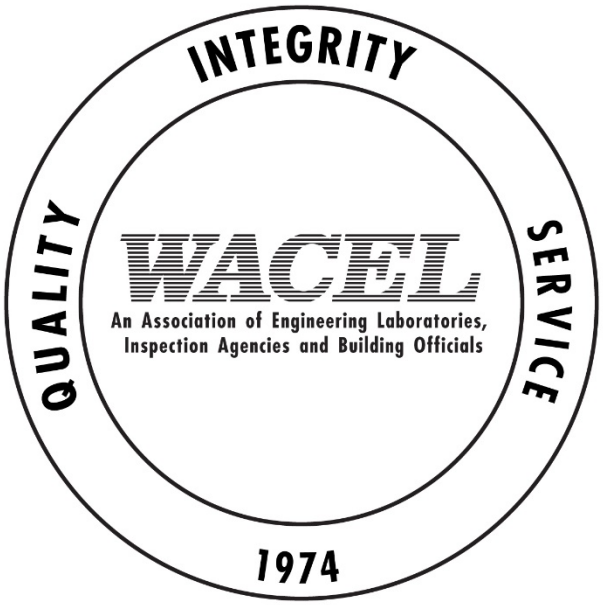

STUDY GUIDE
WACEL
CONCRETE I

May 2024

CONCRETE I
STUDY GUIDE

Scope:

A technician who successfully earns the WACEL Concrete I certification has demonstrated in writing and in practice his or her ability to conduct basic quality control testing for concrete. In addition, he or she will have a basic understanding of how concrete as a construction material works. This includes concrete materials, the hydration and strength-gain process, water-cementitious materials ratio, admixtures, air entrainment, and ready-mixed concrete specifications.

Examinations:

The Concrete I written examination is a 50 question, multiple-choice test, and is based on the following references. It will be 2 hours in length and is a closed–book examination. A grade of 75 percent or better is required for passing. A basic, non-recording calculator is authorized. Scratch paper will be provided, and it must be turned in at the completion of the examination. Mobile phones are not authorized.

In addition, the Concrete I technician candidate must successfully pass a practical examination that demonstrates his or her ability to properly conduct the following quality control tests: obtaining a composite sample, temperature, slump, density (unit weight), air content (pressure and volumetric method), and casting compressive strength cylinders. The practical examination is graded on a pass/fail basis.

Both written and the practical examinations must be successfully passed within 90 calendar days of each other for the Concrete I certification to be issued.

Required References:

A. ASTM C31-24, Making and Curing Concrete Test Specimens in the Field.
B. ASTM C94-24, Specifications for Ready-Mixed Concrete.
C. ASTM C138-23, Density (Unit Weight) of Concrete.
D. ASTM C143-20, Slump of Hydraulic Cement Concrete.
E. ASTM C172-17, Sampling Freshly – Mixed Concrete.
F. ASTM C173-23, Air Content of Freshly Mixed Concrete by the Volumetric Method.
G. ASTM C231-24, Air Content of Freshly Mixed Concrete by the Pressure Method.
H. ASTM C1064-23, Temperature of Freshly Mixed Portland Cement Concrete.
I. Design and Control of Concrete Mixtures, Portland Cement Association, 17th Edition, 2021 (Chapter 1).
J. A copy of this Study Guide.

Optional Reference:

K. Concrete Inspection Handbook, Fourth Edition, Portland Cement Association, 2005.

Learning Objectives:

I. Fundamentals of Concrete (ASTM C94 and "Design and Control of Concrete Mixtures")).

A. Knows that the basic ingredients used in making concrete are cement, water, coarse aggregate, and fine aggregate.

B. Has a basic understanding of the various quality indicators that can be used to evaluate either freshly mixed or hardened concrete with an emphasis on compressive strength.

C. Understand that hydration is a complex chemical process that produces heat.

D. Knows that for hydration or the strength gain of the concrete to be maximized, temperature, moisture, and vibrations must be controlled.

