STUDY GUIDE
WACEL

CONCRETE/MASONRY STRENGTH TESTING TECHNICIAN

April 2021

Study Guide
Concrete/Masonry Strength Testing Technician

General:

This study guide describes in detail the organization and content of WACEL's certification program for Concrete/Masonry Strength Testing Technician. The goal of the program is to ensure that laboratory technicians who are certified by WACEL have demonstrated the skills, knowledge, and abilities to test the more-common concrete and masonry strength specimens as specified in industry standards.

The goals and substance of this program are fully in agreement with WACEL's laboratory accreditation requirements for concrete laboratories. The procedures and processes that are part of this certification can and will be revisited during concrete laboratory accreditation visits or annual audits.

This certification program was originally intended to parallel and be the equivalent to the American Concrete Institute's Strength Testing Technician Certification. What has evolved is an expanded scope that also incorporates drilled cores, cast beams, and the more-routine masonry specimens that several WACEL members test. This expansion addresses what most WACEL laboratories actually do and attempts to more fully comply with the intent of ASTM E329 and ASTM C1077.

Laboratories that do not test cast or sawed beams for flexural strength in accordance with ASTM C78, this certification can be issued incorporating the scope of C78 or without inclusion of C78.

- The choice of options is reflected on the attached proficiency checklists.

- In all cases, however, candidate technicians will be required to respond to written questions based on C78 and the related learning objectives contained in this Study Guide.

Similar to the approach taken for flexural beams, candidate technicians will be required to answer written questions on both types of bonded caps (sulfur mortar and high-strength gypsum paste) for both hardened concrete cylinders and drilled cores. They will, however, only be required to only demonstrate proficiency on one of the two methods.

Examinations:

Certification as a WACEL Concrete/Masonry Strength Testing Technician requires both the successful completion of a 2-hour, written examination and by a performance evaluation.

The written examination is an open-book 60-question test that reasonably represents the learning objectives and references incorporated into this Study Guide. Listed references a. through i. can be used. A grade of 75 percent is required for passing. The authorized references without any markings will be brought to the examination site by individual certification candidates.

The performance evaluation is an integral part of this certification. It will be witnessed by an approved WACEL Practical Examiner and must be successfully completed within 60 days of passing the written examination. If the practical is administered by an approved WACEL examiner in-house, e.g. by a representative of the firm that employs the technician, each test must be video-taped and submitted to WACEL for grading. Make individual videos for each proficiency test as opposed to one long video that tapes all of the tests at the same time.

- The date of the second successfully-completed evaluation instrument will be the date of certification.

- Every reasonable effort will be given to administering the performing evaluation at the office that the candidate technician or technicians are assigned to.

- The evaluation checklists that will be used by the WACEL examiner are included as part of this Study Guide.

References:

a. ASTM C39-21, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens."

b. ASTM C42-20, "Obtaining and Testing Drilled Cores and Sawed Beams of Concrete."

c. ASTM C78-21, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)."

d. ASTM C109-20b, "Compressive Strength of Hydraulic Cement Mortar."

e. ASTM C617-15 (sulfur mortar only), "Standard Practice for Capping Cylindrical Concrete Specimens."

f. ASTM C780-20, "Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry."

g. ASTM C1019-20, Sampling and Testing Grout.

h. ASTM C1231-15, "Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders."

i. ASTM C1542-19, "Standard Test Method for Measuring Length of Concrete Cores."

j. "Concrete Strength Testing Technician," ACI Technician Workbook CP-19, 24th edition.

Learning Objectives:

I. Can safely and properly cap cylindrical concrete or masonry specimens using molten sulfur mortar as delineated in ASTM C617:

   A. Knows how to select the correct type and size capping plates.

   B. Understands how to correctly heat and use sulfur mortar to include continuous venting, peripheral heating, correct temperature, reuse of material, and fire danger considerations.

   C. Can properly evaluate the end conditions of cylinder specimens to determine if capping can proceed without further actions such as cleaning, sawing, or grinding.

