC procedures. A lot is a preselected quantity that may represent hours of production, a quantity or number of loads of material, or an interval of time. A lot may be comprised of several portions that are called sublots or units. The number of sublots comprising a lot will be determined by the agency’s specifications.

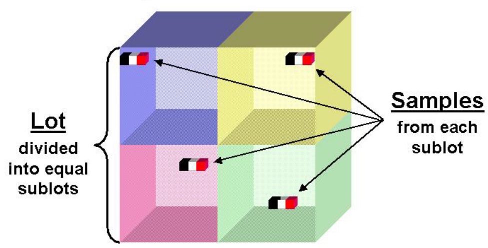
Straight Random Sampling

One or more sample locations may be selected, using the entire lot as a single unit



Stratified Random Sampling

The lot is divided into two or more equal sublots. Samples are taken from each sublot



05 **Straight Random Sampling vs. Stratified Random Sampling:** Straight random sampling considers an entire lot as a single unit and determines each sample location based on the entire lot size. Stratified random sampling divides the lot into a specified number of sublots or units and then determines each sample location within a distinct sublot. Both methods result in random distribution of samples to be tested for compliance with the agency's specification.

Agencies stipulate when to use straight random sampling or stratified random sampling. AASHTO
06 R 90, Sampling Aggregate Products, for example, specifies a straight random sampling procedure.

Picking Random Numbers from a Table

07 Table 1 contains pairs of numbers. The first number is the "pick" number and the second is the Random Number, "RN". The table was generated with a spreadsheet and the cells (boxes at the intersection of rows and columns) containing the RNs actually contain the "random number function." Every time the spreadsheet is opened or changed, all the RNs change.

1. Select a Pick number in a random method. The first two or last two digits in the next automobile license plate you see would be one way to select. Another would be to start a digital stop watch and stop it several seconds later, using the decimal part of the seconds as your Pick number.
2. Find the RN matching the Pick number.

Picking Random Numbers with a Calculator

08

09 Many calculators have a built-in random number function. To obtain a random number, key in the code or push the button(s) the calculator's instructions call for. The display will show a number between 0.000 and 1.000 and this will be your random number.

TABLE 1
Random Numbers

Pick	RN	Pick	RN	Pick	RN	Pick	RN	Pick	RN
01	0.998	21	0.758	41	0.398	61	0.895	81	0.222
02	0.656	22	0.552	42	0.603	62	0.442	82	0.390
03	0.539	23	0.702	43	0.150	63	0.821	83	0.468
04	0.458	24	0.217	44	0.001	64	0.187	84	0.335
05	0.407	25	0.000	45	0.521	65	0.260	85	0.727
06	0.062	26	0.781	46	0.462	66	0.815	86	0.708
07	0.370	27	0.317	47	0.553	67	0.154	87	0.161
08	0.410	28	0.896	48	0.591	68	0.007	88	0.893
09	0.923	29	0.848	49	0.797	69	0.759	89	0.255
10	0.499	30	0.045	50	0.638	70	0.925	90	0.604
11	0.392	31	0.692	51	0.006	71	0.131	91	0.880
12	0.271	32	0.530	52	0.526	72	0.702	92	0.656
13	0.816	33	0.796	53	0.147	73	0.146	93	0.711
14	0.969	34	0.100	54	0.042	74	0.355	94	0.377
15	0.188	35	0.902	55	0.609	75	0.292	95	0.287
16	0.185	36	0.674	56	0.579	76	0.854	96	0.461
17	0.809	37	0.509	57	0.887	77	0.240	97	0.703
18	0.105	38	0.013	58	0.495	78	0.851	98	0.866
19	0.715	39	0.497	59	0.039	79	0.678	99	0.616
20	0.380	40	0.587	60	0.812	80	0.122	00	0.759

Examples of Straight Random Sampling Procedures Using Random Numbers

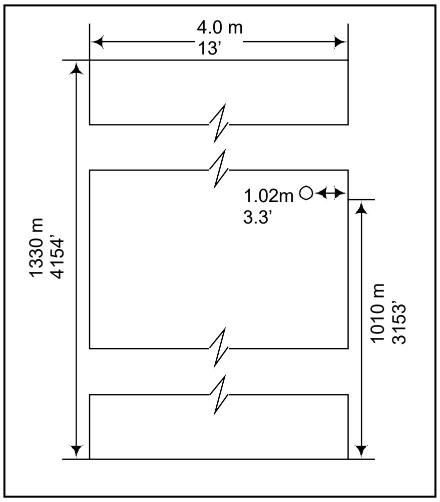
10

Sampling from a Belt or Flowing Stream: Agencies specify the frequency of sampling in terms of time, volumes, or masses. The specification might call for one sample from every 1,000,000 kg(1000 t) or 1100 Tons(T) of aggregate. If the random number was 0.317, the sample would be taken at (0.317)(1,000,000 kg) = 317,000 kg (317 t). Or (.317) (1100 T) = 349 T.

11 One sample per day might also be specified. If the day were 9 hours long and the random number 0.199, the sample would be taken at (0.199) (9 hrs) = 1.79 hr = 1 hr, 48 minutes into the day.

12 **Sampling from Haul Units:** Based on the agency's specifications – in terms of time, volume, or mass – determine the number of haul units that comprise a lot. Multiply the selected random number(s) by the number of units to determine which unit(s) will be sampled.

For example, if 20 haul units comprise a lot and one sample is needed, pick one RN. If the RN were 0.773, then the sample would be taken from the (0.773) (20) = 15.46, or 16th haul unit.



Sampling from a roadway

Sampling from a Roadway with Previously Placed Material: The agency's specified frequency of sampling – in time, volume, or mass – can be translated into a location on a job. For example, if a sample is to be taken every 800 m^3 (1000yd^3) and material is being placed 0.15 m
13 (0.50 ft) thick and 4.0 m (13 ft) wide, then the lot is 1330 m (4154 ft) long. You would select two RNs in this case. To convert yd^3 to ft^3 multiply by
14 27.

The first RN would be multiplied by the length to determine where the sample would be taken along
15 the project. The second would be multiplied by the width to determine where, widthwise, the sample would be taken. For example, a first RN of 0.759
16 would specify that the sample would be taken at (0.759)(1330 m) or (4154 ft) = 1010 m or 3153 ft from the beginning. A second RN of 0.255 would specify that the sample would be taken at (0.255)(4.0 m) or (13 ft) = 1.02 m or 3.3 ft from the right edge of the material. To avoid problems associated with taking samples too close to the edge, no sample is taken closer than 0.3 m (1 ft) to the edge. If the RN specifies a location closer than 0.3 m (1 ft), then 0.3 m (1 ft) is added to or subtracted from the distance calculated.

17 **Sampling from a Stockpile:** AASHTO R 90 recommends against sampling from stockpiles. However, some agencies use random procedures in determining sampling locations from a stockpile. Bear in mind that stockpiles are prone to segregation and that a sample obtained from a stockpile may not be representative. Refer to AASHTO R 90 for guidance on how to sample from a stockpile.

In-Place Density Testing: Agency specifications will indicate the frequency of tests. For example, one test per 500 m^3 (650 yd^3) might be required. If

the material is being placed 0.15 m (0.50 ft) thick
18 and 10.0 m (33 ft) wide, then the lot is 333 m
(1090 ft) long. You would select two RNs in this
case.

The first RN would be multiplied by the length to
determine where the sample would be taken along
the project. The second would be multiplied by the
width to determine where, widthwise, the sample
19 would be taken. For example, a first RN of 0.387
would specify that the sample would be taken at
(0.387)(333 m) or (1090 ft) = 129 m or (422 ft)
from the beginning. A second RN of 0.558 would
specify that the sample would be taken at
(0.588)(10.0 m) or (33 ft) = 5.88 m or (19 ft) from
the right edge of the material. To avoid problems
associated with taking samples too close to the
edge, no sample is taken closer than 0.3 m (1 ft) to
the edge. If the RN specifies a location closer than
0.3 m (1 ft), then 0.3 m (1 ft) is added to or
subtracted from the distance calculated.

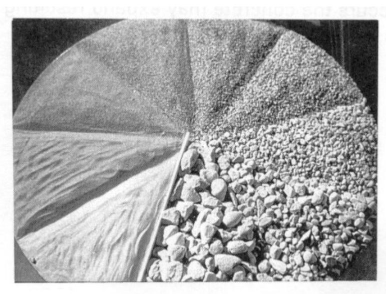
BASICS OF CONCRETE

Introduction

01 Concrete is made up of five primary constituents:

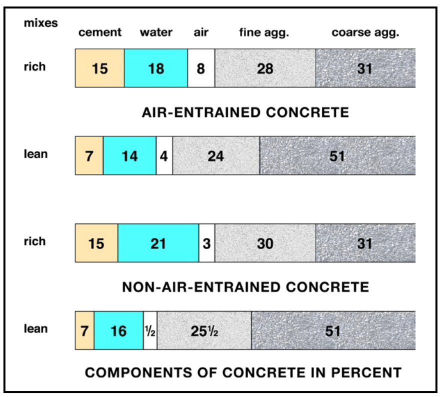
- 02 Water
- Cement (cementitious)
- Air
- Fine aggregate (FA)
- Coarse aggregate (CA)

Cementitious material is portland cement and all
03 supplementary cementitious materials (SCMs).
SCMs are materials that, when used in conjunction
with portland cement, contribute to the properties
of hardened concrete.



Concrete materials

Water and cementitious material form a paste
04 which binds the aggregate into a rock-like mass
through a chemical reaction called 'hydration.' The
paste includes entrapped air, introduced by
mechanical mixing, and entrained air, introduced
by the addition of chemical admixtures. Between
25 and 40 percent of the volume of concrete is
05 paste most of the rest is aggregate. A portion of the
volume is air which is measured by the FOP for
AASHTO T 152. The air content in concrete varies
06 from about 1/2 to 2 percent in non-air-entrained
concrete. Entrapped air is the larger air voids in
concrete which are not purposely entrained. By
adding air-entraining admixtures to the concrete,
the air content is raised to about 4 to 8 percent.
Entrained air is microscopic air bubbles
intentionally incorporated into the paste of concrete
during mixing. The bubbles are intended to
provide better durability to freezing and thawing.



FA, sometimes called 'sand,' is composed of
particles that pass the 4.75 mm (No. 4) sieve. CA,
07 or 'gravel,' consists of particles retained on the
4.75 mm (No. 4) sieve. Well-graded aggregate,
consisting of a wide range of FA and CA sizes,
provides for efficient use of the water/cement paste.

Map cracking

D-cracking

Since aggregate is most of the mix volume, it should have adequate strength and resistance to exposure conditions.

08 Categories of potential problems:

- Unsuitable materials
- 10 Improper production (batching) or transport
- Improper construction technique
- Environmental conditions

09 The selection of concrete materials has a tremendous impact on the quality of a project. For example, poor quality aggregate can result in a
11 number of problems. Soft aggregates can cause pop outs in the concrete surface by expanding and breaking. Siliceous aggregates react with the alkali in cement, in a condition called alkali-silica reactivity, resulting in concrete expansion and map or alligator cracking. Porous aggregates, subject to moisture and freeze-thaw cycles, will deteriorate and generate D-cracking.

Water/Cement (Cementitious) Ratio

12 The water to cementitious ratio (w/c) largely determines the strength and durability of the concrete when it is cured properly. The w/c ratio refers to the mass of water to the mass of cement used in the concrete mix. A w/c ratio of 0.4 means that for every 100 lbs. of cementitious material used in the concrete, 40 lbs. of water is added.

Higher w/c ratios result in lower strength concrete. For example, a w/c of 0.4 in air-entrained concrete will typically have 5000 psi or greater compressive strength and a w/c of 0.7 will have around 2500 psi compressive strength.

13 Advantages of lower water content include:

- Increased compressive and flexural strength
- Decreased permeability (increased watertightness)
- Lower absorption
- Increased durability (resistance to weathering)

- Better bond between successive layers
- Better bond between concrete and reinforcement
- Less bleeding
- Less volume change between wet and dry conditions

Fresh Concrete Considerations

Include:

14
- Uniformity
- Workability
- Consolidation
- Hydration

Fresh concrete should be plastic and capable of being molded by hand. Each aggregate particle should be coated with paste and spaces between aggregate particles should be filled. A well-designed plastic mix keeps the components in place and does not segregate during transport. Plastic concrete should not crumble, but flow like a paste.

Measuring slump

15 **Uniformity** – Fresh concrete should be uniform from batch to batch. For the finished product to have consistent quality throughout, each batch of plastic concrete that goes into a structure should be uniform. A commonly used measure of uniformity or consistency is slump, which can be measured by the FOP for AASHTO T 119. Factors such as water content, temperature, FA content, aggregate shape, air content, and admixtures can influence the slump of concrete. A thorough understanding of factors that can influence slump is important, and a change in slump should not be simply adjusted by varying the water content.

Workability – Concrete must be relatively easy to place and consolidate but should not segregate or
16 bleed water while being worked. Transporting and placing fresh concrete as close as possible to its final location will reduce problems and save resources.

17 **Consolidation** – Consolidation is the process which expels entrapped air and compacts the

Vibrating cylinder specimens

Improperly consolidated concrete

Concrete core

aggregate particles to increase the density and strength of concrete. Consolidation also enhances the bond between the concrete and reinforcement.

For concrete that cannot be consolidated manually, such as stiff or coarse mixtures, vibration is used. Although, over-vibrating fluid mixes can cause segregation, under-consolidation can result in large voids or honeycombing.

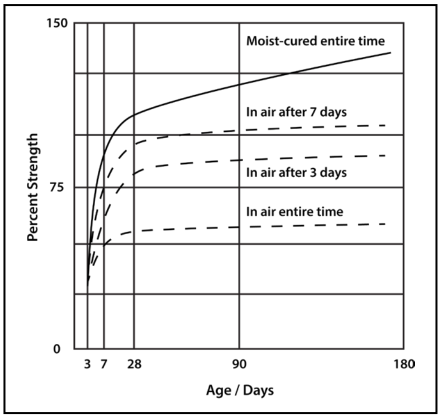
18 **Hydration** – The chemical reaction between
19 cement and water is called hydration which bonds the aggregate particles. Portland cement is an inorganic substance made up of many compounds. The anhydrous (dry) crystalline structure of cement is transformed during hydration to form calcium
20 hydroxide (lime), calcium silicate hydrate, and other components. The concrete properties of set time and strength depend mainly upon the formation of calcium silicate hydrate. Heat is released during hydration, and the rate of the reaction is critical to the quality of the finished concrete. Depending on the chemical makeup of the cement and curing conditions, the rate of hydration and the resulting strength gain can vary significantly.

Strength

21 Strength, which can be measured using specimens cast according to the FOP for AASHTO R 100, is usually the primary concern in concrete mix designing. Compressive strength is required for bridges and structures, while flexural strength is required for pavements and slabs. Flexural strength, resistance to bending, is normally about 7.5 to 10 times the square root of the compressive strength. Concrete has little tensile strength – only about 10 percent of its compressive strength – and almost all structures are designed as though it has no tensile strength. Reinforcement provides the necessary tensile strength in concrete structures.

22 The principal factors affecting concrete strength are:

- Cement content
- Water-cementitious ratio



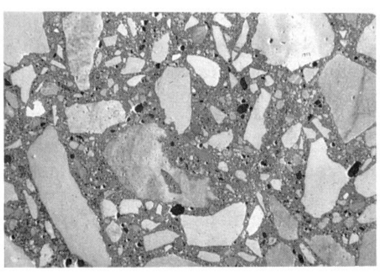
- Age

23 Compressive strength increases as w/c ratio
decreases and increases with age. The water and
cementitious in concrete will continue to react as
long as there is moisture available and until all the
anhydrous cement is consumed. It is critical to
keep concrete continuously moist during curing as
it will ultimately reach greater strength than
concrete that is allowed to dry. It is important to
remember that concrete does not harden by drying.
When concrete dries, it ceases to gain strength.
Even if it is made wet again, it will not reach the
same strength as concrete kept continuously moist.

Density

24 Concrete that is normally used in highway work has
a density (sometimes called unit weight) around
2320 kg/m^3 (145 lb/ft^3). The density test, FOP for
AASHTO T 121, is used to determine the
uniformity of concrete from batch to batch. Factors
affecting concrete density include aggregate
density, air content, and the water and cement
content in the mix – all of which are governed by
the maximum aggregate size. Density of
lightweight concrete can be as low as 240 kg/m^3
(14 lb/ft^3) and that of heavyweight concrete can run
as high as 6000 kg/m^3 (375 lb/ft^3).