E. Understands the importance of the water-cement ratio in predicting the ultimate strength of the concrete.

1. Knows to sample after job-site water, if any, is added.

2. Is aware of the importance of reporting the amount of job-site water added.

3. Knows that the quantity of water added at the job site must be recorded.

F. Is familiar with the effects of and the reasons for the use of air-entraining admixtures.

1. Knows the expected range of air content in non-air entrained concrete will generally be less than 2 percent.

2. Knows that slump, temperature, and air content tests must be taken whenever compressive strength cylinders are prepared.

3. Is knowledgeable of the effects of air entrainment on increasing workability, decreasing bleeding, increasing freeze-thaw resistance, and decreasing compressive strength.

G. Understands the purpose and content of approved concrete mix designs and how to determine what approvals are required.

H. Knows what information is or should be available on the batch ticket with particular attention to project location, mix designations, and batch time.

1. Can demonstrate an ability to locate specified batch-to-placement time limitations.

2. Knows how to correctly compute batch-to-placement time.

3. Knows what to do if an unapproved mix designation is found on a batch ticket.

I. Is aware that best industry practice – and most referenced ASTMs – require that all test equipment and surfaces be dampened before they come in contact with fluid concrete with the exception of single-use, plastic cylinder molds.

II. Knows how to properly sample freshly mixed concrete (ASTM C172).

A. Understands the meaning of composite samples.

B. Knows how to determine the frequency and randomness of obtaining representative samples for testing.

C. Can properly obtain a composite sample from a ready-mix truck.

D. Understands why sampling is not started until job-site water and admixtures, if any, are added.

E. Knows the time limitations associated with sampling and testing as contained in ASTM C172.

F. Knows how to determine the size of the composite sample to be taken based on the required tests and the quantity of compressive strength cylinders to be made (minimum 1 cubic foot, if compressive strength cylinders are being made).

G. Knows how to protect the composite sample.

III. Can properly take concrete temperature (ASTM C1064).

A. Understands that temperature measuring devices require calibration at least annually.

B. Knows that the acceptable temperature ranges for freshly mixed concrete are defined by the American Concrete Institute, ASTM C94, and/or project specifications.

C. Is aware of the minimum concrete cover and time requirements when taking the temperature of concrete.

D. Knows that the temperature measuring device must be left in the fluid concrete for at least 2 minutes but not more than 5 minutes for an acceptable reading.

E. Knows to wait until temperature readings have stabilized before recording the result.

F. Knows the accuracy to which temperature readings are taken and recorded.

IV. Can properly perform a slump test (ASTM C143).

A. Understands the purpose of testing the slump of freshly-mixed concrete.

B. Knows where to find the allowable range of slump values for a particular type of concrete using project documents.

C. Knows what equipment is needed to properly conduct a slump test.

D. Can correctly follow the testing procedure prescribed in ASTM C143.

E. Knows how to properly measure the slump of concrete to include the required accuracy.

F. Knows what to do if the concrete subsides below the top of the mold while rodding the top layer.

G. Is aware of the time limitation for the conduct of this test.

V. Can properly test for concrete density (unit weight) (ASTM C138).

A. Is familiar with the differences between normal weight and lightweight concrete.

B. Knows what tools and equipment are required to properly conduct a density (unit weight) test.

C. Is aware of the calibration requirements for unit weight equipment.

D. Knows how to determine acceptable ranges of the density (unit weight) of fresh concrete using project documents.

E. Knows how to determine the correct size of container to use based on the nominal, maximum size of coarse aggregates (in particular for 1-inch and 2-inch coarse aggregate).