D. Is familiar with the need and reason for warming the capping plate prior to use.

E. Knows the testing requirements to determine the suitability of sulfur mortar capping material to include:

1. Testing on receipt of a new lot.

2. Quarterly testing within a lot.

3. Minimum strength requirements.

4. Special qualification testing for specimens with a strength greater than cube verification strength.

F. Is aware of the requirement to lightly oil the capping plate prior to use.

G. Can correctly apply a sulfur mortar cap using an alignment device and/or a bull's-eye level.

H. Knows criteria for and can correctly check applied caps for both planeness and perpendicularity.

I. Demonstrates an understanding of the standards for maximum cap thickness (both individual and average thicknesses) and the testing requirements to confirm compliance with these standards.

J. Knows how to check applied sulfur mortar caps for voids or steam pockets, and that specimens are to be kept moist after capping.

K. Knows how long sulfur mortar caps should be allowed to harden prior to testing.

II. Can properly cap hardened concrete cylinders and drilled cores using high-strength gypsum paste in accordance with ASTM C617:

A. Knows how to select the correct type and size capping plates.

B. Can properly evaluate the end conditions of cylindrical specimens to determine if capping can proceed without further actions such as cleaning, sawing, or grinding.

C. Knows the testing requirements to determine the suitability high-strength gypsum paste material to include:

1. Testing for compressive strength at fixed water-cement ratio on receipt of a new lot.

2. Repeat testing of the same lot at intervals not exceeding three months.

3. Ensuring the compressive strength results equal or exceed minimum strength requirements.

4. Special qualification testing for specimens with a strength greater than the cube verification strength.

D. Can properly mix the high-strength gypsum paste material to the verified water-cement ratio (usually between 0.26 and 0.30).

E. Can correctly use the high-strength gypsum paste using a flat capping plate and a bull's -eye level.

F. Knows capping plates may be coated with a think layer of mineral or grease to prevent adhesion.

G. Knows criteria for and correctly check applied caps for both planeness and perpendicularity.

H. Demonstrates an understanding of the standards for maximum cap thickness (both individual and average thicknesses) and the testing requirements to confirm compliance with these standards.

I. Knows how to check applied high-strength gypsum paste caps for any voids and that specimens are to be kept moist after capping.

J. Knows how long high-strength gypsum paste caps should be allowed to harden prior to testing.

III. Can correctly use unbonded caps in the testing of cylindrical concrete or masonry specimens as specified in ASTM C1231:

A. Knows the upper and lower compressive strength limits for using unbonded caps.

B. Is aware that unbonded caps for drilled cores must meet the same retaining ring diameter restrictions as cast cylinders.

C. Is knowledgeable of requirements and criteria for checking retaining rings for excessive gauges, grooves, or indentations.

D. Knows standards for sizes of retaining rings in relation to the specimens being tested.

E. Knows the minimum depth and size of retaining rings in relation to the caps being used.

F. Is knowledgeable of the different durometer hardness available for neoprene caps and how they effect use.

G. Knows limits on the number of uses of neoprene caps and the need to document such uses.

H. Is aware of criteria to discard caps if excessive wear or damage is noted.

I. Understands the end condition and perpendicularity limitations for using unbonded caps and the action to be taken if they are exceeded.

J. Knows that special qualification testing is required for using unbonded caps when the designed specimen strengths are greater than 7,000 psi.

K. Know that special qualification testing is also required when the anticipated cylindrical mortar specimens is less than 1,500 psi.

IV. Can correctly determine the compressive strength of cylindrical concrete or masonry specimens in accordance with ASTM C39:

A. Understands that the compressive strength of concrete test specimens is dependent on many variables to include size and shape of the specimen, age, temperature, mix proportioning, and moisture during curing and at testing.

B. Is aware that this test procedure is limited to test specimens having a unit weight in excess of 50 lb/ft^3.

C. Knows the verification requirements for testing machines.

D. Is aware that testing machines must be power operated and capable of applying loads continuously, rather than intermittently, and without shock.