Durability



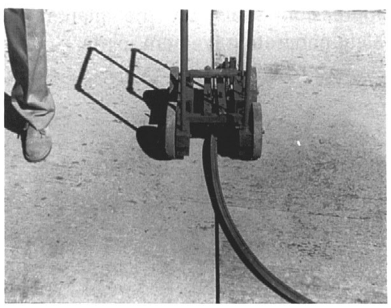
Air voids

25 Durable concrete must have high strength, be
resistant to freeze-thaw damage, have low
permeability, be abrasion resistant, and be resistant
to shrinking and cracking. Nondurable, saturated
26 concrete deteriorates due to repeated freezing and
thawing cycles of water in the concrete paste. Air
entrained concrete has greater resistance to freeze
27 thaw. A network of air bubbles provides pressure
relief during freezing. Concrete made without air
entrainment is subject to more scaling, local flaking
or peeling of the concrete surface, than air
entrained concrete.

Concrete exposed to severe weather conditions
28 should have low permeability (relatively
watertight), since water can penetrate permeable
concretes. Water containing a high chloride

content, such as sea water and deicing salt, can deteriorate the reinforcing steel and cause failure of the structure. The permeability of concrete depends on cement content, w/c ratio, and the length of moist curing. The lower the water-cement ratio, the less water leakage that occurs. The longer concrete is moist cured, the more watertight the concrete is.

29 A related durability issue is control of cracking. Cracking can be caused by applied loads, expansion and contraction, or drying shrinkage. Proper placement of joints in concrete reduces the amount of cracking, particularly if the joints are constructed before contraction or drying occurs. Plastic shrinkage cracks result when water evaporates from the surface of unhardened concrete. This problem is most common when concrete is placed in hot, windy, and/or low humidity weather, and the concrete is not kept moist.



Control joint

30 Depending on the use of the concrete, abrasion resistance may also be important. Pavements can wear with age; particularly where studded tires are used. Worn pavements can be slippery if the aggregates are easily abraded. Susceptibility to abrasion is influenced by concrete strength and aggregate type.

Summary

High quality concrete requires a proper combination of materials, workmanship, and environmental conditions. The testing technician plays a critical role by testing materials according to proper procedures to determine if the materials meet the project specification. No amount of good workmanship can compensate for poor material quality.

SAMPLING FRESHLY MIXED CONCRETE
WAQTC TM 2

01 Significance

Testing fresh concrete in the field begins with obtaining and preparing the sample to be tested. Standardized procedures for obtaining a representative sample from various types of mixing and agitating equipment have been established.
02 Specific time limits regarding when tests for temperature, slump, and air content must be started and for when the molding of test specimens must begin are also established.

Sampling from truck mixer

Technicians must be patient and refrain from obtaining the sample too quickly. Doing so would
03 be a violation of the specifications under which the
04 concrete is being supplied and it may result in a non-representative sample of concrete. If one considers that the specifications may require strength tests to be made only once every 100 to 150 m^3 or 100 to 150 yd^3, the need for a truly representative sample is apparent. The minimum 0.03 m^3 (1 ft^3) sample from which the compressive strength test specimens will be made represents only 0.02 to 0.03 percent of the total quantity of concrete placed. For this reason, every precaution must be taken to obtain a sample that is truly representative of the entire batch and then to protect that sample from the effects of evaporation, contamination, and physical damage.

Scope

This practice covers procedures for obtaining representative samples of fresh concrete delivered
05 to the project site. The practice includes sampling from stationary, paving and truck mixers, and from agitating and non-agitating equipment used to transport central mixed concrete.

06 This practice also covers the removal of large aggregate particles is by wet sieving.

Sampling concrete may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices.

07 **Warning**—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

08 Apparatus

Sampling apparatus

- Receptacle: wheelbarrow, bucket or other suitable container that does not alter the properties of the material being sampled
- Sample cover (plastic, canvas, or burlap)
- 09 Shovel
- Cleaning equipment, including scrub brush, rubber gloves, water
- Apparatus for wet sieving including a sieve(s), meeting the requirements of FOP for AASHTO T 27/T 11, minimum of 2 ft^2 (0.19 m^2) of sieving area, conveniently arranged and supported so that the sieve can be shaken rapidly by hand.

10 Procedure

1. Use every precaution in order to obtain samples representative of the true nature and condition
11 of the concrete being placed being careful not to obtain samples from the very first or very last portions of the batch. The size of the sample will be 1.5 times the volume of concrete required for the specified testing, but not less than 0.03 m^3 (1 ft^3).
2. Dampen the surface of the receptacle just before sampling, empty any excess water.

Note 1: Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as at the discharge of a concrete pump.

12 3. Use one of the following methods to obtain the sample:

- **Sampling from stationary mixers**

  Obtain the sample after a minimum of 1/2 m^3 (1/2 yd^3) of concrete has been discharged. Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a receptacle. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and non-tilting mixers.

13

- **Sampling from paving mixers**

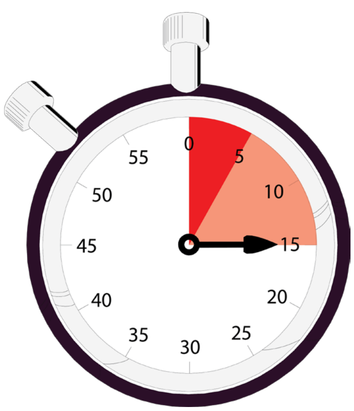
  Obtain the sample after the contents of the paving mixer have been discharged. Obtain increments from at least five different locations in the pile and combine into one test sample. Avoid contamination with subgrade material or prolonged contact with absorptive subgrade. To preclude contamination or absorption by the subgrade, the concrete may be sampled by placing a shallow container on the subgrade and discharging the concrete across the container.

- **Sampling from revolving drum truck mixers or agitators**

  Obtain the sample after a minimum of 1/2 m^3 (1/2 yd^3) of concrete has been discharged. Obtain sample after all of the water has been added to the mixer. Do not obtain sample from the very first or last portions of the batch discharge. Perform sampling by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a receptacle. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

Open-top truck

Sampling at pump discharge



5 and 15 Minutes

- 14 **Sampling from open-top truck mixers, agitators, non-agitating equipment, or other types of open-top containers**

  Obtain the sample by whichever of the procedures described above is most applicable under the given conditions.

- 15 **Sampling from pump or conveyor placement systems**

  Obtain the sample after a minimum of
  1/2 m^3 (1/2 yd^3) of concrete has been
  discharged. Obtain sample after all of the
  pump slurry has been eliminated. Perform
  sampling by repeatedly passing a receptacle
  through the entire discharge system or by
  completely diverting the discharge into a
  16 receptacle. Do not lower the pump arm
  from the placement position to ground level
  17 for ease of sampling, as it may modify the
  18 air content of the concrete being sampled.
  Do not obtain sample from the very first or
  last portions of the batch discharge.

19

4. Transport sample to the testing location.
5. Remix with a shovel the minimum amount necessary to ensure uniformity. Protect the sample from direct sunlight, wind, rain, and sources of contamination.
6. Complete test for temperature and start tests for
   20 slump and air content within 5 minutes of
   obtaining the sample. Start molding specimens
   for strength tests within 15 minutes of obtaining
   the sample. Complete the test methods as
   expeditiously as possible.

Wet Sieving

When required due to oversize aggregate, the
concrete sample shall be wet sieved after
transporting but prior to remixing for slump testing,
air content testing or molding test specimens, by the
21 following:

22

1. Place the sieve designated by the test procedure over the dampened receptacle.

2. Pass the concrete over the designated sieve. Do not overload the sieve (one particle thick).
3. Shake or vibrate the sieve until no more material passes the sieve. A horizontal back and forth motion is preferred.
4. Discard oversize material including all adherent mortar.
5. Repeat until sample of sufficient size is obtained. Mortar adhering to the wet-sieving equipment shall be included with the sample.
6. With a shovel, remix the sample the minimum amount necessary to ensure uniformity.

23 ***Note 2:*** Wet sieving is not allowed for samples being used for density determinations according to the FOP for AASHTO T 121.

Report

24
- On standard agency forms
- Sample ID
- Date
- Time
- Location
- Quantity represented

25

Tips!

- Read the specs.
- Start tests within the time specified.
- Organize all the equipment in advance.
- Do not obtain sample from the very first or very last portions of the batch.

REVIEW QUESTIONS

1. This practice covers sampling from five types of mixers or placement systems, four of which are _____________, _____________, _______________, and ______________.

2. What is the minimum size of sample to be taken?

3. When sampling from a stationary or revolving drum truck mixer, how must the concrete be sampled during discharge of the batch?

4. The concrete sample must be protected from contamination, _______________, _______________, and _______________.

5. What time limits are specified for testing after obtaining a sample?

PERFORMANCE EXAM CHECKLIST

SAMPLING FRESHLY MIXED CONCRETE
WAQTC TM 2

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Receptacle dampened and excess water removed?	_____	_____
2. Obtain a representative sample from drum mixer:		
a. Concrete sampled after 1/2 m^3 (1/2 yd^3) discharged?	_____	_____
b. Receptacle passed through entire discharge stream or discharge stream completely diverted into sampling container?	_____	_____
3. Obtain a representative sample from a paving mixer:		
a. Concrete sampled after all the concrete has been discharged?	_____	_____
b. Material obtained from at least 5 different locations in the pile?	_____	_____
c. Avoid contaminating the sample with sub-grade materials.	_____	_____
4. Obtain a representative sample from a pump:		
a. Concrete sampled after 1/2 m^3 (1/2 yd^3) has been discharged?	_____	_____
b. All the pump slurry is out of the lines?	_____	_____
c. Receptacle passed through entire discharge stream or discharge stream completely diverted into sampling container?	_____	_____
d. Do not lower the pump arm from the placement position.	_____	_____
5. Sample transported to place of testing?	_____	_____
6. Sample combined, or remixed, or both?	_____	_____
7. Protect sample against rapid evaporation and contamination?	_____	_____
8. Minimum size of sample used for strength tests 0.03 m^3 (1ft^3)?	_____	_____
9. Completed temperature test within 5 minutes of obtaining sample?	_____	_____
10. Start tests for slump and air within 5 minutes of obtaining sample?	_____	_____
11. Start molding cylinders within 15 minutes of obtaining sample?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
12. Wet Sieving:		
a. Required sieve size determined for test method to be performed?	_____	_____
b. Concrete placed on sieve and doesn't overload the sieve?	_____	_____
c. Sieve shaken until no more material passes the sieve?	_____	_____
d. Sieving continued until required testing size obtained?	_____	_____
e. Oversized aggregate discarded?	_____	_____
f. Sample remixed?	_____	_____

Comments: First attempt: Pass_____Fail_______ Second attempt: Pass______Fail_____

____

____

____

Examiner Signature _______________________________WAQTC #:_______________

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PERFORMANCE EXAM CHECKLIST (ORAL)

SAMPLING FRESHLY MIXED CONCRETE
WAQTC TM 2

Participant Name ______________________________Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. What is the minimum sample size?		
a. 0.03 m^3 or 1 ft^3	_____	_____
2. Describe the surface of the receptacle before the sample is introduced into it?		
a. It must be dampened.	_____	_____
3. Describe how to obtain a representative sample from a drum mixer.		
a. Sample the concrete after 1/2 m3 (1/2 yd3) has been discharged.	_____	_____
b. Pass receptacle through entire discharge stream or completely divert discharge stream into sampling container.	_____	_____
4. Describe how to obtain a representative sample from a paving mixer.		
a. Sample the concrete after all the concrete has been discharged.	_____	_____
b. Obtain the increments from at least 5 different locations in the pile.	_____	_____
c. Avoid contaminating the sample with sub-grade materials.	_____	_____
5. Describe how to obtain a representative sample from a pump:		
a. Sample the concrete after 1/2 m^3 (1/2 yd^3) has been discharged.	_____	_____
b. Make sure all the pump slurry is out of the lines.	_____	_____
c. Pass receptacle through entire discharge stream or completely divert discharge stream into sampling container.	_____	_____
d. Do not lower the pump arm from the placement position.	_____	_____
6. After obtaining the sample what must you do?		
a. Transport to place of testing.	_____	_____
7. What must be done with the sample once you have transported them to the place of testing?		
a. Combine and remix the sample.	_____	_____
b. Protect sample against rapid evaporation and contamination.	_____	_____

OVER

Procedure Element	Trial 1	Trial 2
8. What are the two time parameters associated with sampling?		
a. Complete temperature test and start tests for slump and air within 5 minutes of sample being obtained?	_____	_____
b. Start molding cylinders within 15 minutes of sample being obtained?	_____	_____
9. What test methods may require wet sieving?		
a. Slump, air content, and strength specimens?	_____	_____
10. The sieve size used for wet sieving is based on?		
a. The test method to be performed.	_____	_____
11. How long must you continue wet sieving?		
a. Until a sample of sufficient size for the test being performed is obtained.	_____	_____
12. What is done with the oversized aggregate?		
a. Discard it.	_____	_____
13. What must be done to the sieved sample before testing?		
a. Remix.	_____	_____

Comments: First attempt: Pass_____Fail_______ Second attempt: Pass______Fail_____

____

____

____

Examiner Signature ________________________________WAQTC #:________________

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TEMPERATURE OF FRESHLY MIXED PORTLAND CEMENT CONCRETE FOP FOR AASHTO T 309

01 Significance

Concrete temperature is one of the most important
factors influencing the quality, time of set, and
strength of concrete. Without control of concrete
temperature, predicting the concrete's performance
is difficult, if not impossible. Concrete with a high
initial temperature will probably have higher than
normal early strength and lower than normal
ultimate strength. Overall quality of the concrete
will also probably be lowered. Conversely,
concrete placed and cured at low temperatures will
02 develop strength at a slower rate, but ultimately will
have higher strength and be of a higher quality.

The temperatures of concrete and of the air are used
to determine the type of curing and protection that
will be needed, as well as the length of time curing,
and protection should be maintained. Ideally,
concrete temperature will be between 16 and 27°C
(60 and 80°F) during placement, and agency
03 specifications may prohibit placement when air
temperature is low, say below 2°C (36°F) or high,
say above 32°C (90°F). Controlling concrete
temperature and limiting placement to certain air
temperatures will reduce or eliminate many
problems, including those associated with strength
development and durability.

Scope

04 This procedure covers the determination of the temperature of freshly mixed Portland Cement Concrete in accordance with AASHTO T 309-22.

05 **Warning**—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Container — Made of non-absorptive material
  and large enough to cover the sensor with
  concrete at least 75 mm (3 in.) in all directions;
  06 concrete cover must also be a least three times

Temperature of fresh concrete

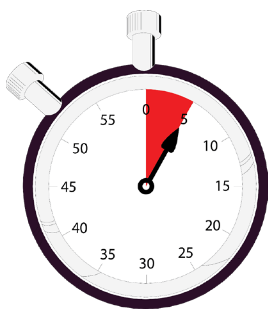
the nominal maximum size of the coarse
07 aggregate.

- Thermometer — Capable of measuring the temperature of the concrete throughout the temperature range likely to be encountered, at least –18 to 50°C (0 to 120°F), and readable to ±0.5°C (±1°F) or smaller.

Note 1: Thermometer types suitable for use include ASTM E1 mercury thermometer or ASTM E2251 Low Hazard Precision Liquid-in-glass thermometer; ASTM E2877 digital metal stem thermometer; or thermocouple thermometer ASTM E230, Type T Special or IEC 60584 Type T, Class 1.

Standardization of Thermometer

Each thermometer shall be verified for accuracy annually and whenever there is a question of accuracy. Standardization shall be performed by comparing readings on the thermometer with another calibrated thermometer at two temperatures at least 15°C or 27°F apart.



5 Minutes

Sample Locations and Times

The temperature of freshly mixed concrete may be
measured in the transporting equipment, in forms,
08 or in sample containers, provided the sensor of the
09 thermometer has at least 75 mm (3 in.) of concrete
cover in all direction around it.

Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.


Pressing concrete around sensing device

Procedure

1. Dampen the sample container.
2. 10 Obtain the sample in accordance with the FOP for WAQTC TM 2.
3. Place sensor of the thermometer in the freshly mixed concrete so that it has at least 75 mm (3 in.) of concrete cover in all directions around it.
4. Gently press the concrete in around the sensor of the thermometer at the surface of the concrete
11 so that air cannot reach the sensor.

12 5. Leave the sensor of the thermometer in the freshly mixed concrete for a minimum of two minutes, or until the temperature reading stabilizes.

6. Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.