F. Can properly complete the specified steps in ASTM C138 to correctly conduct a unit density (unit weight) test.

G. Provided with the necessary test information, can correctly compute unit weight.

H. Knows the accuracy to which density (unit weight) results are reported.

I. Can compute the weight of a cubic yard of concrete given its density (unit weight).

VI. Can correctly test for air entrainment (Pressure Method: ASTM C231 and Volumetric Method: ASTM C173). (Type B meter only)

A. Pressure Method (ASTM C231) (Type B meter only).

1. Knows that testing for air by the Pressure Method can only be used for normal weight concrete.

2. Knows where to find acceptable range of air content values for the concrete being tested using project documents.

3. Can correctly follow the testing procedures prescribed in ASTM C231.

4. Understands what "Initial Pressure" is and how it is determined.

5. Knows the accuracy to which the air content is read.

6. Understands the reason for an "Aggregate Correction Factors"; how it is determined; and, if provided or computed, how it effects the recorded air content of the concrete being tested.

B. Volumetric Method (ASTM C173)

1. Knows the principle by which this test works and why it can be used for either lightweight or normal weight concrete.

2. Can correctly and completely follow the required testing procedures listed in ASTM C173.

3. Knows the accuracy to which the air content is read.

4. Knows that, even if provided, an Aggregate Correction Factor is not used to adjust the results of this test.

5. Knows that if after a maximum of three 1-minute rollings and readings that if two consecutive tests are not within 0.25 percent of each other, that the sample is discarded and a new test using a new sample and more alcohol is conducted.

VII. Can properly cast, store, and transport concrete cylinders (ASTM C31).

A. Knows the two standard cylinder mold sizes authorized by ASTM C31 and the limits on the nominal maximum coarse aggregate size for each.

B. Can determine how many test specimens are required for a given test. Knows how many are to be designated as field-cured and how many laboratory-cured using project documents.

C. Knows how to determine if a particular set of compressive strength test specimens are to be consolidated by rodding or vibration.

D. Knows the allowable range of temperatures for the initial curing of test specimens.

E. Knows how to properly prepare test specimens as prescribed in ASTM C31. This includes the procedural differences when using 6x12-inch molds or 4x8-inch molds.

F. Is aware of the criticality of properly marking test specimens so they can be traced to the concrete placement they represent.

G. Understands the reasons for and the handling differences between field-cured and laboratory-cured test specimens.

H. Knows the time limits for and the handling limitations for transportation of laboratory-cured specimens.

VIII. Can prepare thorough and legible field reports.

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(updated May 2024)

Name (Technician): _____ Date: _____

Office / Location: _____ Final Rating (P or F): _____

Head Evaluator: _____

ASTM C172-17 Sampling Freshly Mixed Concrete		**Pass**	**Fail**
1.	Familiar with necessary equipment to perform testing of fresh concrete. (wheelbarrow; bucket; brush/sponge; scoop; strike-off bar/plate; rods [3/8-inch & 5/8-inch dia.]; pressure air meter; volumetric air meter [with alcohol]; syringe; slump cone with flat, level, rigid, non-absorbent base; tape measure; cylinder molds & caps; calibrated concrete thermometer; rubber mallet; scale.		
2.	Knows that all equipment must be moistened (except cylinder molds) before contacting concrete.		
3.	Knows that 2 or more portions are necessary to obtain a representative sample.		
4.	Knows that the maximum time between obtaining first and final portion of sample is 15-minutes.		
5.	The different portions of the representative sample shall be mixed to make a composite sample before testing.		
6.	Familiar with sample sizes:		
	• For making strength specimens, a minimum sample size of 1-ft^3 is required.		
	• For other testing, sample size is determined by number and type of tests required as well as max aggregate size.		
7.	Slump, temperature, and air content tests started within 5-minutes of obtaining final portion of sample.		
8.	Start molding strength specimens within 15-minutes of fabricating composite sample.		
Signature of Proctor observing	**OVERALL**		