E. Knows that the compressive axial load must be applied at a prescribed rate.

F. Knows that testing machines must have two steel bearing blocks.

1. One must be solid and the other must be spherically seated.

2. The spherically seated block must be designed so that it does not permanently deform under repeated use with loads up to the capacity of the testing machine.

G. Understands that the spherically seated block must be kept clean and lubricated with petroleum–type oil such as conventional motor oil.

H. Knows that specimens are not to be tested if a measured diameter of a test specimen varies by more than 2 percent from any other diameter or the same specimen.

I. Knows that the diameter used to determine the cross-sectional area of the specimen is the average of two diameters taken at right angles to each other at about mid-height of the specimen.

J. Is knowledgeable of the criteria for using and average diameter for a day's testing and can correctly determine the value to be used.

1. All molds from the same lot.

2. All diameters consistently fall within a range of 0.02 in (0.5 mm).

3. Average diameters of at least three specimens per day or for each ten specimens, whichever is greater.

K. Understands that moist-cured specimens should be tested as soon as practical after removal from moist storage or kept moist during the period between removal and testing.

L. Knows the allowable time tolerances for testing specimens of a designated age.

M. Knows that the rate of loading a specimen should be within the range of 35 ± psi/second, that a higher rate may be applied during the first half of the loading cycle, and can compute an acceptable loading rate based on specimen diameter.

N. Understands how to apply an appropriate correction factor if the length to diameter ratio of the test cylinder is less than 1.75.

O. Can correctly compute and report the compressive strength of a specimen given a maximum load and an average diameter to include individual cylinder results and set averages.

    1. Individual cylinder results are calculated to the actual compressive strength but reported to the nearest 10 psi.

    2. Set averages are computed using the actual individual cylinder results with the average being rounded to the nearest 10 psi.

P. Can describe the type of fracture of a cylindrical specimen using the sketches provided in ASTM C39.

Q. When using unbounded caps knows to recheck a specimen being tested for perpendicularity after applying approximately 10 percent of the anticipated load.

V. Can properly test a cast, flexural strength test specimen using third-point loading as specified in ASTM C78:

A. Knows that the flexural strength of cast or sawed beams is calculated and reported as the "Modulus of Rupture."

B. Understands that cross-sections of a beam must be geometrically true with sides at right angles with the top and bottom and that all surfaces shall be smooth and free of scars, indentations, or inscribed marks.

C. Is aware that cast beams are loaded on their side with respect to the position as molded; and that sawed beams are loaded so that the tension face corresponds to the top or bottom of the specimen as cut from the parent material.

D. Knows that any gaps between the specimen and the load-applying or support blocks are checked with feeler gauges after the loading system is positioned and approximately 3 to 6 percent of the estimated ultimate load is applied.

E. Understands that smaller gaps up to 0.015 inch (0.40 mm) can be shimmed using leather strips extending across the full width of the specimen

F. Is aware that flexural specimens should be loaded continuously and without shock and at a rate such that the extreme fiber stress increases between 125 and 175 psi/minute (using the formula provided in ASTM C78).

G. Knows that the average width and depth are determined by taking three measurements for each (each edge and center) across one of the fractured faces.

H. Based on the location of the fracture can correctly selected and apply the appropriate formula to determine the modulus of rupture.

I. Understands that test results should be disregarded if fracture in the tension surface is outside the middle third of the span length by more than 5 percent of the span length.

J. Knows to record the following information for the preparation of a complete report:

1. Specimen identification.

2. Average width.

3. Average depth.

4. Span length.

5. Maximum applied load.

6. Calculated modulus of rupture.

7. Curing history and moisture condition when tested.

8. Use of shims, capping, or grinding if applicable.

9. Test age of specimen.

VI. Can correctly prepare and test drilled cores for compressive strength testing in accordance with ASTM C42.

A. Understands that drilled cores for compressive strength testing should normally have a diameter at least two times the normal maximum size of the coarse aggregate with a preferred minimum diameter of 3.70 inches (94 mm).