7. Read and record the temperature to the nearest 0.5°C (1°F).

13

Report

- Results on forms approved by the agency
- Sample ID
- Measured temperature of the freshly mixed concrete to the nearest 0.5°C (1°F)

14

Tips!

- Complete within 5 minutes of obtaining sample.
- Use calibrated thermometer.
- Ensure that the sensor is surrounded by concrete, not air.
- Allow time for temperature to stabilize.

REVIEW QUESTIONS

1. Why is the temperature of concrete generally taken?

2. Summarize the specifications for the thermometer.

3. The thermometer shall be standardized __________________, or whenever there is a question of __________________.

4. Where can the temperature be measured?

5. After the temperature of the concrete is read, what is then required?

PERFORMANCE EXAM CHECKLIST

TEMPERATURE OF FRESHLY MIXED CONCRETE
FOP FOR AASHTO T 309

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Obtain sample of concrete large enough to provide a minimum of 75 mm (3 in.) of concrete cover around sensor in all directions?	_____	_____
2. Place thermometer in sample with a minimum of 75 mm (3 in.) cover around sensor?	_____	_____
3. Gently press concrete around thermometer?	_____	_____
4. Read temperature after a minimum of 2 minutes or when temperature reading stabilizes?	_____	_____
5. Complete temperature measurement within 5 minutes of obtaining sample?	_____	_____
6. Record temperature to nearest 0.5°C (1°F)?	_____	_____

Comments: First attempt: Pass_____Fail_______ Second attempt: Pass______Fail_____

Examiner Signature ________________________________WAQTC #:_______________

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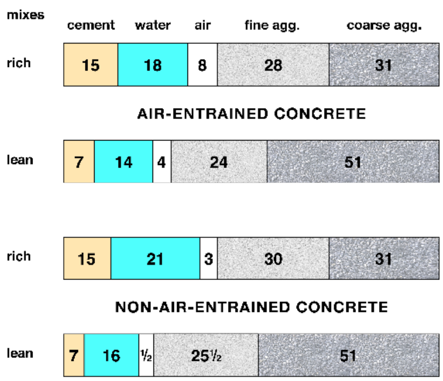
SLUMP OF HYDRAULIC CEMENT CONCRETE
FOP FOR AASHTO T 119

01 Significance

02 The slump test is used to determine the consistency
of concrete. Consistency is a measure of the
relative fluidity or mobility of the mixture. Slump
does not measure the water content of the concrete.
While it is true that an increase or decrease in the
water content will cause a corresponding increase or
decrease in the slump of the concrete, many other
factors can cause slump to change without any
03 change in water content.



COMPONENTS OF CONCRETE IN PERCENT

Also, water content may increase or decrease
without any change in slump. Factors such as a
change in aggregate properties, grading, mix
04 proportions, air content, concrete temperature, or
the use of special admixtures can influence the
slump of the concrete. These can also result in a
change in the water requirement for maintaining a
given slump. For these reasons, one cannot assume
that the water/cement ratio is being maintained
simply because the slump is within the specification
limits.

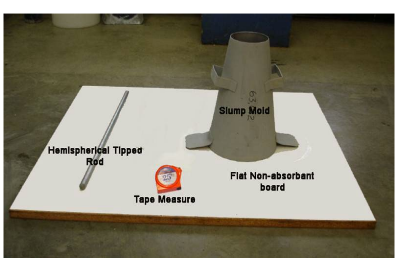
Scope

05 This procedure provides instructions for
determining the slump of hydraulic cement concrete
in accordance with AASHTO T 119-23. It is not
06 applicable to non-plastic and non-cohesive concrete.

Warning—Fresh Hydraulic cementitious mixtures
07 are caustic and may cause chemical burns to skin
and tissue upon prolonged exposure.

Apparatus

- Mold: conforming to AASHTO T 119
  - Metal: a frustum of a cone provided with
foot pieces and handles. The mold must be
constructed without a seam. The interior of
08 the mold shall be relatively smooth and free
from projections such as protruding rivets.
The mold shall be free from dents,
deformations, and adhered mortar. A mold
that clamps to a rigid nonabsorbent base
plate is acceptable provided the clamping



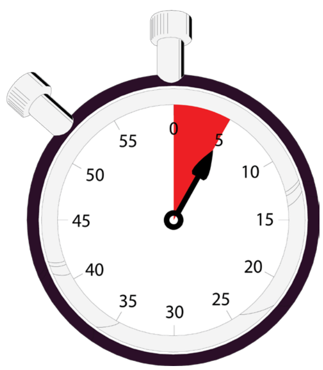
Apparatus

arrangement is such that it can be fully released without movement of the mold.

- Non-metal: see AASHTO T 119 Section 5.1.2.

- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Tape measure or ruler with at least 5 mm or 1/8 in. graduations
- Base: flat, rigid, nonabsorbent moistened surface on which to set the slump mold

Procedure



Five Minutes

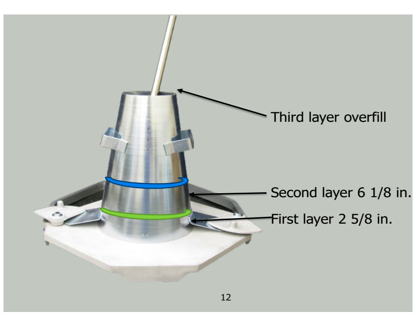
09 1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If the concrete mixture
10 contains aggregate retained on the 37.5 mm (1½ in.) sieve, the aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

Begin testing within five minutes of obtaining the sample.

2. Dampen the inside of the mold and place it on a dampened, rigid, nonabsorbent surface that is level and firm.

11

3. Stand on both foot pieces to hold the mold firmly in place.



Three layers by volume

4. Use the scoop to fill the mold 1/3 full by volume, to a depth of approximately 67 mm
12 (2 5/8 in.).

5. Consolidate the layer with 25 strokes of the
13 tamping rod, using the rounded end. Rod the bottom layer throughout its depth. Distribute the strokes evenly over the entire cross section of the concrete.

For the bottom layer, incline the rod slightly and make approximately half the strokes near the perimeter, and then progress with vertical strokes, spiraling toward the center.

6. Use the scoop to fill the mold 2/3 full by volume, to a depth of approximately 155 mm
14 (6 1/8 in.).

Consolidating top layer

7. Consolidate this layer with 25 strokes of the
15 tamping rod, penetrate approximately 25 mm (1 in.) into the bottom layer. Distribute the strokes evenly.
8. Use the scoop to fill the mold to overflowing.
9. Consolidate this layer with 25 strokes of the tamping rod; penetrate approximately 25 mm (1 in.) into the second layer. Distribute the strokes evenly. If the concrete falls below the top of the mold, stop, add more concrete, and continue rodding for a total of 25 strokes. Always keep an excess of concrete above the top of the mold. Distribute strokes evenly.

Striking off surface

16 10. Strike off the top surface of concrete with a screeding and rolling motion of the tamping rod.
11. Clean overflow concrete away from the base of
17 the mold.
12. Remove the mold from the concrete by raising it carefully in a vertical direction. Raise the mold 300 mm (12 in.) in 5 ±2 seconds by a steady upward lift with no lateral or torsional (twisting) motion being imparted to the concrete.

    Complete the entire operation from the start of the filling through removal of the mold without interruption and complete within an elapsed time of 2 1/2 minutes.
13. Immediately measure the slump.
    a. Invert the slump mold and set it next to the specimen.
    b. Lay the tamping rod across the mold so that it is over the test specimen.

18 c. Measure the distance between the bottom of the rod and the displaced original center of
19 the top of the specimen to the nearest 5 mm (1/4 in.).

Measuring slump

d. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and perform a new test on another portion of the sample.

Note 1: If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks the plasticity and cohesiveness necessary for the slump test to be applicable.

14. Discard the tested sample.

Report

20
- Results on forms approved by the agency
- Sample ID
- Slump to the nearest 5 mm (1/4 in.)

Tips!

21
- Start within 5 minutes of obtaining sample.
- Avoid locations subject to vibration.
- Consolidation strokes in middle and top layers; do not go through entire sample.
- Fill in thirds by volume, not height.

REVIEW QUESTIONS

1. This procedure is not for all concrete. Under what concrete conditions would this procedure not be used?

2. Describe the mold used for making the slump test.

3. The surface on which the mold is placed must be ____________________.

4. The approximate concrete depth (in vertical distance) after placing the first layer is _______ and the second layer is ________________.

5. When rodding the bottom layer, the tamping rod must be _____________ to uniformly distribute the strokes.

6. If, while rodding the top layer, the concrete drops below the top of the slump cone, what must be done?

7. The measurement for slump is made from the top of the mold to what point of the concrete specimen?

8. While the technician is checking the slump of the concrete, there is a decided falling away or shearing off of concrete from one side of the sample. What should the technician do?

PERFORMANCE EXAM CHECKLIST

SLUMP OF HYDRAULIC CEMENT CONCRETE
FOP FOR AASHTO T 119

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
First layer		
1. Mold and floor or base plate dampened?	_____	_____
2. Mold held firmly against the base by standing on the two foot pieces? Mold not allowed to move in any way during filling?	_____	_____
3. Representative sample scooped into the mold?	_____	_____
4. Mold approximately one third (by volume), 67 mm (2 5/8 in.) deep?	_____	_____
5. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
Second layer		
6. Representative samples scooped into the mold?	_____	_____
7. Mold filled approximately two thirds (by volume), 155 mm (6 1/8 in.), deep?	_____	_____
8. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes, penetrate approximately 25 mm (1 in.) into the bottom layer?	_____	_____
Third layer		
9. Representative sample scooped into the mold?	_____	_____
10. Mold filled to just over the top of the mold?	_____	_____
11. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes, penetrate approximately 25 mm (1 in.) into the second layer?	_____	_____
12. Excess concrete kept above the mold at all times while rodding?	_____	_____
13. Concrete struck off level with top of mold using tamping rod?	_____	_____

OVER

Procedure Element	Trial 1	Trial 2
14. Concrete removed from around the outside bottom of the mold?	_____	_____
15. Mold lifted upward 300 mm (12 in.) in one smooth motion, without a lateral or twisting motion of the mold, in 5 ±2 seconds?	_____	_____
16. Test performed from start of filling through removal of the mold within 2 1/2 minutes?	_____	_____
17. Slump immediately measured to the nearest 5 mm (1/4 in.) from the top of the mold to the displaced original center of the top surface of the specimen?	_____	_____

Comments: First attempt: Pass_____Fail_______ Second attempt: Pass_____Fail_____

____

____

____

____

____

____

Examiner Signature _______________________________WAQTC #:_______________

DENSITY (UNIT WEIGHT), YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE
FOP FOR AASHTO T 121

01 Significance

Density, formerly called “unit weight”, is an
02 important parameter used to control the quality of
freshly mixed concrete. After a concrete mix
design has been established, a change in a
concrete’s density will indicate a change in one or
03 more of the other concrete performance
requirements. A lower density may indicate:

1. that the cement or aggregate has a lower specific gravity than expected
2. a higher air content
3. a higher water content
4. a change in the proportions of ingredients
5. a lower cement / cementitious content

Conversely, a higher density would indicate the reverse of the above-mentioned characteristics.

A lower density from the established concrete mix
proportion will often indicate an “over-yield,”
meaning that the volume is greater than intended.
As a result, cement content per unit of volume is
lower than the mix design cement content. Lower
strength is to be expected as well as a reduction of
the other desirable qualities. If the reduction in
04 density is due to an increase in air content, the
concrete may be more durable in its resistance to
cycles of freezing and thawing, but strength,
abrasion resistance, and resistance to chemical
attack, shrinkage, and cracking will be adversely
affected. A change in density could affect the
ability to pump, place, and finish the concrete. The
density test can also be used to determine the air
content of concrete, as long as the theoretical
density of the concrete computed on an air-free
basis is known.

Scope

This procedure covers the determination of density, or unit weight, of freshly mixed concrete in accordance with AASHTO T 121-23. It also
05 provides formulas for calculating the volume of concrete produced from a mixture of known quantities of component materials and provides a method for calculating cement content and cementitious material content – the mass of cement or cementitious material per unit volume of concrete. A procedure for calculating water/cement ratio is also covered.

06 **Warning**—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

Apparatus

- Measure: May be the bowl portion of the air meter used for determining air content under the FOP for AASHTO T 152. Otherwise, it shall be a metal cylindrical container meeting the
07 requirements of AASHTO T 121. The capacity
08 and dimensions of the measure shall conform to those specified in Table 1.
- Balance or scale: Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) longer than the depth of the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.

- Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in).
- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb) for use with measures of 14 L (1/2 ft^3) or less or having a mass of 1.02 ±0.23 kg (2.25 ±0.5 lb) for use with measures larger than 14 L (0.5 ft^3).

Table 1
Dimensions of Measures*

Capacity m^3 (ft^3)	Inside Diameter mm (in.)	Inside Height mm (in.)	Minimum Thicknesses mm (in.)		Nominal Maximum Size of Coarse Aggregate *** mm (in.)
			Bottom	Wall	
0.0071	203 ±2.54	213 ±2.54	5.1	3.0	25
(1/4)**	(8.0 ±0.1)	(8.4 ±0.1)	(0.20)	(0.12)	(1)
0.0142	254 ±2.54	279 ±2.54	5.1	3.0	50
(1/2)	(10.0 ±0.1)	(11.0 ±0.1)	(0.20)	(0.12)	(2)

* ***Note 1:*** The indicated size of measure shall be for aggregates of nominal maximum size equal to or smaller than that listed.

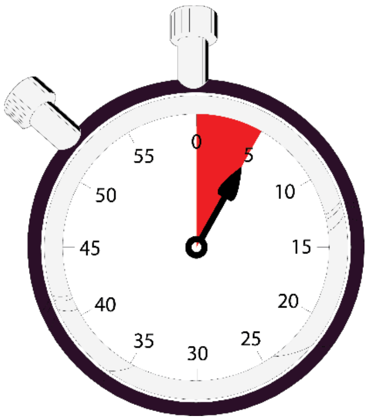
** Measure may be the base of the air meter used in the FOP for AASHTO T 152.

***Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Consolidation Selection

9 There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 75 mm (3 in.), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in.), internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency to obtain consistent, comparable results. For concrete with slump less than 25 mm (1 in.), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

When using measures greater than 0.0142 m^3 (1/2 ft^3) see AASHTO T 121.



5 Minutes

10 ## Procedure

11 ### Sampling

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. Testing may be performed in conjunction with the FOP for AASHTO T 152. When doing so, this FOP should be performed before the FOP for AASHTO T 152.

Note 2: If the two tests are being performed using the same sample, this test shall begin within five minutes of obtaining the sample.

Rodding

12 1. Dampen the inside of the measure and empty excess water.

Consolidation

2. Determine and record the mass of the measure.
3. Use the scoop to fill the measure approximately 1/3 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

13 4. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.

14 5. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.

Tapping measure

6. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

15 7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.

8. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
9. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

10. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
11. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
12. Continue with 'Strike-off and Determining Mass.'

Internal Vibration

16 1. Dampen the inside of the measure and empty excess water.
2. Determine and record the mass of the measure.
3. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Insert the vibrator three different points in each layer measure is used. Do not let the vibrator touch the bottom or side of the measure.
17 Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
5. Slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Insert the vibrator at three different points penetrating the first layer approximately 25 mm (1 in.). Do not let the vibrator touch the side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material.
7. Continue with 'Strike-off and Determining Mass.'

Self-Consolidating Concrete

18 1. Dampen the inside of the measure and empty excess water.
2. Determine and record the mass of the measure.
3. Use the scoop to slightly overfill the measure. Do not exceed 125 mm (5 in.) drop height.

Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

4. Continue with 'Strike-off and Determining Mass.'

Striking off surface

Cover 2/3 and withdraw

Cover 2/3 and forward

19 Strike-off and Determining Mass

20 1. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.

2. Press the strike-off plate flat against the top surface, covering approximately 2/3 of the measure.

3. Withdraw the strike-off plate with a sawing motion to finish the 2/3 originally covered.

21 4. Cover the original 2/3 again with the plate; finishing the remaining 1/3 with a sawing motion (do not lift the plate; continue the
22 sawing motion until the plate has cleared the
23 24 surface of the measure).

5. Finish the surface with the inclined edge of the strike-off plate. The surface should be smooth and free of voids.

6. Clean off all excess concrete from the exterior of the measure including the rim.

25 7. Determine and record the mass of the measure and the concrete.

8. If the air content of the concrete is to be determined, ensure the rim (flange) is clean and proceed to 'Strike-off and Air Content' Step 3 of the FOP for AASHTO T 152.