ASTM C1064-23 Temperature of Freshly Mixed Hydraulic-Cement Concrete		**Pass**	**Fail**
1.	Choose correct thermometer (readable to 1°F from 30 to 120°F) and allows 3- or greater immersion.		
2.	Knows that the thermometer must be calibrated.		
4.	Thermometer inserted into concrete such that end is immersed a minimum of 3-inches and there is at least 3-inches of cover around the thermometer.		
5.	Concrete pressed around shaft of thermometer to close void left by placement (to avoid ambient air temperature from affecting reading).		
6.	Thermometer (temperature) allowed to stabilize for 2 to 5-minutes.		
7.	Temperature read to nearest 1°F while thermometer is in the concrete.		
Signature of Proctor observing	**OVERALL**		

ASTM C143-20 Slump of Hydraulic-Cement Concrete		**Pass**	**Fail**
1.	Cone moistened and base moistened, flat, and level.		
2.	Cone firmly secured to the base (either by standing on foot pieces or clamping).		
3.	Cone filled to approximately 1/3 full by volume (roughly 2 5/8-inches).		
4.	Concrete rodded 25 times, taking care incline the rod to ensure that some of the rods reach the perimeter of the bottom of the cone.		
5.	Concrete added into the cone to approximately 2/3 full by volume (roughly 6 1/8-inches total height).		
6.	Concrete rodded 25 times, taking care incline the rod to ensure that some of the rods reach the perimeter of the cone, and the rods penetrate the underlying layer approximately 1-inch.		
7.	Concrete added into the cone until concrete is heaped over the top edge of the cone.		

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8.	Concrete rodded 25 times, taking care incline the rod to ensure that some of the rods reach the perimeter of the cone, and the rods penetrate the underlying layer approximately 1-inch.		
9.	Care taken to ensure that the cone remains full of concrete; either by adding concrete during the rodding process or by addition of concrete after the 25 rods is complete, if necessary (with no additional rodding).		
10.	Excess concrete removed using the tamping rod in a screeding and rolling motion.		
11.	Excess concrete removed from the base around the perimeter of the bottom of the mold.		
12.	Mold raised a height of at least 12-inches, without twisting or turning, in a period of 3-7-seconds.		
13.	Slump measured to the nearest ¼-inch by measuring from the top of the mold to the original displaced center of the top surface of the specimen.		
14.	Test completed (from start [filling the mold] to finish [removal of the mold]) within 2.5-minutes.		
Signature of Proctor observing	**OVERALL**		

ASTM C31-24 Making and Curing Concrete Test Specimens in the Field		**Pass**	**Fail**
1.	Dry mold placed on a level, rigid surface that is free of vibration.		
2.	Proper tamping rod selected based upon the size of the cylinder mold being used:		
	• 4x8 cylinders require a 3/8-inch diameter rod.		
	• 6x12 cylinders require a 5/8-inch diameter rod.		
3.	4x8 cylinders filled in 2 equal layers by volume; 6x12 cylinders filled in 3 equal layers by volume.		
4.	First layer placed into mold, filling to either ½ or 1/3 by volume (based upon #3).		
5.	Concrete rodded 25 times, evenly distributing the rods, throughout the layer.		
6.	Outside of mold tapped 10-15 times using the mallet (preferable) or the open hand.		
7.	Second layer placed into mold, filling to either overflowing or 2/3 full by volume (based upon #3).		
8.	Concrete rodded 25 times, evenly distributing the rods, throughout the layer and penetrating the underlying layer approximately 1-inch.		
9.	Outside of mold tapped 10-15 times using the mallet (preferable) or the open hand. (If using 4x8 cylinders, skip #10-11 and proceed to #12.)		
10.	Third layer placed into mold, filling to overflowing. (6x12 only)		
11.	Concrete rodded 25 times, evenly distributing the rods, throughout the layer and penetrating the underlying layer approximately 1-inch. (6x12 only)		
12.	Outside of mold tapped 10-15 times using the mallet (preferable) or the open hand.		
13.	Excess concrete struck off with tamping rod, finished, and capped.		
14.	Cylinders carefully transported to storage area maintained between 60-80°F (for concrete with design strength <6,000 psi) or 68-78°F (for concrete with design strength ≥6,000 psi).		
Signature of Proctor observing	**OVERALL**		