B. Understands that the moisture conditions of the drilled cores prior to test focus more on reproducible test results that minimizing the effects of drilling rather than replicating the moisture condition of the concrete in the structure.

1. Wipe dry after drilling.

2. When surface appears dry, but not later than 1 hour after drilling, place core in a sealed plastic bag to prevent moisture loss.

3. Deliver to laboratory.

4. If water used for sawing, accomplish end preparation within 2 days of drilling. Wipe off excess moisture, allow the core to dry and replace it in the plastic bag.

5. Note: capping in accordance with ASTM C617 may be desired at the same time.

6. Allow cores to remain in sealed plastic bags for at least 5 days after last being wetted prior to testing.

C. Knows that the preferred length of a capped or ground core is between 1.9 and 2.1 times the diameter and that any prepared core with an uncapped height less than 95 percent of its diameter should not be tested.

D. Understands that sawing will be required to remove end projections that extend more than 0.2 inches (5 mm) above the surface or when end surfaces depart from perpendicularity to the longitudinal axis by more than 0.5 degrees.

E. Is aware that when capping is needed that caps meeting ASTM C617 or ASTM C1231 are required. If unbonded caps are used, the gap between the core and the retaining ring shall meet the requirements of ASTM C1231.

F. Is knowledgeable the perpendicularity and planeness requirements of ASTM C39 apply to drilled cores.

G. Knows how to determine the "calculated density" of cores being tested for strength.

H. Understands the purposes for and the limitations of the "calculated density" information.

I. Knows that the average length of cores taken for compressive strength testing is determined to the nearest 1 mm using the jaw caliper procedure of ASTM C1542.

J. Knows that average diameter used to compute the compressive strength of a core is the average of two diameters taken at right angles to each other at mid-height of the specimen.

1. Measure to the nearest 0.01 inch (0.2 mm) when differences in diameters do not exceed 2 percent of their average.

2. Do not test core if a diameter exceeds 5 percent of their average.

VII. Can correctly determine the compressive strength of masonry mortar specimens in accordance with ASTMs C109 and C780:

A. Knows that cube molds must be made of hard metal of sufficient rigidity to prevent spreading and warping.

B. In addition to 2-inch cubes, is aware that ASTM C780 allows for the use of 2x4-inch or 3x6-inch cylinders.

C. Is aware that loose sand grains and incrustations must be removed from cube faces that will come in contact with bearing blocks of the testing machine.

D. Knows that the proper loading rate for testing 2-inch cubes is 200-400 pounds per second, and that this loading is attained during the first half of loading and maintained thereafter.

E. Knows that if cylindrical test specimens are used, they are to be capped in accordance with ASTM C617 or ASTM C1231 and tested in accordance with ASTM C39.

F. Knows that a single cube should not be tested if more than minor grinding is required to obtain a plane surface.

G. Knows that all mortar test specimens are to be cured in only moist storage (no water tanks) and kept moist after removal from moist storage until tested.

H. Understands that the compressive strength results of the mortar cubes of the same sample and test age should be averaged and reported to the nearest 10 pounds per square inch.

VIII. Can correctly and properly determine the compressive strength of masonry grout prisms as specified in ASTM C1019:

A. Knows that at least three specimens must be tested at each age specified.

B. Is aware that specimens should be molded using in-situ masonry units unless detailed, job-specific comparative testing of an alternative method has been conducted.

C. Is knowledgeable that the ASTM C617 requirements and the ASTM C39 requirements for testing apply to grout prisms.

D. Can calculate average cross-sectional area by measuring the width of each face at about mid-height, by averaging the width of opposite faces, and by multiplying the average widths.

E. Knows how to check each side of the prism for out-of-planeness and perpendicularity.

F. Knows the load is to be applied continuously and without shock.

G. Knows that compressive strength results for grout prisms at a specified age are to be reported individually as well as a set average.