Calculations 26

Mass of concrete in the measure

$$concrete\ mass = M_c - M_m$$

Where:

Concrete mass	=	mass of concrete in measure
M_c	=	mass of measure and concrete
M_m	=	mass of measure

Density

27

$$\rho = \frac{concrete\ mass}{V_m}$$

Where:

ρ	=	density of the concrete mix
V_m	=	volume of measure (Annex)

Yield m³

$$Y_{m^3} = \frac{W}{\rho}$$

Where:

$Y_{m}{}^{3}$	=	yield (m^3 of the batch of concrete)
W	=	total mass of the batch of concrete

Yield yd³

$$Y_{ft^3} = \frac{W}{\rho} \qquad Y_{yd^3} = \frac{Y_{ft^3}}{27 ft^3/yd^3}$$

Where:

$Y_{ft}{}^{3}$	=	yield (ft^3 of the batch of concrete)
$Y_{yd}{}^{3}$	=	yield (yd^3 of the batch of concrete)
W	=	total mass of the batch of concrete
ρ	=	density of the concrete mix

Note 5: The total mass, W, includes the masses of the cement, water, and aggregates in the concrete.

Cement Content

$$N = \frac{N_t}{Y}$$

Where:

N	=	actual cementitious materials content per $Y_{m}{}^{3}$ or $Y_{yd}{}^{3}$
N_t	=	mass of cementitious materials in the batch
Y	=	$Y_{m}{}^{3}$ or $Y_{yd}{}^{3}$

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Water Content 34

The mass of water in a batch of concrete is the sum of:

- water added at batch plant
- water added in transit
- water added at jobsite
- free water on coarse aggregate*
- free water on fine aggregate*
- liquid admixtures (if required by the agency)

*Mass of free water on aggregate

This information is obtained from concrete batch tickets collected from the driver. Use the Table 2 to convert liquid measures.

Table 2
Liquid Conversion Factors 35

To Convert From	To	Multiply By
Liters, L	Kilograms, kg	1.0
Gallons, gal	Kilograms, kg	3.785
Gallons, gal	Pounds, lb	8.34
Milliliters, mL	Kilograms, kg	0.001
Ounces, oz	Milliliters, mL	28.4
Ounces, oz	Kilograms, kg	0.0284
Ounces, oz	Pounds, lb	0.0625
Pounds, lb	Kilograms, kg	0.4536

Mass of free water on aggregate

36

$$Free\ Water\ Mass = CA\ or\ FC\ Aggregate - \frac{CA\ or\ FC\ Aggregate}{1 + (Free\ Water\ Percentage/100)}$$

Where:

Free Water Mass	=	on coarse or fine aggregate
FC or CA Aggregate	=	mass of coarse or fine aggregate
Free Water Percentage	=	percent of moisture of coarse or fine aggregate

Water/Cement Ratio

$$\frac{Water\ Content}{C} \tag{39}$$

Where:

Water Content	=	total mass of water in the batch
C	=	toatl mass of cementitious materials

Example

Mass of concrete in measure (M_m)	16.290 kg (36.06 lb)
Volume of measure (V_m)	0.007079 m^3 (0.2494 ft^3)
<u>From batch ticket:</u>	
Yards batched	4 yd^3
Cement	950 kg (2094 lb)
Fly ash	180 kg (397 lb)
Coarse aggregate	3313 kg (7305 lb)
Fine aggregate	2339 kg (5156 lb)
Water added at plant	295 L (78 gal)
<u>Other</u>	
Water added in transit	0
Water added at jobsite	38 L (10 gal)
Total mass of the batch of concrete (W)	7115 kg (15,686 lb)
Moisture content of coarse aggregate	1.7%
Moisture content of coarse aggregate	5.9%

Density

$$\rho = \frac{concrete\ mass}{V_m}$$

$$\rho = \frac{16.920\ kg}{0.007079\ m^3} = 2390\ \ kg/m^3 \quad \rho = \frac{36.06\ lb}{0.2494\ ft^3} = 144.6\ \ lb/ft^3$$

Given:

concrete mass = 16.920 kg (36.06 lb)

V_m = 0.007079 m^3 (0.2494 ft^3) (Annex)

Yield m^3

$$Y_{m^3} = \frac{W}{\rho}$$

$$Y_{m^3} = \frac{7115\ kg}{2390\ kg/m^3} = 2.98\ m^3$$

Given:

Total mass of the batch of concrete (W), kg = 7115 kg

Yield yd^3

$$Y_{ft^3} = \frac{W}{\rho} \qquad Y_{yd^3} = \frac{Y_{ft^3}}{27 ft^3/yd^3}$$

$$Y_{ft^3} = \frac{15{,}686\ lb}{144.6 \frac{lb}{ft^3}} = \ 108.48\ ft^3 \qquad Y_{yd^3} = \frac{108.48\ ft^3}{27 \frac{ft^3}{yd^3}} = 4.02\ yd^3$$

Given:

Total mass of the batch of concrete (W), lb = 15,686 lb

Cement Content

$$N = \frac{N_t}{Y}$$ 33

$$N = \frac{950\,kg + 180\,kg}{2.98\,m^3} = 379\,kg/m^3 \quad N = \frac{2094\,lb + 397\,lb}{4.02\,yd^3} = 620\;lb/yd^3$$

Given:

N_t (cement)	=	950 kg (2094 lb)
N_t (flyash)	=	180 kg (397 lb)

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Mass of free water on aggregate

$$Free\ Water\ Mass = CA\ or\ FC\ Aggregate - \frac{CA\ or\ FC\ Aggregate}{1 + (Free\ Water\ Percentage/100)}$$

$$CA\ Free\ Water = 3313\ kg - \frac{3313\ kg}{1 + (1.7/100)} = 55\ kg$$

$$CA\ Free\ Water = 7305\ lb - \frac{7305\ lb}{1 + (1.7/100)} = 122\ lb$$ 37

$$FA\ Free\ Water = 2339\ kg - \frac{2339\ kg}{1 + (5.9/100)} = 130\ kg$$

$$FA\ Free\ Water = 5156\ lb - \frac{5156\ lb}{1 + (5.9/100)} = 287\ lb$$

Given:

CA aggregate	=	3313 kg (7305 lb)
FC aggregate	=	2339 kg (5156 lb)
CA moisture content	=	1.7%
FC moisture content	=	5.9%

Water Content

Total of all water in the mix.

38

$$Water\ Content = [(78\ gal + 10\ gal) * 3.785\ kg/gal] + 55\ kg + 130\ kg = 518\ kg$$

$$Water\ Content = [(78\ gal + 10\ gal) * 8.34\ lb/gal] + 122\ lb + 287\ lb = 1143\ lb$$

Given:

Water added at plant	=	295 L (78 gal)
Water added at the jobsite	=	38 L (10 gal)

Water/ Cement Ratio

40

$$W/C = \frac{518\ kg}{950\ kg + 180\ kg} = 0.458 \quad W/C = \frac{1143\ lb}{2094\ lb + 397\ lb} = 0.459$$

Report 0.46

41

Report

- Results on forms approved by the agency
- Sample ID
- Density (unit weight) to the nearest 1 kg/m^3 (0.1 lb/ft^3).
- Yield to the nearest 0.01 m^3 (0.01 yd^3)
- Cement content to the nearest 1 kg/m^3 (1 lb/yd^3)
- Cementitious material to the nearest 1 kg/m^3 (1 lb/yd^3)
- Water/Cement ratio to 0.01

Tips!

- Start within 5 minutes of obtaining sample if done along with the FOP for AASHTO T 152.
- Consolidation technique depends on slump. Rodding and/or vibration may be appropriate for different slumps.
- Use a standardized measure.

43 **ANNEX**

STANDARDIZATION OF MEASURE

(Mandatory Information)

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to
44 perform the standardization procedures as described herein will produce inaccurate or unreliable test results.

45 **Apparatus**

- Listed in the FOP for AASHTO T 121
  - Measure
  - Balance or scale
  - Strike-off plate
- Thermometer: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)

Procedure

46

Measure and strike-off plate

1. Determine the mass of the dry measure and
47 strike-off plate.
2. Fill the measure with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the strike-off plate in such a way as to eliminate bubbles and excess water.
3. Wipe the outside of the measure and cover plate dry, being careful not to lose any water from the measure.
4. Determine the mass of the measure, strike-off plate, and water in the measure.
5. 48 Determine the mass of the water in the measure by subtracting the mass in Step 1 from the mass in Step 4.
6. Measure the temperature of the water and determine its density from Table A1, interpolating, as necessary.
7. Calculate the volume of the measure, V_m, by dividing the mass of the water in the measure by the density of the water at the measured temperature.

Calculations 50

$$V_m = \frac{M}{\rho_w}$$

Where:

V_m	=	volume of the mold
M	=	mass of water in the mold
ρ_w	=	density of water at the measured temperature

Example 51

Mass of water in measure	=	7.062 kg (15.53 lb)
Density of water at 23°C (73.4°F) (ρ_w)	=	997.54 kg/m^3 (62.274 lb/ft^3)

$$V_m = \frac{7.062\ kg}{997.54\ kg/m^3} = 0.007079\ m^3 \quad V_m = \frac{15.53\ lb}{62.274\ lb/ft^3} = 0.2494\ ft^3$$

Table A1 49
Unit Mass of Water (15°C to 30°C)

°C	(°F)	kg/m³	(lb/ft³)	°C	(°F)	kg/m³	(lb/ft³)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

52 **Report**

- Measure ID
- Date Standardized
- Temperature of the water
- Volume, V_m, of the measure

REVIEW QUESTIONS

1. What is the required shape of the tamping end of the rod?

2. What is the minimum thickness of a metal strike off plate?

3. What is the minimum thickness for a glass or acrylic strike-off plate?

4. What is the specified mass of the mallet used on measures having a volume of 0.028 m^3 (1 ft^3)?

5. Air meter bases used for this test must conform to what test method?

6. How is the measure filled when testing self-consolidating concrete (SCC)?

7. If, after consolidation of the final layer, the concrete level is 12.5 mm (1/2 in) above the top of the measure, what should be done?

8. After completing the strike-off procedure, what must be done before determining the mass of the measure and sample?

PERFORMANCE EXAM CHECKLIST

DENSITY (UNIT WEIGHT), YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE
FOP FOR AASHTO T 121

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Mass of dampened measure determined?	_____	_____
First Layer		
2. Measure filled approximately one third full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?	_____	_____
3. Layer rodded throughout its depth 25 times, without forcibly striking the bottom of the measure, with hemispherical end of rod, uniformly distributing strokes?	_____	_____
4. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?	_____	_____
Second layer		
5. Measure filled approximately two thirds full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?	_____	_____
6. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in.) 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
7. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?	_____	_____
Third layer		
8. Measure slightly overfilled, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?	_____	_____
9. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in.) 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
10. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding each layer?	_____	_____
11. Any excess concrete removed using a trowel or a scoop, or small quantity of concrete added to correct a deficiency, after consolidation of final layer?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
12. Strike-off plate placed flat on the measure covering approximately 2/3 of the surface, then sawing action used to withdraw the strike-off plate across the previously covered surface?	_____	_____
13. Strike-off plate placed flat on the measure covering approximately 2/3 of the surface, then sawing action used to advance the plate across the entire measure surface?	_____	_____
14. Strike off completed using the inclined edge of the plate creating a smooth surface?	_____	_____
15. All excess concrete cleaned off and mass of full measure determined?	_____	_____
16. Concrete mass calculated?	_____	_____
17. Density calculated correctly?	_____	_____

Comments: First attempt: Pass_____Fail_______ Second attempt: Pass_____Fail____

____

____

____

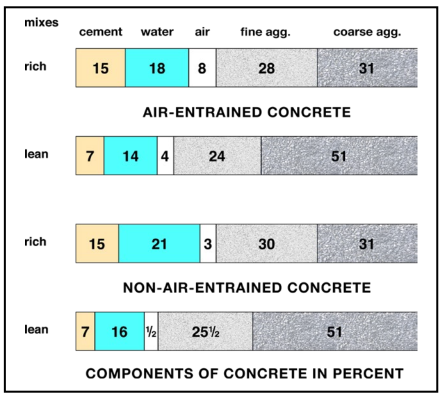
____

Examiner Signature _______________________________WAQTC #:_______________

AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD FOP FOR AASHTO T 152

01 ## Significance

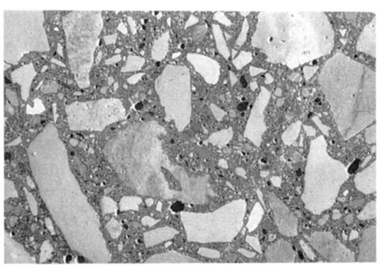
Concrete is not a solid, but rather a solid with void
spaces. The voids may contain gas such as air, or
02 liquid, such as water. All concrete contains air
voids, and the amount can be increased by the
addition of an air-entraining agent to the mix.



Air-entraining admixtures do not generate bubbles. They stabilize microscopic bubbles that are created during the mixing process by:

- Reducing the surface tension of the mixing water to promote the development of the microscopic bubbles.
- Stabilizing the bubbles by forming a sturdy shell that repels water, hinders their coalescence, and promotes attraction to cement and aggregate particles.

When such an agent is used, the size of the voids drastically decreases and the number of voids greatly increases, providing a much greater dispersal of voids.



Air Voids

Air entrainment is necessary in concrete that will be
saturated and exposed to cycles of freezing and
thawing, and to de-icing chemicals. The
03 microscopic, entrained air voids provide a site for
relief of internal pressure that develops as water
04 freezes and thaws inside the concrete. Without the
proper entrained-air content, normal concrete that is
saturated and is exposed to cycles of freezing and
thawing can fail prematurely by scaling, spalling, or
cracking.

Care must be taken, however, not to have too much
entrained air. As the air content increases, there
05 will be a corresponding reduction in the strength
and other desirable properties of the concrete.
06 Typically, this strength reduction will be on the
order of 3 to 5 percent for each 1 percent of air
content. A concrete mix design proportioned for
5 percent air, for example, will be approximately
15 to 25 percent lower in strength if the air content
were to double.

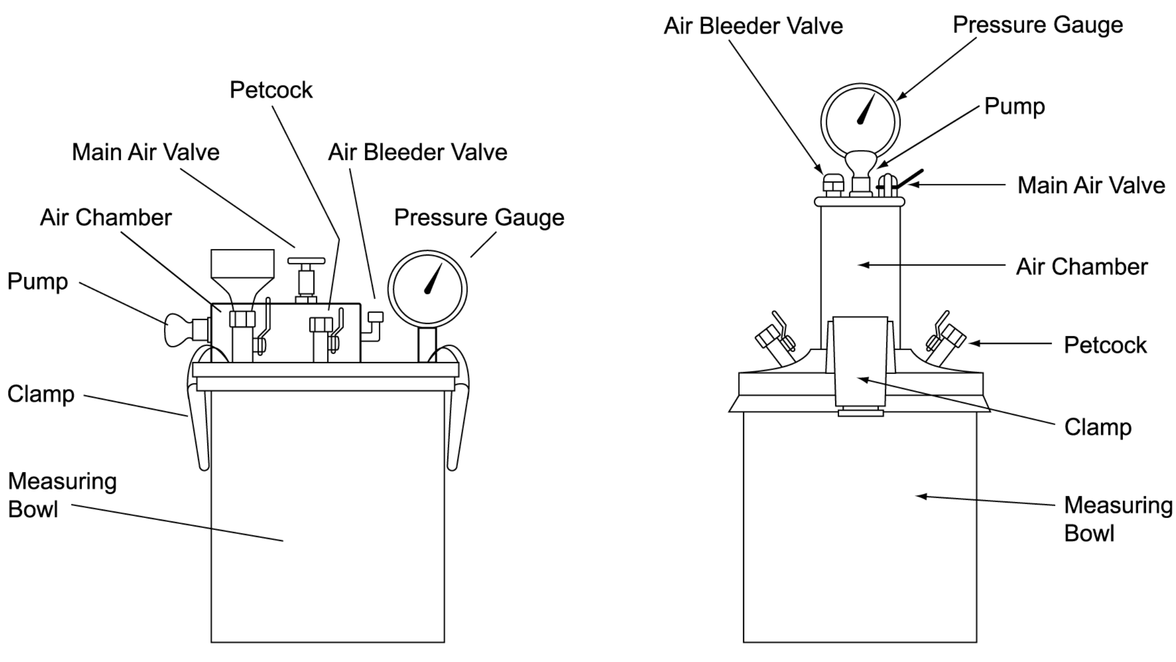
Scope

07 This procedure covers determination of the air
08 content in freshly mixed Portland Cement Concrete containing dense aggregates in accordance with AASHTO T 152-23, Type B meter. It is not for use with lightweight or highly porous aggregates. This procedure includes standardization of the Type B air meter gauge, Annex.