ASTM C138-23 Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete		**Pass**	**Fail**
1.	Knows that the calibrated volume of the measure must be given/known (V_m).		
2.	Knows the proper size of measure (NW – min 0.2 ft^3 for <1-inch agg and min 0.5 ft^3 for <2-inches agg; LW – 0.5 ft^3).		
3.	Measure moistened.		
4.	Mass of moistened, empty measure determined (M_e).		
5.	Measure filled with concrete to approximately 1/3 full by volume (roughly 3-inches for PM bowls).		

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6.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the measure, taking care not to forcibly strike the bottom of the measure.		
7.	Sides of measure tapped 10-15 times with mallet.		
8.	Measure filled with concrete to approximately 2/3 full by volume (roughly 3 additional inches for PM bowls).		
9.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the measure, penetrating the underlying layer approximately 1-inch.		
10.	Sides of measure tapped 10-15 times with mallet.		
11.	Measure filled with concrete to overflowing (grossly excessive concrete after consolidation is not desirable).		
12.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the measure, penetrating the underlying layer approximately 1-inch.		
13.	Sides of measure tapped 10-15 times with mallet.		
14.	Excess concrete struck off using the strike-off plate.		
	• Plate pressed flat on top surface for measure, covering approximately 2/3 of the top surface.		
	• Plate withdrawn, using a sawing motion, finishing the area originally covered.		
	• Plate placed back to the original starting position (flat).		
	• Plate advanced, using a sawing motion, until the plate slides completely off of the measure.		
	• Surface finished using an inclined edge of the plate.		
15.	Excess concrete cleaned from the outside of the measure, returning the outside of the measure to the condition it was in when M_e was obtained.		
16.	Mass of full measure determined (M_f).		
17.	Unit weight (Density) calculated using $D = (M_f - M_e) / V_m$		
18.	Unit weight (Density) expressed in lbs/ft^3 (pcf). (to nearest 0.1 lb/ft^3		
Signature of Proctor observing	**OVERALL**		

ASTM C231-24 Air Content of Freshly Mixed Concrete by the Pressure Method		**Pass**	**Fail**
1.	Equipment moistened.		
2.	Bowl filled with concrete to approximately 1/3 full by volume (roughly 3-inches).		
3.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the bowl, taking care not to forcibly strike the bottom of the bowl.		
4.	Sides of bowl tapped 10-15 times with mallet.		
5.	Bowl filled with concrete to approximately 2/3 full by volume (roughly 3 additional inches).		
6.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the bowl, penetrating the underlying layer approximately 1-inch.		
7.	Sides of bowl tapped 10-15 times with mallet.		
8.	Bowl filled with concrete to overflowing (grossly excessive concrete after consolidation is not desirable).		
9.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the bowl, penetrating the underlying layer approximately 1-inch.		
10.	Sides of bowl tapped 10-15 times with mallet.		
11.	Excess concrete struck off using either the strike-off plate or strike-off bar.		
12.	Rim of bowl cleaned such that a seal will be attained.		
13.	Top (seal moistened) placed on bowl and clamped into place.		
14.	Water added into meter through petcock until water emerges from the opposite petcock. Meter gently jarred (or tilted [preferable]) and additional water added until water emerges from opposite petcock		

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15.	Meter pumped up to the calibrated initial pressure (petcocks are still open, bleeder valve is closed tight).		
16.	Gauge lightly tapped to ensure that the needle is settled, if necessary, adjusting the pressure (either additional pumping or bleeding off at the bleeder valve) until the initial pressure is set.		
17.	Petcocks closed.		
18.	Main air valve released, and the side(s) of the bowl tapped with the mallet.		
19.	Gauge lightly tapped to ensure that the needle is settled, and the air content read to the nearest 0.1%.		
20.	Aggregate correction factor (if supplied/available) subtracted from air content on the gauge.		
Signature of Proctor observing	**OVERALL**		