H. Can properly compute and report compressive strength results of grout prisms.

Enclosures: Skills Checklist for Practical Evaluation

INSTRUCTIONS

(As of March 2021)

On the following pages are the proficiency checklists that will be used by the approved WACEL Practical Examiner to record the candidate technician's skills in the processing and testing of the identified concrete and masonry specimens.

Candidate technicians are strongly encouraged to use these checklists to properly prepare for formal evaluation.

All of the tests included in this set of worksheets, with two exceptions, must be performed by the technician and witnessed by an approved WACEL Practical Examiner.

One optional test method is ASTM C78. If a laboratory tests flexural beams, it is required that the test method be included. If a laboratory does not perform C78 testing, it may be omitted. A technician's certificate will indicate whether or not C78 was included. The other exception is that only one of the common methods of applying bonded caps in accordance with ASTM C617 (sulfur mortar or high strength gypsum paste) needs to be demonstrated.

Not all of the tests need to be witnessed on the same date. If tests are spread out over several days, include the range of dates on page 2 on the date line and include the actual date of witness for each test method in the box requiring the signature of the examiner.

The approved WACEL Practical Examiner must sign the signature box for each test method as well as the final page. If the testing is performed-in house, the approved Practical Examiner must video tape each test and submit them to WACEL for grading. Make individual videos for each test as opposed to videotaping all tests concurrently.

Name (Technician): _____ Date(s): _____

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

Name of Examiner: _____

Instructions: Approved WACEL examiners shall observe the testing technician perform the following tests. Rate the performance appropriately and score the overall performance as either pass or fail. A failure of any individual test will result as a failure of the practical exam. The Examiner shall sign as witnessing each individual test method and shall print his/her name on the final page. Completed forms will be maintained on file by WACEL.

ASTM C39-20, Compressive Strength of Cylindrical Concrete Specimens (Applies to ASTM C780-20 for Cylindrical Masonry Mortar Specimens and ASTM C42-20 for drilled concrete cores)	**Pass**	**Fail**	**N/A**
1. Remove specimen from moist storage.			
2. Check for perpendicularity (< 0.12 inches over 12 inches).			
3. Ends plane to within 0.002"? If not, specimens to be sawed, ground, capped, or unbonded caps used.			
4. Determine diameter (average 2 diameters at right angles to each other at middle – closest 0.01 inch).			
5. Bearing surfaces of specimen and upper and lower bearing blocks wiped clean.			
6. Position specimen on lower block and align axis with center of thrust of upper block.			
7. Zero load verified. If necessary, adjustments made.			
8. Spherically seated top block gently moved by hand so that the bearing face appears parallel to top of test specimen.			
9. **Unbonded Caps Only:** Apply 10% of anticipated load and recheck perpendicularity with suitable device.			
10. Apply first half of anticipated load at a reasonable rate.			
11. During second half of loading phase, load applied at 35 ± 7 psi/sec. Note: 6x12: 791-1187 lbs/sec 4x8: 352-528 lbs/sec			
12. Load applied until indicator shows steadily decreasing load & specimen shows well defined fracture.			
13. Record maximum load and note type of fracture.			
14. Calculate and record compressive strength to actual individual compressive strength using the correct π, but report to nearest 10 psi.			
15. Apply correction factor if L/D less than 1.75.			
Signature of examiner observing OVERALL			

ASTM C1231-15, Unbonded Caps	**Pass**	**Fail**	**N/A**
1. Check for perpendicularity (< 0.12 inches over 12 inches).			
2. Check cylinder end conditions (≤ 0.20 inch [5 mm]).			
3. Proper pad selected for expected strength of concrete tested (use Table 1 from Standard).			
4. Examine pads for excessive wear or damage.			
5. Insert pads into retainers and then apply to cylinder.			
6. Center cylinder on lower bearing block and ensure proper alignment with the upper bearing block.			
7. Procedure continued in accordance with C39.			
Signature of examiner observing OVERALL			

Optional evaluation: Candidate technicians only need to be evaluated on one of the bonded cap methods authorized by ASTM C617.