09 **Warning**—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

10 ## Apparatus

- Air meter: Type B, as described in AASHTO T 152.



2a. Horizontal Air Chamber 2b. Vertical Air Chamber

Type B Meter

Apparatus

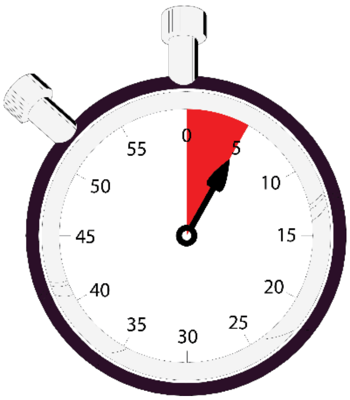
- Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use (for Method 1 standardization only).
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means half a sphere;
  11 the tip is rounded like half of a ball.)
- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to
  12 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) than the depth of the section being vibrated. Check the vibrator frequency periodically.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Container for water: Rubber syringe or plastic wash bottle.
- Strike-off bar: Approximately 300 mm x 22 mm x 3 mm (12 in. x 3/4 in. x 1/8 in.).
- Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in.).

Note 1: Use either the strike-off bar or strike-off plate; both are not required.

- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb).

13 Consolidation Selection

There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 75 mm (3 in.), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in.), internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency to obtain consistent,



5 Minutes

Consolidation

Tapping measure

comparable results. For concrete with slump less than 25 mm (1 in.), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

Procedure

14
Sampling

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate 37.5 mm (1½ in.) or larger is present, aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

   Testing shall begin within five minutes of obtaining the sample.

15
Rodding

16
1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to fill the measure approximately 1/3 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Consolidate the layer with 25 strokes of the 17 tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.
4. 18 Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close 19 voids and release trapped air.
5. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.
7. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
8. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a

circular motion around the inner perimeter of the measure.

9. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
10. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
11. Continue with 'Strike-off and Air Content.'

Internal Vibration

1. Dampen the inside of the air meter measure and
20 place on a firm level surface.
2. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Insert the vibrator at three different points. Do not let the vibrator touch the bottom or side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

21 **Vibrating Concrete in Measure**

4. Tap around the perimeter of the measure
22 smartly 10 to 15 times with the mallet.
5. Use the scoop to fill the measure a bit over full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Insert the vibrator at three different points penetrate the first layer approximately 25 mm (1 in.). Do not let the vibrator touch the side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over
23 vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

7. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
8. Continue with ‘Strike-off and Air Content.’

Self-Consolidating Concrete

24 1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Continue with ‘Strike-off and Air Content.’

Strike-Off and Air Content

25 1. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the trowel or scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
2. Strike off the surface of the concrete and finish it smoothly with a sawing action of the strike-off bar or inclined plate, using great care to leave the measure just full. The surface should be smooth and free of voids.
3. Clean the top flange of the measure to ensure a proper seal.
4. Moisten the inside of the cover and check to see that both petcocks are open, and the main air valve is closed.
5. Clamp the cover on the measure.
6. Inject water through a petcock on the cover until water emerges from the petcock on the opposite side. Jar the meter gently until all air is expelled from this same petcock.

26 7. Verify that water is present in both petcocks.

27 8. Close the air bleeder valve and pump air into the air chamber until the needle goes past the initial pressure determined for the gauge. Allow a few seconds for the compressed air to cool.

Tapping air meter gauge

Tips!

- Start within 5 minutes of obtaining sample.
- Use a standardized air meter.
- Protect the standardization vessel from damage.
- Consolidation technique depends on slump. Rodding and/or vibration may be appropriate for different slumps.

9. Tap the gauge gently with one hand while slowly opening the air bleeder valve until the needle rests on the initial pressure. Close the air
28 bleeder valve.
29 10. Close both petcocks.
11. Open the main air valve.
12. Tap the side of the measure smartly with the mallet.
13. With the main air valve open, lightly tap the gauge to settle the needle, and then read the air content to the nearest 0.1 percent.
14. Release or close the main air valve.
15. Open both petcocks to release pressure, remove the concrete, and thoroughly clean the cover and measure with clean water.
16. Open the main air valve to relieve the pressure in the air chamber.

Report

- Results on forms approved by the agency
30
- Sample ID
- Percent of air to the nearest 0.1 percent.
- Some agencies require an aggregate correction factor to determine the total percent of entrained air.

  Total % entrained air =

  Gauge reading – aggregate correction factor from mix design

  (See AASHTO T 152 for more information.)

31

Apparatus

Adding water

Initial Pressure

33

ANNEX
STANDARDIZATION OF AIR METER GAUGE

(Mandatory Information)

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described
34 below will produce inaccurate or unreliable test results.

Standardization shall be performed at a minimum of once every three months. Record the date of the standardization, the standardization results, and the name of the technician performing the standardization in the logbook kept with each air meter.

There are two methods for standardizing the air meter; mass or volume both are covered below.

35

1. Screw the short piece of straight tubing into the
   36 threaded petcock hole on the underside of the cover.
2. Determine and record the mass of the dry, empty air meter measure and cover assembly (mass method only).
3. Fill the measure nearly full with water.
4. Clamp the cover on the measure with the tube extending down into the water. Mark the petcock with the tube attached for future reference.
5. Add water through the petcock having the pipe extension below until all air is forced out the other petcock.
6. Wipe off the air meter measure and cover
   37 assembly; determine and record the mass of the filled unit (mass method only).
7. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed
   38 air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.

Removing 5 percent

8. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle stabilizes. The gauge should now read 0 percent. If two or more tests show a consistent variation from 0 percent in the result, change the initial pressure line to compensate for the variation, and use the newly established initial pressure line for subsequent tests.

9. Determine which petcock has the straight tube
39 attached to it. Attach the curved tube to external
40 portion of the same petcock.

10. Pump air into the air chamber. Open the petcock with the curved tube attached to it. Open the main air valve for short periods of time until 5 percent of water by mass or volume has been removed from the air meter. Remember to open both petcocks to release the pressure in the measure and drain the water in the curved tube back into the measure. To determine the mass of the water to be removed, subtract the mass found in Step 2 from the mass found in Step 6. Multiply this value by 0.05. This is the mass of the water that must be removed. To remove 5 percent by volume, remove water until the external standardization vessel is level full.

Note A1: Many air meters are supplied with a standardization vessel(s) of known volume that are used for this purpose. Standardization vessel must be protected from crushing or denting. If an external standardization vessel is used, confirm what percentage volume it represents for the air meter being used. Vessels commonly represent 5 percent volume, but they are for specific size meters. This should be confirmed by mass.

5 percent

41 11. Remove the curved tube. Pump up the air
42 pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.

12. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle is stabilized. The gauge should now read 5.0 ±0.1

percent. If the gauge is outside that range, the meter needs adjustment. The adjustment could involve adjusting the starting point so that the gauge reads 5.0 ±0.1 percent when this standardization is run or could involve moving the gauge needle to read 5.0 percent. Any adjustment should comply with the manufacturer's recommendations.

13. When the gauge hand reads correctly at 5.0 percent, additional water may be withdrawn in the same manner to check the results at other values such as 10 percent or 15 percent.
14. If an internal standardization vessel is used, follow Steps 1 through 8 to set initial reading.
15. Release pressure from the measure and remove cover. Place the internal standardization vessel into the measure. This will displace 5 percent of the water in the measure. (See AASHTO T 152 for more information on internal standardization vessels.)
16. Place the cover back on the measure and add water through the petcock until all the air has been expelled.
17. Pump up the air pressure chamber to the initial pressure. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
18. Close both petcocks and immediately open the main air valve, exhausting air into the measure. Wait a few seconds until the meter needle stabilizes. The gauge should now read 5 percent.
19. Remove the extension tubing from threaded petcock hole in the underside of the cover before starting the test procedure.

43 **Report**

- On forms approved by the agency
- Air meter ID
- Date standardized
- Initial pressure (IP)

REVIEW QUESTIONS

1. Can the pressure method of determining air content be used on all types of concrete? Explain.

2. What are the required characteristics of the tamping rod used in this test method?

3. What is the specified size of the mallet required for this test method?

4. Describe the calibration process by mass and volume.

5. How is the measure filled when testing self-consolidating concrete (SCC)?

6. After rodding each layer, what should be done to the measure before adding another layer of concrete?

7. What tools may be used for striking off the top surface of the concrete following consolidation of the final layer?

OVER

8. What must be done if there is a slight deficiency in the quantity of concrete in the measure following consolidation of the final layer?

9. What must be done if there is an excessive amount of concrete in the measure following consolidation of the final layer?

PERFORMANCE EXAM CHECKLIST

AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD FOP FOR AASHTO T 152

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Representative sample selected?	_____	_____
First Layer		
2. Dampened measure filled approximately one third full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?	_____	_____
3. Layer rodded throughout its depth 25 times, without forcibly striking the bottom of the measure, with hemispherical end of rod, uniformly distributing strokes?	_____	_____
4. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?	_____	_____
Second layer		
5. Measure filled approximately two thirds full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?	_____	_____
6. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in.)) 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
7. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?	_____	_____
Third layer		
8. Measure slightly overfilled, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?	_____	_____
9. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in.)) 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
10. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding each layer?	_____	_____
11. Concrete struck off level with top of the measure using the bar or inclined strike-off plate?	_____	_____
12. Top flange of measure cleaned?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
Using a Type B Meter:		
13. Both petcocks open?	_____	_____
14. Air valve closed between air chamber and the measure?	_____	_____
15. Inside of cover cleaned and moistened before clamping to base?	_____	_____
16. Water injected through petcock until it flows out the other petcock?	_____	_____
17. Meter jarred gently until all air is expelled?	_____	_____
18. Water is present in both petcocks?	_____	_____
19. Air pumped up to just past initial pressure line?	_____	_____
20. A few seconds allowed for the compressed air to stabilize?	_____	_____
21. Gauge adjusted to the initial pressure?	_____	_____
22. Both petcocks closed?	_____	_____
23. Air valve opened between chamber and measure?	_____	_____
24. The outside of measure tapped smartly with the mallet?	_____	_____
25. With the main air valve open, gauge lightly tapped and air percentage read to the nearest 0.1 percent?	_____	_____
26. Air valve released or closed and then petcocks opened to release pressure before removing the cover?	_____	_____
27. Aggregate correction factor applied if required?	_____	_____
28. Air content recorded to 0.1 percent?	_____	_____

Comments: First attempt: Pass_____Fail_______ Second attempt: Pass_____Fail_____

Examiner Signature _______________________________WAQTC #:_____________

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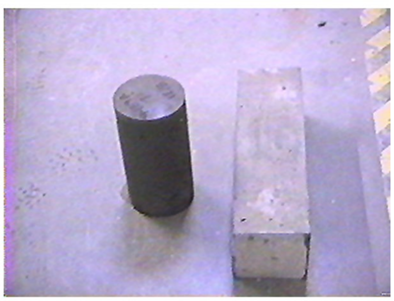
METHOD OF MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD FOP FOR AASHTO R 100

01
Significance

02 Concrete is specified primarily on the basis of strength. Standard specimens are made and subsequently tested to determine the acceptability of concrete. Concrete strength test specimens are made in accordance with a standard procedure to produce results that are reliable and tests that can be reproduced by someone else with the same concrete, following the same procedures.

03 Specimens are molded according to standard procedures and then cured under proper temperature and moisture conditions. Deviation from the standard procedures can cause significant differences in strength results. For example, specimens improperly cured between 32 and 38°C (90 and 100°F) will develop strength at a different rate than specimens cured at the specified temperature range of 16 to 27°C (60 to 80°F) required by this method. Ultimate strength is also affected.



Typical Strength Specimens

04 This FOP pertains to specimens cast for the purpose of acceptance. Agencies sometimes specify curing practices other than those presented here (to determine adequacy of protection or when a structure may be placed in service, for example).

05
Scope

This practice covers the method for making, initially curing, and transporting concrete test specimens in the field in accordance with AASHTO R 100-23.

06 **Warning**—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

Apparatus

- Concrete cylinder molds: Conforming to AASHTO M 205 with a length equal to twice the diameter. Standard specimens shall be 150 mm (6 in.) by 300 mm (12 in.) cylinders. Mold
07 diameter must be at least three times maximum
08 aggregate size unless wet sieving is conducted according to the FOP for WAQTC TM 2. Agency specifications may allow cylinder molds of 100 mm (4 in.) by 200 mm (8 in.) size when the nominal maximum aggregate size does not exceed 25 mm (1 in.).

09

- Beam molds: Rectangular in shape with ends and sides at right angles to each other. Must be sufficiently rigid to resist warpage. Surfaces must be smooth. Molds shall produce length no more than 1.6 mm (1/16 in.) shorter than that required (greater length is allowed). Maximum variation from nominal cross section shall not exceed 3.2 mm (1/8 in.). Ratio of width to depth may not exceed 1.5; the smaller dimension must be at least 3 times maximum aggregate size. Standard beam molds shall result in specimens having width and depth of not less than 150 mm (6 in.). Agency specifications may allow beam molds of 100 mm (4 in.) by 100 mm (4 in.) when the nominal maximum aggregate size does not exceed 25 mm (1 in.). Specimens shall be cast and hardened with the long axes horizontal.
- Standard tamping rod: 16 mm (5/8 in.) diameter
10 and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 150 mm (6 in.) x 300 mm (12 in.) cylinders.
- Small tamping rod: 10 mm (3/8 in.) diameter and 305 mm (12 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 100 mm (4 in.) x 200 mm (8 in.) cylinders
- Vibrator: At least 9000 vibrations per minute, diameter no more than ¼ the diameter or width

of the mold and at least 75 mm (3 in.) longer than the section being vibrated.

- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Trowel or float
- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb.).
- Rigid base plates and cover plates: may be metal, glass, or plywood.
- Initial curing facilities: Temperature controlled curing box or enclosure capable of maintaining the required range of 16 to 27°C (60 to 80°F) during the entire initial curing period (for concrete with compressive strength of 40 Mpa (6000 psi) or more, the temperature shall be 20 to 26°C (68 to 78ºF). As an alternative, sand or earth for initial cylinder protection may be used provided that the required temperature range is maintained, and the specimens are not damaged.
- Thermometer: Capable of registering both maximum and minimum temperatures during the initial cure meeting the requirements for FOP for AASHTO T 309.

Consolidation Selection

11 There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 25 mm (1 in.), consolidation may be by rodding or vibration. When the slump is 25 mm (1 in.) or less, consolidate the sample by internal vibration. Agency specifications may dictate when rodding or vibration will be used.

Procedure – Molding Specimens

12 1. Obtain the sample according to the FOP for WAQTC TM 2.
2. Wet Sieving per the FOP for WAQTC TM 2 is required for 150 mm (6 in.) diameter specimens containing aggregate with a nominal maximum

size greater than 50 mm (2 in.); screen the sample over the 50 (2 in.) mm sieve.

13
3. Remix the sample after transporting to testing location.
4. Begin making specimens within 15 minutes of obtaining the sample.
5. Set molds upright on a level, rigid base in a location free from vibration and relatively close to where they will be stored.
6. Fill molds in the required number of layers, overfilling the mold on the final layer.

Casting Cylinders

Rodding

1. For the standard 150 mm (6 in.) by 300 mm (12 in.) specimen, fill each mold in three approximately equal layers, moving the scoop or trowel around the perimeter of the mold to
14 evenly distribute the concrete. For the 100 mm (4 in.) by 200 mm (8 in.) specimen, fill the mold in two layers. When filling the final layer, slightly overfill the mold.

Consolidation of concrete in cylinder by rodding

15
2. Consolidate each layer with 25 strokes of the appropriate tamping rod, using the rounded end. Distribute strokes evenly over the cross section of the concrete. Rod the first layer throughout its depth without forcibly hitting the bottom. For subsequent layers, rod the layer throughout
16 its depth penetrating approximately 25 mm (1 in.) into the underlying layer.
3. After rodding each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Internal Vibration

17 1. Fill the mold in two layers.

2. Insert the vibrator at the required number of
different points for each layer (two points for
150 mm (6 in.) diameter cylinders; one point for
100 mm (4 in.) diameter cylinders). When
18 vibrating the bottom layer, do not let the
vibrator touch the bottom or sides of the mold.
When vibrating the top layer, penetrate into the
underlying layer approximately 25 mm (1 in.).