ASTM C173-23 Air Content of Freshly Mixed Concrete by the Volumetric Method		**Pass**	**Fail**
1.	Equipment moistened.		
2.	Bowl filled with concrete to approximately ½ full by volume.		
3.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the bowl, taking care not to forcibly strike the bottom of the bowl.		
4.	Sides of bowl tapped 10-15 times with mallet.		
5.	Bowl filled with concrete to overflowing.		
6.	Concrete rodded with 25 strokes of the rod, distributing the strokes uniformly over the cross section of the bowl, penetrating the underlying layer approximately 1-inch.		
7.	Sides of bowl tapped 10-15 times with mallet.		
8.	Excess concrete struck off using the strike-off bar.		
9.	Rim of bowl cleaned such that a seal will be attained.		
10.	Top (seal moistened) placed on bowl and clamped into place.		
11.	Funnel placed into top of meter.		
12.	At least (preferably approximately) 1-pint of water added through funnel.		
13.	Minimum of ½-pint of alcohol (some concrete may require more) added through funnel.		
14.	Continue adding water through funnel until the water is readable in the neck of the meter preferably near top).		
15.	Funnel removed and water level adjusted using the syringe until the bottom of the meniscus is at the 0 mark.		
16.	Cap tightened into top.		
17.	Meter picked up and then inverted and agitated, attempting to break all of the concrete loose from the bowl.		
	• Inversion and agitation period should continue for at least 45-seconds.		
	• The meter should not be inverted for more than 5-seconds at a time.		
18.	On a hard surface, tilt the meter to a 45^{o} angle and vigorously roll for a period of approximately 1-minute.		
	• Roll the meter between ¼ and ½ turn (min and max range of motion) for 20 seconds.		
	• Spin the meter 1/3 of a turn.		
	• Roll the meter between ¼ and ½ turn (min and max range of motion) for 20-seconds.		
	• Spin the meter 1/3 of a turn.		
	• Roll the meter between ¼ and ½ turn (min and max range of motion) for 20-seconds.		
19.	Meter set upright, and cap loosened, allowing the meter to stabilize.		
	• Stabilization should occur between 2-6-minutes (minimum of 2-minutes, maximum of 6-minutes).		
	• If water level does not stabilize before 6-minutes, test restarted (new sample) and more alcohol used.		
	• There must be less than 2% foam present in the neck for a valid test to continue. If more than 2% foam is present, test restarted (new sample) and more alcohol used.		
20.	Water level (bottom of meniscus) read to nearest 0.25% and noted as *initial reading (or 1st reading).*		
21.	Cap placed back onto meter and rolling procedure repeated.		
22.	Cap removed and meter allowed to stabilize for 2-6-minutes.		

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23.	Second reading taken to the nearest 0.25%.		
	• If 2nd reading is within 0.25% of initial, record 2nd reading as *final reading (air content)* to nearest 0.25%.		
	• If 2nd reading exceeds 1st reading by more than 0.25%, proceed to take one more reading.		
24.	If 3rd reading is necessary, cap placed back onto meter and rolling procedure repeated.		
25.	Cap removed and meter allowed to stabilize for 2-6-minutes.		
26.	Third reading taken to the nearest 0.25%.		
	• If 3rd reading is within 0.25% of 2nd , record 3rd reading as *final reading (air content)* to nearest 0.25%.		
	• If 3rd reading exceeds 2nd reading by more than 0.25%, the test is invalid. Obtain a new sample and restart the test using more alcohol.		
27.	If portions of undisturbed material are still present (aggregate covered w/ cement paste stuck in bowl), test considered invalid.		
Signature of Proctor observing	**OVERALL**		