19 3. Remove the vibrator slowly, so that no large air pockets are left in the material.

Note1: Continue vibration only long enough to achieve proper consolidation of the concrete. Over-vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

4. After vibrating each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
5. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
6. Immediately begin initial curing.

20 Self-Consolidating Concrete

1. Use the scoop to slightly overfill the mold. Evenly distribute the concrete in a circular motion around the inner perimeter of the mold.
2. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
3. Immediately begin initial curing

Casting Flexural Beams

21 Rodding

1. Fill the mold in two approximately equal layers with the second layer slightly overfilling the mold.

22 2. Consolidate each layer with the tamping rod once for every 1300 mm^2 (2 in^2) using the rounded end. Rod each layer throughout its depth taking care to not forcibly strike the bottom of the mold when compacting the first

layer. Rod the second layer throughout its depth, penetrating approximately 25 mm (1 in.) into the lower layer.

3. After rodding each layer, strike the mold 10 to 15 times with the mallet and spade along the sides and end using a trowel.
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Internal Vibration

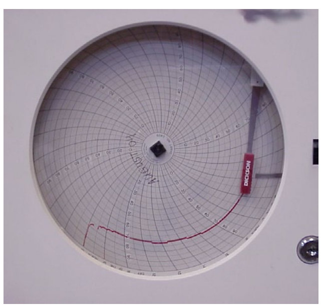
Making Beams
Internal Vibration

23 1. Fill the mold to overflowing in one layer.

2. Consolidate the concrete by inserting the vibrator vertically along the centerline at
24 intervals not exceeding 150 mm (6 in.). Take care to not over vibrate and withdraw the vibrator slowly to avoid large voids. Do not contact the bottom or sides of the mold with the vibrator.

25 3. After vibrating, strike the mold 10 to 15 times with the mallet.

4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.



Recording Thermometer

26
Initial Curing

27 • When moving cylinder specimens made with single use molds, support the bottom of the mold with trowel, hand or other device.

• For initial curing of cylinders, there are two methods, use of which depends on the agency.
28 In both methods, the curing place must be firm, within ¼ in. of a level surface, and free from vibrations or other disturbances.

• Maintain initial curing temperature:

Thermostatically Controlled
Cure Box

29 - 16 to 27°C (60 to 80°F) for concrete with
30 design strength up to 40 Mpa (6000 psi).

- 20 to 26°C (68 to 78°F) for concrete with design strength of 40 Mpa (6000 psi) or more.

- Prevent loss of moisture.

Burial in sand

Method 1 – Initial cure in a temperature-controlled chest-type curing box

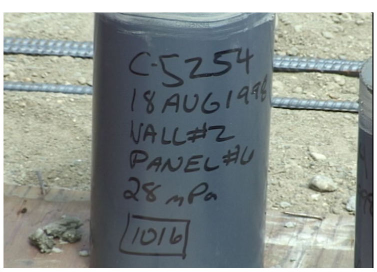
1. Finish the cylinder using the tamping rod, straightedge, float, or trowel. The finished
31 surface shall be flat with no projections or depressions greater than 3.2 mm (1/8 in.).
2. Place the mold in the curing box. When lifting light-gauge molds be careful to avoid distortion (support the bottom, avoid squeezing the sides).
3. Place the lid on the mold to prevent moisture loss.
4. Mark the necessary identification data on the
32 cylinder mold and lid.

Under cure box

Method 2 – Initial cure by burying in earth or by
33 **using a curing box over the cylinder**

34 *Note 2:* This procedure may not be the preferred method of initial curing due to problems in maintaining the required range of temperature.

1. Move the cylinder with excess concrete to the initial curing location.
2. Mark the necessary identification data on the cylinder mold and lid.
3. Place the cylinder on level sand or earth, or on a board, and pile sand or earth around the cylinder to within 50 mm (2 in.) of the top.
4. Finish the cylinder using the tamping rod, straightedge, float, or trowel. Use a sawing
35 motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (1/8 in.).
5. If required by the agency, place a cover plate on top of the cylinder and leave it in place for the duration of the curing period, or place the lid on the mold to prevent moisture loss.



Specimen identification

36

Transporting Specimens

- Initially cure the specimens for 24 to 48 hours. Transport specimens to the laboratory for final cure. Specimen identity will be noted along with the date and time the specimen was made and the maximum and minimum temperatures registered during the initial cure.
- Protect specimens from jarring, extreme changes in temperature, freezing, or moisture loss during transport.
- Secure cylinders so that the axis is vertical.
- Do not exceed 4 hours transportation time.

Final Curing

- Upon receiving cylinders at the laboratory, remove the cylinder from the mold and apply
37 the appropriate identification.
- For all specimens (cylinders or beams), final curing must be started within 30 minutes of mold removal. Temperature shall be maintained at 23° ±2°C (73º ±3°F) Free moisture must be present on the surfaces of the specimens during the entire curing period. Curing may be accomplished in a moist room or water tank conforming to M 201.
- For cylinders, during the final 3 hours before testing the temperature requirement may be waived, but free moisture must be maintained on specimen surfaces at all times until tested and ambient temperature is between 20 to 30°C (68 to 80°F).
- Final curing of beams must include immersion in lime-saturated water for at least 20 hours before testing.

Report

38

- On forms approved by the agency
- Placement information for identification of project, element(s) represented, etc.
- Sample ID

- Date molded and time molded
- Test ages
- Slump, air content and density
- Temperature (concrete, initial cure max. and min., and ambient)
- Method of initial curing
- Other information as required by agency, such as: concrete supplier, truck number, invoice number, water added, etc.

Tips!

- Start within 15 minutes of obtaining sample. 39
- Use hand, for tapping single-use, light-gauge molds.
- Consolidation technique depends on the slump. Rodding and/or vibration may be appropriate for different slumps.
- Protect specimens from damage during transport and keep cylinders vertical.

REVIEW QUESTIONS

1. The FOP for AASHTO R 100 gives standardized procedures for __________, ____________, and ______________ of test specimens.

2. Describe two methods for initially curing test specimens.

3. When consolidating a flexural strength test specimen by rodding, rod one stroke for each ______ of top surface area.

4. Describe the process for making flexural beam specimens using internal vibration. What precautions must be taken?

5. During transportation, what must be done to protect test specimens?

PERFORMANCE EXAM CHECKLIST

MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD FOP FOR AASHTO R 100 (4 X 8)

Participant Name ________________________________ Exam Date _______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Molds placed on a level, rigid, horizontal surface free of vibration?	_____	_____
2. Representative sample selected?	_____	_____
3. Making of specimens begun within 15 minutes of sampling?	_____	_____
First layer		
4. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____
5. Mold filled approximately half full?	_____	_____
6. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
7. Sides of the mold tapped 10-15 times after rodding?		
a. With mallet for reusable steel molds	_____	_____
b. With the open hand for flexible light-gauge molds	_____	_____
Second layer		
8. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____
9. Mold slightly overfilled on the last layer?	_____	_____
10. Layer rodded 25 times with hemispherical end of rod, uniformly distributing strokes and penetrating 25 mm (1 in.) into the underlying layer?	_____	_____
11. Sides of the mold tapped 10-15 times after rodding each layer?		
a. With mallet for reusable steel molds	_____	_____
b. With the open hand for flexible light-gauge molds	_____	_____
12. Concrete struck off with tamping rod, float or trowel?	_____	_____
13. Specimens covered with non-absorptive, non-reactive cap or plate?	_____	_____
14. Initial curing addressed?	_____	_____

OVER

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass______Fail_____

Examiner Signature _______________________________WAQTC #_______________

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PERFORMANCE EXAM CHECKLIST

MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD FOP FOR AASHTO R 100 (6 X 12)

Participant Name ______________________________ Exam Date ______________

Record the symbols “P” for passing or “F” for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Molds placed on a level, rigid, horizontal surface free of vibration?	_____	_____
2. Representative sample selected?	_____	_____
3. Making of specimens begun within 15 minutes of sampling?	_____	_____
First layer		
4. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____
5. Mold filled approximately one third full?	_____	_____
6. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
7. Sides of the mold tapped 10-15 times after rodding each layer?		
a. With mallet for reusable steel molds	_____	_____
b. With the open hand for flexible light-gauge molds	_____	_____
Second layer		
8. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____
9. Mold filled approximately two thirds full?	_____	_____
10. Layer rodded 25 times with hemispherical end of rod, uniformly distributing strokes and penetrating 25 mm (1 in.) into the underlying layer?	_____	_____
11. Sides of the mold tapped 10-15 times after rodding?		
a. With mallet for reusable steel molds	_____	_____
b. With the open hand for flexible light-gauge molds	_____	_____
Third layer		
12. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____

OVER

Procedure Element	Trial 1	Trial 2
13. Mold slightly overfilled on the last layer?	_____	_____
14. Layer rodded 25 times with hemispherical end of rod, uniformly distributing strokes and penetrating 25 mm (1 in.) into the underlying layer?	_____	_____
15. Sides of the mold tapped 10-15 times after rodding?		
a. With mallet for reusable steel molds	_____	_____
b. With the open hand for flexible light-gauge molds	_____	_____
16. Concrete struck off with tamping rod, straightedge, float, or trowel?	_____	_____
17. Specimens covered with non-absorptive, non-reactive cap or plate?	_____	_____
18. Initial curing addressed?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

____

____

____

____

Examiner Signature _______________________________WAQTC #:_______________

This checklist is derived, in part, from copyrighted material printed in ACI CP-1, published by the American Concrete Institute.

APPENDIX A
FIELD OPERATING PROCEDURES – SHORT FORM

SAMPLING FRESHLY MIXED CONCRETE
WAQTC TM 2

Scope

This practice covers procedures for obtaining representative samples of fresh concrete delivered to the project site. The practice includes sampling from stationary, paving and truck mixers, and from agitating and non-agitating equipment used to transport central mixed concrete.

This practice also covers the removal of large aggregate particles by wet sieving.

Sampling concrete may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Receptacle: wheelbarrow, bucket or other suitable container that does not alter the properties of the material being sampled
- Sample cover (plastic, canvas, or burlap)
- Shovel
- Cleaning equipment, including scrub brush, rubber gloves, water
- Apparatus for wet sieving, including: a sieve(s), meeting the requirements of FOP for AASHTO T 27/T 11, minimum of 2 ft^2 (0.19 m^2) of sieving area, conveniently arranged and supported so that the sieve can be shaken rapidly by hand.

Procedure

1. Use every precaution in order to obtain samples representative of the true nature and condition of the concrete being placed being careful not to obtain samples from the very first or very last portions of the batch. The size of the sample will be 1.5 times the volume of concrete required for the specified testing, but not less than 0.03 m^3 (1 ft^3).
2. Dampen the surface of the receptacle just before sampling, empty any excess water.

Note 1: Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as at the discharge of a concrete pump.

3. Use one of the following methods to obtain the sample:

   - **Sampling from stationary mixers**

     Obtain the sample after a minimum of 1/2 m^3 (1/2 yd^3) of concrete has been discharged. Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a receptacle. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and non-tilting mixers.

   - **Sampling from paving mixers**

     Obtain the sample after the contents of the paving mixer have been discharged. Obtain increments from at least five different locations in the pile and combine into one test sample. Avoid contamination with subgrade material or prolonged contact with absorptive subgrade. To preclude contamination or absorption by the subgrade, the concrete may be sampled by placing a shallow container on the subgrade and discharging the concrete across the container.

   - **Sampling from revolving drum truck mixers or agitators**

     Obtain the sample after a minimum of 1/2 m^3 (1/2 yd^3) of concrete has been discharged. Obtain sample after all of the water has been added to the mixer. Do not obtain sample from the very first or last portions of the batch discharge. Perform sampling by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a receptacle. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

   - **Sampling from open-top truck mixers, agitators, non-agitating equipment, or other types of open-top containers**

     Obtain the sample by whichever of the procedures described above is most applicable under the given conditions.

   - **Sampling from pump or conveyor placement systems**

     Obtain sample after a minimum of 1/2 m^3 (1/2 yd^3) of concrete has been discharged. Obtain sample after all of the pump slurry has been eliminated. Perform sampling by repeatedly passing a receptacle through the entire discharge system or by completely diverting the discharge into a receptacle. Do not lower the pump arm from the placement position to ground level for ease of sampling, as it may modify the air content of the concrete being sampled. Do not obtain samples from the very first or last portions of the batch discharge.

4. Transport sample to the testing location.

5. Remix with a shovel the minimum amount necessary to ensure uniformity. Protect the sample from direct sunlight, wind, rain, and sources of contamination.

6. Complete test for temperature and start tests for slump and air content within 5 minutes of obtaining the sample. Start molding specimens for strength tests within 15 minutes of obtaining the sample. Complete the test methods as expeditiously as possible.

Wet Sieving

When required due to oversize aggregate, the concrete sample shall be wet sieved, after transporting but prior to remixing, for slump testing, air content testing or molding test specimens, by the following:

1. Place the sieve designated by the test procedure over the dampened receptacle.
2. Pass the concrete over the designated sieve. Do not overload the sieve (one particle thick).
3. Shake or vibrate the sieve until no more material passes the sieve. A horizontal back and forth motion is preferred.
4. Discard oversize material including all adherent mortar.
5. Repeat until sample of sufficient size is obtained. Mortar adhering to the wet-sieving equipment shall be included with the sample.
6. Using a shovel, remix the sample the minimum amount necessary to ensure uniformity.

Note 2: Wet sieving is not allowed for samples being used for density determinations according to the FOP for AASHTO T 121.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

TEMPERATURE OF FRESHLY MIXED PORTLAND CEMENT CONCRETE FOP FOR AASHTO T 309

Scope

This procedure covers the determination of the temperature of freshly mixed Portland Cement Concrete in accordance with AASHTO T 309-22.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Container: Made of non-absorptive material and large enough to cover the sensor with concrete at least 75 mm (3 in.) in all directions; concrete cover must also be a least three times the nominal maximum size of the coarse aggregate.
- Thermometer: Capable of measuring the temperature of the concrete throughout the temperature range likely to be encountered, at least –18 to 50°C (0 to 120°F), and readable to ±0.5°C (±1°F) or smaller.

Note 1: Thermometer types suitable for use include ASTM E1 mercury thermometer or ASTM E2251 Low Hazard Precision Liquid-in-glass thermometer; ASTM E2877 digital metal stem thermometer; or thermocouple thermometer ASTM E230, Type T Special or IEC 60584 Type T, Class 1.

Standardization of Thermometer

Each thermometer shall be verified for accuracy annually and whenever there is a question of accuracy. Standardization shall be performed by comparing readings on the thermometer with another calibrated thermometer at two temperatures at least 15°C or 27°F apart.

Sample Locations and Times

The temperature of freshly mixed concrete may be measured in the transporting equipment, in forms, or in sample containers, provided the sensor of the thermometer has at least 75 mm (3 in.) of concrete cover in all direction around it.

Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.

Procedure

1. Dampen the sample container.
2. Obtain the sample in accordance with the FOP for WAQTC TM 2.
3. Place sensor of the thermometer in the freshly mixed concrete so that it has at least 75 mm (3 in.) of concrete cover in all directions around it.
4. Gently press the concrete in around the sensor of the thermometer at the surface of the concrete so that air cannot reach the sensor.
5. Leave the sensor of the thermometer in the freshly mixed concrete for a minimum of two minutes, or until the temperature reading stabilizes.
6. Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.
7. Read and record the temperature to the nearest 0.5°C (1°F).

Report

- Results on forms approved by the agency
- Sample ID
- Measured temperature of the freshly mixed concrete to the nearest 0.5°C (1°F)

.

SLUMP OF HYDRAULIC CEMENT CONCRETE
FOP FOR AASHTO T 119

Scope

This procedure provides instructions for determining the slump of hydraulic cement concrete in accordance with AASHTO T 119-23. It is not applicable to non-plastic and non-cohesive concrete.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Mold: conforming to AASHTO T 119
  - Metal: a metal frustum of a cone provided with foot pieces and handles. The mold must be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections such as protruding rivets. The mold shall be free from dents, deformations, and adhered mortar. A mold that clamps to a rigid nonabsorbent base plate is acceptable provided the clamping arrangement is such that it can be fully released without movement of the mold.
  - Non-metal: see AASHTO T 119, Section 5.1.2.
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means “half a sphere”; the tip is rounded like half of a ball.)
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Tape measure or ruler with at least 5 mm or 1/8 in. graduations
- Base: flat, rigid, non-absorbent moistened surface on which to set the slump mold

Procedure

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If the concrete mixture contains aggregate retained on the 37.5mm (1½ in.) sieve, the aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

   Begin testing within five minutes of obtaining the sample.
2. Dampen the inside of the mold and place it on a dampened, rigid, nonabsorbent surface that is level and firm.
3. Stand on both foot pieces to hold the mold firmly in place.
4. Use the scoop to fill the mold 1/3 full by volume, to a depth of approximately 67 mm (2 5/8 in.).
5. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Rod the bottom layer throughout its depth. Distribute the strokes evenly over the entire cross section of the concrete.

For the bottom layer, incline the rod slightly and make approximately half the strokes near the perimeter, and then progress with vertical strokes, spiraling toward the center.

6. Use the scoop to fill the mold 2/3 full by volume, to a depth of approximately 155 mm (6 1/8 in.).
7. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in.) into the bottom layer. Distribute the strokes evenly.
8. Use the scoop to fill the mold to overflowing.
9. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in.) into the second layer. Distribute the strokes evenly. If the concrete falls below the top of the mold, stop, add more concrete, and continue rodding for a total of 25 strokes. Always keep an excess of concrete above the top of the mold. Distribute strokes evenly.
10. Strike off the top surface of concrete with a screeding and rolling motion of the tamping rod.
11. Clean overflow concrete away from the base of the mold.
12. Remove the mold from the concrete by raising it carefully in a vertical direction. Raise the mold 300 mm (12 in.) in 5 ±2 seconds by a steady upward lift with no lateral or torsional (twisting) motion being imparted to the concrete.

    Complete the entire operation from the start of the filling through removal of the mold without interruption within an elapsed time of 2 1/2 minutes.
13. Immediately measure the slump:
    a. Invert the slump mold and set it next to the specimen.
    b. Lay the tamping rod across the mold so that it is over the test specimen.
    c. Measure the distance between the bottom of the rod and the displaced original center of the top of the specimen to the nearest 5 mm (1/4 in.).
    d. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and perform a new test on another portion of the sample.

Note 1: If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks the plasticity and cohesiveness necessary for the slump test to be applicable.

14. Discard the tested sample.

Report

- Results on forms approved by the agency
- Sample ID
- Slump to the nearest 5 mm (1/4 in.).

DENSITY (UNIT WEIGHT), YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE
FOP FOR AASHTO T 121

Scope

This method covers the determination of density, or unit weight, of freshly mixed concrete in accordance with AASHTO T 121-23. It also provides formulas for calculating the volume of concrete produced from a mixture of known quantities of component materials and provides a method for calculating cement content and cementitious material content – the mass of cement or cementitious material per unit volume of concrete. A procedure for calculating water/cement ratio is also covered.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Measure: May be the bowl portion of the air meter used for determining air content under the FOP for AASHTO T 152. Otherwise, it shall be a cylindrical metal container meeting the requirements of AASHTO T 121. The capacity and dimensions of the measure shall conform to those specified in Table 1.
- Balance or scale: Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) longer than the depth of the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in.).
- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb) for use with measures of 14 L (1/2 ft^3) or less or having a mass of 1.02 ±0.23 kg (2.25 ±0.5 lb) for use with measures larger than 14 L (0.5 ft^3).

Table 1
Dimensions of Measures*

Capacity m^3 (ft^3)	Inside Diameter mm (in.)	Inside Height mm (in.)	Minimum Thicknesses mm (in.) Bottom	Minimum Thicknesses mm (in.) Wall	Nominal Maximum Size of Coarse Aggregate*** mm (in.)
0.0071	203 ±2.54	213 ±2.54	5.1	3.0	25
(1/4)**	(8.0 ±0.1)	(8.4 ±0.1)	(0.20)	(0.12)	(1)
0.0142	254 ±2.54	279 ±2.54	5.1	3.0	50
(1/2)	(10.0 ±0.1)	(11.0 ±0.1)	(0.20)	(0.12)	(2)

* ***Note 1:*** The indicated size of measure shall be for aggregates of nominal maximum size equal to or smaller than that listed.

** Measure may be the base of the air meter used in the FOP for AASHTO T 152.

*** Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Consolidation Selection

There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 75 mm (3 in.), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in.), internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency to obtain consistent, comparable results. For concrete with slump less than 25 mm (1 in.), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

When using measures greater than 0.0142 m^3 (1/2 ft^3), see AASHTO T 121.

Procedure

Sampling

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. Testing may be performed in conjunction with the FOP for AASHTO T 152. When doing so, this FOP should be performed before the FOP for AASHTO T 152.

   Note 2: If the two tests are being performed using the same sample, this test shall begin within five minutes of obtaining the sample.

Rodding

1. Dampen the inside of the measure and empty excess water.
2. Determine and record the mass of the measure.
3. Use the scoop to fill the measure approximately 1/3 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

4. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.
5. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.
6. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.
8. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
9. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
10. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
11. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
12. Continue with 'Strike-off and Determining Mass.'

Internal Vibration

1. Dampen the inside of the measure and empty excess water.
2. Determine and record the mass of the measure.
3. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Insert the vibrator at three different points in each layer. Do not let the vibrator touch the bottom or side of the measure. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
5. Slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Insert the vibrator at three different points, penetrating the first layer approximately 25 mm (1 in.). Do not let the vibrator touch the side of the measure.
7. Continue with 'Strike-off and Determining Mass.'

Self-Consolidating Concrete

1. Dampen the inside of the measure and empty excess water.
2. Determine and record the mass of the measure.
3. Use the scoop to slightly overfill the measure. Do not exceed 125 mm (5 in.) drop height. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

5. Continue with 'Strike-off and Determining Mass.'

Strike-off and Determining Mass

1. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
2. Press the strike-off plate flat against the top surface, covering approximately 2/3 of the measure.
3. Withdraw the strike-off plate with a sawing motion to finish the 2/3 originally covered.
4. Cover the original 2/3 again with the plate; finishing the remaining 1/3 with a sawing motion (do not lift the plate; continue the sawing motion until the plate has cleared the surface of the measure).
5. Finish the surface with the inclined edge of the strike-off plate. The surface should be smooth and free of voids.
6. Clean off all excess concrete from the exterior of the measure including the rim.
7. Determine and record the mass of the measure and the concrete.
8. If the air content of the concrete is to be determined, ensure the rim (flange) is clean and proceed to 'Strike-off and Air Content' Step 3 of the FOP for AASHTO T 152.

Calculations

Mass of concrete in the measure

$$concrete\ mass = M_c - M_m$$

Where:

Concrete mass	=	mass of concrete in measure
M_c	=	mass of measure and concrete
M_m	=	mass of measure

Density

$$\rho = \frac{concrete\ mass}{V_m}$$

Where:

ρ	=	density of the concrete mix
V_m	=	volume of measure (Annex)

Yield m^3

$$Y_{m^3} = \frac{W}{\rho}$$

Where:

$Y_m{}^3$	=	yield (m^3 of the batch of concrete)
W	=	total mass of the batch of concrete

Yield yd^3

$$Y_{ft^3} = \frac{W}{\rho} \qquad\qquad Y_{yd^3} = \frac{Y_{ft^3}}{27ft^3/yd^3}$$

Where:

Y_{ft}^3	=	yield (ft^3 of the batch of concrete)
Y_{yd}^3	=	yield (yd^3 of the batch of concrete)
W	=	total mass of the batch of concrete
ρ	=	density of the concrete mix

Note 5: The total mass, W, includes the masses of the cement, water, and aggregates in the concrete.

Cement Content

$$N = \frac{N_t}{Y}$$

Where:

N	=	actual cementitous material content per Y_m^3 or Y_{yd}^3
N_t	=	mass of cementitious material in the batch
Y	=	Y_m^3 or Y_{yd}^3

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Water Content

The mass of water in a batch of concrete is the sum of:

- water added at batch plant
- water added in transit
- water added at jobsite
- free water on coarse aggregate*
- free water on fine aggregate*
- liquid admixtures (if required by the agency)

*Mass of free water on aggregate

This information is obtained from concrete batch tickets collected from the driver. Use the Table 2 to convert liquid measures.

Table 2
Liquid Conversion Factors

To Convert From	To	Multiply By
Liters, L	Kilograms, kg	1.0
Gallons, gal	Kilograms, kg	3.785
Gallons, gal	Pounds, lb	8.34
Milliliters, mL	Kilograms, kg	0.001
Ounces, oz	Milliliters, mL	28.4
Ounces, oz	Kilograms, kg	0.0284
Ounces, oz	Pounds, lb	0.0625
Pounds, lb	Kilograms, kg	0.4536

Mass of free water on aggregate

$$Free\ Water\ Mass = CA\ or\ FC\ Aggregate - \frac{CA\ or\ FC\ Aggregate}{1 + (Free\ Water\ Percentage/100)}$$

Where:

Free Water Mass	=	on coarse or fine aggregate
FC or CA Aggregate	=	mass of coarse or fine aggregate
Free Water Percentage	=	percent of moisture of coarse or fine aggregate

Water/Cement Ratio

$$\frac{Water\ Content}{C}$$

Where:

Water Content	=	total mass of water in the batch
C	=	total mass of cementitious materials

Example

Mass of concrete in measure (M_m)	16.290 kg (36.06 lb)
Volume of measure (V_m)	0.007079 m^3 (0.2494 ft^3)

From batch ticket:

Yards batched	4 yd^3
Cement	950 kg (2094 lb)
Fly ash	180 kg (397 lb)
Coarse aggregate	3313 kg (7305 lb)
Fine aggregate	2339 kg (5156 lb)
Water added at plant	295 L (78 gal)

Other

Water added in transit	0
Water added at jobsite	38 L (10 gal)
Total mass of the batch of concrete (W)	7115 kg (15,686 lb)
Moisture content of coarse aggregate	1.7%
Moisture content of coarse aggregate	5.9%

Density

$$\rho = \frac{concrete\ mass}{V_m}$$

$$\rho = \frac{16.920\ kg}{0.007079\ m^3} = 2390\ \ kg/m^3 \quad \rho = \frac{36.06\ lb}{0.2494\ ft^3} = 144.6\ \ lb/ft^3$$

Given:

concrete mass = 16.920 kg (36.06 lb)

V_m = 0.007079 m^3 (0.2494 ft^3) (Annex)

Yield m^3

$$Y_{m^3} = \frac{W}{\rho}$$

$$Y_{m^3} = \frac{7115\ kg}{2390\ kg/m^3} = 2.98\ m^3$$

Given:

Total mass of the batch of concrete (W), kg = 7115 kg

Yield yd³

$$Y_{ft^3} = \frac{W}{\rho} \qquad Y_{yd^3} = \frac{Y_{ft^3}}{27 ft^3/yd^3}$$

$$Y_{ft^3} = \frac{15{,}686\ lb}{144.6\ lb/ft^3} = 108.48\ ft^3 \qquad Y_{yd^3} = \frac{108.48\ ft^3}{27\ ft^3/yd^3} = 4.02\ yd^3$$

Given:

Total mass of the batch of concrete (W), lb = 15,686 lb

Cement Content

$$N = \frac{N_t}{Y}$$

$$N = \frac{950\ kg + 180\ kg}{2.98\ m^3} = 379\ kg/m^3 \quad N = \frac{2094\ lb + 397\ lb}{4.02\ yd^3} = 620\ lb/yd^3$$

Given:

N_t (cement)	=	950 kg (2094 lb)
N_t (flyash)	=	180 kg (397 lb)
Y	=	Y_{m^3} or Y_{yd^3}

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Free water

$$Free\ Water\ Mass = CA\ or\ FC\ Aggregate - \frac{CA\ or\ FC\ Aggregate}{1 + (Free\ Water\ Percentage/100)}$$

$$CA\ Free\ Water = 3313\ kg - \frac{3313\ kg}{1 + (1.7/100)} = 55\ kg$$

$$CA\ Free\ Water = 7305\ lb - \frac{7305\ lb}{1 + (1.7/100)} = 122\ lb$$

$$FA\ Free\ Water = 2339\ kg - \frac{2339\ kg}{1 + (5.9/100)} = 130\ kg$$

$$FA\ Free\ Water = 5156\ lb - \frac{5156\ lb}{1 + (5.9/100)} = 287\ lb$$

Given:

CA aggregate	=	3313 kg (7305 lb)
FC aggregate	=	2339 kg (5156 lb)
CA moisture content	=	1.7%
FC moisture content	=	5.9%

Water Content

Total of all water in the mix.

$$Water\ Content = [(78\ gal + 10\ gal) * 3.785\ kg/gal] + 55\ kg + 130\ kg = 518\ kg$$

$$Water\ Content = [(78\ gal + 10\ gal) * 8.34\ lb/gal] + 122\ lb + 287\ lb = 1143\ lb$$

Given:

Water added at plant	=	295 L (78 gal)
Water added at the jobsite	=	38 L (10 gal)

Water/ Cement Ratio

$$W/C = \frac{518\ kg}{950\ kg + 180\ kg} = 0.458 \quad W/C = \frac{1143\ lb}{2094\ lb + 397\ lb} = 0.459$$

Report 0.46

Report

- Results on forms approved by the agency
- Sample ID
- Density (unit weight) to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Yield to the nearest 0.01 m^3 (0.01 yd^3)
- Cement content to the nearest 1 kg/m^3 (1 lb/yd^3)
- Cementitious material content to the nearest 1 kg/m^3 (1 lb/yd^3)
- Water/Cement ratio to the nearest 0.01

ANNEX – STANDARDIZATION OF MEASURE

(Mandatory Information)

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described herein will produce inaccurate or unreliable test results.

Apparatus

- Listed in the FOP for AASHTO T 121
    - Measure
    - Balance or scale
    - Strike-off plate
- Thermometer: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)

Procedure

1. Determine the mass of the dry measure and strike-off plate.
2. Fill the measure with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the strike-off plate in such a way as to eliminate bubbles and excess water.
3. Wipe the outside of the measure and cover plate dry, being careful not to lose any water from the measure.
4. Determine the mass of the measure, strike-off plate, and water in the measure.
5. Determine the mass of the water in the measure by subtracting the mass in Step 1 from the mass in Step 4.
6. Measure the temperature of the water and determine its density from Table A1, interpolating as necessary.
7. Calculate the volume of the measure, V_m, by dividing the mass of the water in the measure by the density of the water at the measured temperature.

Calculations

$$V_m = \frac{M}{\rho_w}$$

Where:

V_m	=	volume of the mold
M	=	mass of water in the mold
ρ_w	=	density of water at the measured temperature

Example

Mass of water in Measure	=	7.062 kg (15.53 lb)
Density of water at 23°C (73.4°F) (ρ_w)	=	997.54 kg/m^3 (62.274 lb/ft^3)

$$V_m = \frac{7.062\ kg}{997.54\ kg/m^3} = 0.007079\ m^3 \qquad V_m = \frac{15.53\ lb}{62.274\ lb/ft^3} = 0.2494\ ft^3$$

Table A1
Unit Mass of Water
15°C to 30°C

°C	(°F)	kg/m³	(lb/ft³)	°C	(°F)	kg/m³	(lb/ft³)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Report

- Measure ID
- Date Standardized
- Temperature of the water
- Volume, V_m, of the measure

AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD FOP FOR AASHTO T 152

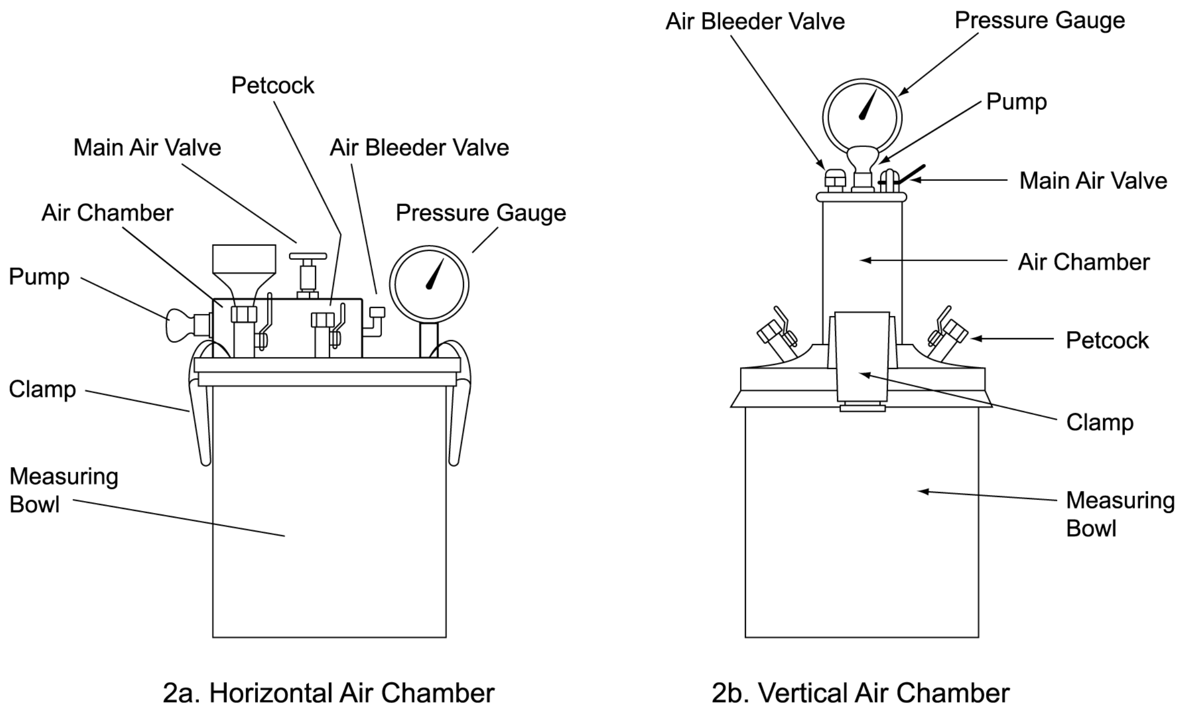
Scope

This procedure covers determination of the air content in freshly mixed Portland Cement Concrete containing dense aggregates in accordance with AASHTO T 152-23, Type B meter. It is not for use with lightweight or highly porous aggregates. This procedure includes standardization of the Type B air meter gauge, Annex.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Air meter: Type B, as described in AASHTO T 152



Type B Meter

- Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use (for Method 1 standardization only)
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means “half a sphere”; the tip is rounded like half of a ball.)

- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) than the depth of the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Container for water: rubber syringe or plastic wash bottle
- Strike-off bar: Approximately 300 mm x 22 mm x 3 mm (12 in. x 3/4 in. x 1/8 in.)
- Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in.).

  Note 1: Use either the strike-off bar or strike-off plate; both are not required.
- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb)

Consolidation Selection

There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 75 mm (3 in.), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in.), internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency to obtain consistent, comparable results. For concrete with slumps less than 25 mm (1 in.), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

Procedure

Sampling

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If the concrete mixture contains aggregate retained on the 37.5mm (1½ in.) sieve, the aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

   Testing shall begin within five minutes of obtaining the sample.

Rodding

1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to fill the measure approximately 1/3 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.
4. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.

5. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.
7. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
8. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
9. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
10. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
11. Continue with 'Strike-off and Air Content.'

Internal Vibration

1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Insert the vibrator at three different points. Do not let the vibrator touch the bottom or side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
4. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
5. Use the scoop to fill the measure a bit over full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Insert the vibrator at three different points, penetrating the first layer approximately 25 mm (1 in.). Do not let the vibrator touch the side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
7. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
8. Continue with 'Strike-off and Air Content.'

Self-Consolidating Concrete

1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Continue with 'Strike-off and Air Content.'

Strike-Off and Air Content

1. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the trowel or scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
2. Strike off the surface of the concrete and finish it smoothly with a sawing action of the strike-off bar or inclined plate, using great care to leave the measure just full. The surface should be smooth and free of voids.
3. Clean the top flange of the measure to ensure a proper seal.
4. Moisten the inside of the cover and check to see that both petcocks are open, and the main air valve is closed.
5. Clamp the cover on the measure.
6. Inject water through a petcock on the cover until water emerges from the petcock on the opposite side. Jar the meter gently until all air is expelled from this same petcock.
7. Verify that water is present in both petcocks.
8. Close the air bleeder valve and pump air into the air chamber until the needle goes past the initial pressure determined for the gauge. Allow a few seconds for the compressed air to cool.
9. Tap the gauge gently with one hand while slowly opening the air bleeder valve until the needle rests on the initial pressure. Close the air bleeder valve.
10. Close both petcocks.
11. Open the main air valve.
12. Tap the side of the measure smartly with the mallet.
13. With the main air valve open, lightly tap the gauge to settle the needle, and then read the air content to the nearest 0.1 percent.
14. Release or close the main air valve.
15. Open both petcocks to release pressure, remove the concrete, and thoroughly clean the cover and measure with clean water.
16. Open the main air valve to relieve the pressure in the air chamber.

Report

- On forms approved by the agency
- Sample ID
- Percent of air to the nearest 0.1 percent.
- Some agencies require an aggregate correction factor to determine total percent of entrained air.

  Total % entrained air = Gauge reading – aggregate correction factor from mix design

  (See AASHTO T 152 for more information.)

ANNEX
STANDARDIZATION OF AIR METER GAUGE

(Mandatory Information)

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described below will produce inaccurate or unreliable test results.

Standardization shall be performed at a minimum of once every three months. Record the date of the standardization, the standardization results, and the name of the technician performing the standardization in the logbook kept with each air meter.

There are two methods for standardizing the air meter, mass or volume, both are covered below.

1. Screw the short piece of straight tubing into the threaded petcock hole on the underside of the cover.
2. Determine and record the mass of the dry, empty air meter measure and cover assembly (mass method only).
3. Fill the measure nearly full with water.
4. Clamp the cover on the measure with the tube extending down into the water. Mark the petcock with the tube attached for future reference.
5. Add water through the petcock having the pipe extension below until all air is forced out the other petcock.
6. Wipe off the air meter measure and cover assembly; determine and record the mass of the filled unit (mass method only).
7. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
8. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle stabilizes. The gauge should now read 0 percent. If two or more tests show a consistent variation from 0 percent in the result, change the initial pressure line to compensate for the variation, and use the newly established initial pressure line for subsequent tests.
9. Determine which petcock has the straight tube attached to it. Attach the curved tube to external portion of the same petcock.
10. Pump air into the air chamber. Open the petcock with the curved tube attached to it. Open the main air valve for short periods of time until 5 percent of water by mass or volume has been removed from the air meter. Remember to open both petcocks to release the pressure in the measure and drain the water in the curved tube back into the measure. To determine the mass of the water to be removed, subtract the mass found in Step 2 from the mass found in Step 6. Multiply this value by 0.05. This is the mass of the water that must be removed. To remove 5 percent by volume, remove water until the external standardization vessel is level full.

Note A1: Many air meters are supplied with a standardization vessel(s) of known volume that are used for this purpose. Standardization vessel must be protected from crushing or denting. If an external standardization vessel is used, confirm what percentage volume it represents for the air meter being used. Vessels commonly represent 5 percent volume, but they are for specific size meters. This should be confirmed by mass.

11. Remove the curved tube. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
12. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle is stabilized. The gauge should now read 5.0 ±0.1 percent. If the gauge is outside that range, the meter needs adjustment. The adjustment could involve adjusting the starting point so that the gauge reads 5.0 ±0.1 percent when this standardization is run or could involve moving the gauge needle to read 5.0 percent. Any adjustment should comply with the manufacturer’s recommendations.
13. When the gauge hand reads correctly at 5.0 percent, additional water may be withdrawn in the same manner to check the results at other values such as 10 percent or 15 percent.
14. If an internal standardization vessel is used, follow Steps 1 through 8 to set initial reading.
15. Release pressure from the measure and remove cover. Place the internal standardization vessel into the measure. This will displace 5 percent of the water in the measure. (See AASHTO T 152 for more information on internal standardization vessels.)
16. Place the cover back on the measure and add water through the petcock until all the air has been expelled.
17. Pump up the air pressure chamber to the initial pressure. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
18. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle stabilizes. The gauge should now read 5 percent.
19. Remove the extension tubing from threaded petcock hole in the underside of the cover before starting the test procedure.

Report

- Air meter ID
- Date standardized
- Initial pressure (IP)

METHOD OF MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD FOP FOR AASHTO R 100

Scope

This practice covers the method for making, initially curing, and transporting concrete test specimens in the field in accordance with AASHTO R 100-23.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Concrete cylinder molds: Conforming to AASHTO M 205 with a length equal to twice the diameter. Standard specimens shall be 150 mm (6 in.) by 300 mm (12 in.) cylinders. Mold diameter must be at least three times the maximum aggregate size unless wet sieving is conducted according to the FOP for WAQTC TM 2. Agency specifications may allow cylinder molds of 100 mm (4 in.) by 200 mm (8 in.) when the nominal maximum aggregate size does not exceed 25 mm (1 in.).
- Beam molds: Rectangular in shape with ends and sides at right angles to each other. Must be sufficiently rigid to resist warpage. Surfaces must be smooth. Molds shall produce length no more than 1.6 mm (1/16 in.) shorter than that required (greater length is allowed). Maximum variation from nominal cross section shall not exceed 3.2 mm (1/8 in.). Ratio of width to depth may not exceed 1:5; the smaller dimension must be at least 3 times the maximum aggregate size. Standard beam molds shall result in specimens having width and depth of not less than 150 mm (6 in.). Agency specifications may allow beam molds of 100 mm (4 in.) by 100 mm (4 in.) when the nominal maximum aggregate size does not exceed 25 mm (1 in.). Specimens shall be cast and hardened with the long axes horizontal.
- Standard tamping rod: 16 mm (5/8 in.) in diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 150 mm (6 in.) x 300 mm (12 in.) cylinders.
- Small tamping rod: 10 mm (3/8 in.) diameter and 305 mm (12 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 100 mm (4 in.) x 200 mm (8 in.) cylinders.
- Vibrator: At least 9000 vibrations per minute, with a diameter no more than ¼ the diameter or width of the mold and at least 75 mm (3 in.) longer than the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Trowel or float
- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb.).

- Rigid base plates and cover plates: may be metal, glass, or plywood.
- Initial curing facilities: Temperature-controlled curing box or enclosure capable of maintaining the required range of 16 to 27°C (60 to 80°F) during the entire initial curing period (for concrete with compressive strength of 40 Mpa (6000 psi) or more, the temperature shall be 20 to 26°C (68 to 78°F). As an alternative, sand or earth for initial cylinder protection may be used provided that the required temperature range is maintained, and the specimens are not damaged.
- Thermometer: Capable of registering both maximum and minimum temperatures during the initial cure meeting the requirements for FOP for AASHTO T 309.

Consolidation Selection

There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 25 mm (1 in.), consolidation may be by rodding or vibration. When the slump is 25 mm (1 in.) or less, consolidate the sample by internal vibration. Agency specifications may dictate when rodding or vibration will be used.

Procedure

Molding Specimens – General

1. Obtain the sample according to the FOP for WAQTC TM 2.
2. Wet Sieving per the FOP for WAQTC TM 2 is required for 150 mm (6 in.) diameter specimens containing aggregate with a nominal maximum size greater than 50 mm (2 in.); screen the sample over the 50 mm (2 in.) sieve.
3. Remix the sample after transporting to testing location.
4. Begin making specimens within 15 minutes of obtaining the sample.
5. Set molds upright on a level, rigid base in a location free from vibration and relatively close to where they will be stored.
6. Fill molds in the required number of layers, overfilling the mold on the final layer.

Casting Cylinders

Rodding

1. For the standard 150 mm (6 in.) by 300 mm (12 in.) specimen, fill each mold in three approximately equal layers, moving the scoop or trowel around the perimeter of the mold to evenly distribute the concrete. For the 100 mm (4 in.) by 200 mm (8 in.) specimen, fill the mold in two layers. When filling the final layer, slightly overfill the mold.
2. Consolidate each layer with 25 strokes of the appropriate tamping rod, using the rounded end. Distribute strokes evenly over the cross section of the concrete. Rod the first layer throughout its depth without forcibly hitting the bottom. For subsequent layers, rod the layer throughout its depth penetrating approximately 25 mm (1 in.) into the underlying layer.

3. After rodding each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Internal Vibration

1. Fill the mold in two layers.
2. Insert the vibrator at the required number of different points for each layer (two points for 150 mm (6 in.) diameter cylinders; one point for 100 mm (4 in.) diameter cylinders). When vibrating the bottom layer, do not let the vibrator touch the bottom or sides of the mold. When vibrating the top layer, penetrate into the underlying layer approximately 25 mm (1 in.)
3. Remove the vibrator slowly, so that no large air pockets are left in the material.

Note 1: Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

4. After vibrating each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
5. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
6. Immediately begin initial curing.

Self-Consolidating Concrete

1. Use the scoop to slightly overfill the mold. Evenly distribute the concrete in a circular motion around the inner perimeter of the mold.
2. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
3. Immediately begin initial curing.

Casting Flexural Beams

Rodding

1. Fill the mold in two approximately equal layers with the second layer slightly overfilling the mold.
2. Consolidate each layer with the tamping rod once for every 1300 mm^2 (2 in^2) using the rounded end. Rod each layer throughout its depth, taking care to not forcibly strike the bottom of the mold when compacting the first layer. Rod the second layer throughout its depth, penetrating approximately 25 mm (1 in.) into the lower layer.
3. After rodding each layer, strike the mold 10 to 15 times with the mallet and spade along the sides and end using a trowel.
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Internal Vibration

1. Fill the mold to overflowing in one layer.
2. Consolidate the concrete by inserting the vibrator vertically along the centerline at intervals not exceeding 150 mm (6 in.). Take care to not over-vibrate and withdraw the vibrator slowly to avoid large voids. Do not contact the bottom or sides of the mold with the vibrator.
3. After vibrating, strike the mold 10 to 15 times with the mallet.
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Initial Curing

- When moving cylinder specimens made with single use molds support the bottom of the mold with trowel, hand, or other device.
- For initial curing of cylinders, there are two methods, use of which depends on the agency. In both methods, the curing place must be firm, within ¼ in. of a level surface, and free from vibrations or other disturbances.
- Maintain initial curing temperature:
- 16 to 27°C (60 to 80°F) for concrete with design strength up to 40 Mpa (6000 psi).
- 20 to 26°C (68 to 78°F) for concrete with design strength of 40 Mpa (6000 psi) or more.
- Prevent loss of moisture.

Method 1 – Initial cure in a temperature-controlled chest-type curing box

1. Finish the cylinder using the tamping rod, straightedge, float, or trowel. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (1/8 in.).
2. Place the mold in the curing box. When lifting light-gauge molds be careful to avoid distortion (support the bottom, avoid squeezing the sides).
3. Place the lid on the mold to prevent moisture loss.
4. Mark the necessary identification data on the cylinder mold and lid.

Method 2 – Initial cure by burying in earth or by using a curing box over the cylinder

Note 2: This procedure may not be the preferred method of initial curing due to problems in maintaining the required range of temperature.

1. Move the cylinder with excess concrete to the initial curing location.
2. Mark the necessary identification data on the cylinder mold and lid.
3. Place the cylinder on level sand or earth, or on a board, and pile sand or earth around the cylinder to within 50 mm (2 in.) of the top.

4. Finish the cylinder using the tamping rod, straightedge, float, or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (1/8 in.).
5. If required by the agency, place a cover plate on top of the cylinder and leave it in place for the duration of the curing period, or place the lid on the mold to prevent moisture loss.

Transporting Specimens

- Initially cure the specimens for 24 to 48 hours. Transport specimens to the laboratory for final cure. Specimen identity will be noted along with the date and time the specimen was made and the maximum and minimum temperatures registered during the initial cure.
- Protect specimens from jarring, extreme changes in temperature, freezing, or moisture loss during transport.
- Secure cylinders so that the axis is vertical.
- Do not exceed 4 hours transportation time.

Final Curing

- Upon receiving cylinders at the laboratory, remove the cylinder from the mold and apply the appropriate identification.
- For all specimens (cylinders or beams), final curing must be started within 30 minutes of mold removal. Temperature shall be maintained at 23° ±2°C (73 ±3°F). Free moisture must be present on the surfaces of the specimens during the entire curing period. Curing may be accomplished in a moist room or water tank conforming to AASHTO M 201.
- For cylinders, during the final 3 hours before testing the temperature requirement may be waived, but free moisture must be maintained on specimen surfaces at all times until tested and ambient temperature is between 20 to 30°C (68 to 80°F).
- Final curing of beams must include immersion in lime-saturated water for at least 20 hours before testing.

Report

- On forms approved by the agency
- Pertinent placement information for identification of project, element(s) represented, etc.
- Sample ID
- Date and time molded.
- Test ages.
- Slump, air content, and density.
- Temperature (concrete, initial cure max. and min., and ambient).
- Method of initial curing.
- Other information as required by agency, such as: concrete supplier, truck number, invoice number, water added, etc.