ASTM C617-15, Capping Cylindrical Concrete Specimens (Sulfur Mortar)	**Pass**	**Fail**	**N/A**
1. Cylinder checked for acceptable end condition (≤ 1/8 inch [3 mm]).			
2. Sulfur mortar heated to proper temperature (between 265°F and 290°F).			
• Check capping plate for gouges, then plate warmed and lightly oiled.			
• Cylinder ends clean and free of excess moisture.			
• Sulfur mortar poured into capping plate.			
• Proper use of leveling or alignment device.			
3. Sufficient time allowed for mortar to harden.			
4. Check cap for voids (tap with coin).			
5. Planeness checked (< 0.002 inch) on a minimum of at least 3 different diameters.			
6. Specimens kept moist and procedure continued in conformance with C39.			
7. After breaking cylinder, thickness of caps measured (<7000 psi: < ¼ inch; >7000psi: <1/8 inch).			
Signature of examiner observing OVERALL			

ASTM C617-15, Capping Cylindrical Concrete Specimens (High Strength Gypsum Paste)	**Pass**	**Fail**	**N/A**
1. Cylinder checked for acceptable end condition (≤1/8 inch [3mm]).			
2. Cylinder ends clean and free of excess moisture.			
3. Gypsum paste mixed proper/provided w/c ratio.			
4. Selects proper thickness capping plate (glass: min ¼ inch).			
5. Applies thin layer of mineral oil or grease to underside of plate (optional)			
6. Using a bull's-eye level:			
• Mound of paste on plate and cylinder lowered into it, or			
• Mound of paste on top of cylinder and plate pressed into it.			
7. Paste allowed to harden (typically 45 min).			
Signature of examiner observing OVERALL			

ASTM C1019-18, Grout Specimen	**Pass**	**Fail**	**N/A**
1. Protect from loss of moisture.			
2. Checks all four faces correctly for out-of-plane requirements:			
• Check at mid-width of each face.			
• Measure and record to nearest 1/16 inch.			
• Discard if >1/8 inch.			
3. Check for perpendicularity from both ends using a framing square:			
• Should not depart from perpendicular by more than 1 degree (Approx. 1/8 inch in 6 inches).			
• Measure and record to nearest 1/16 inch.			
• Cut or grind as necessary to correct.			
4. Measure and record the height at mid-width to nearest 1/16 inch.			
5. Measure and record width at mid-height to closest 1/16 inch.			
6. Cap specimen in accordance with ASTM C617.			
7. Test specimen in accordance with ASTM C39.			
8. Note and record description of failure using diagrams in ASTM C39.			
Signature of examiner observing OVERALL			

ASTMs C780-20 and C109-20, Compressive Strength of Hydraulic Cement Mortars using 2-inch Cubes	**Pass**	**Fail**	**N/A**
1. Remove specimens from moist storage; maintain in moist condition until tested.			
2. Wipe specimens to surface-dry condition.			
3. Remove any loose sand grains or instruction from faces in contact with bearing blocks;			
• Check surfaces with straightedge.			
• Minor grinding is allowable.			
• Discard if appreciable curvature.			
4. Place specimen on spacer blocks below center of upper bearing block.			
5. Confirm upper bearing block is free to tilt.			
6. Bring upper bearing in contact with surface or specimen.			
7. Load specimen in range of 200-400 pound/second.			
8. Record load at failure.			
9. Average compressive strengths of all specimens from the sample.			
10. Report to nearest 10psi.			
Signature of examiner observing OVERALL			

Optional Test Method: If the laboratory is capable of performing C78, it is recommended to be included. The actual certificate that a technician receives, upon successful completion, will note whether or not C78 was included.

ASTM C78-18, Flexural Strength of Concrete	**Pass**	**Fail**	**N/A**
1. Protect from loss of moisture.			
2. Test position:			
• Cast: on side as molded.			
• Sawed: tension face either top or bottom as cut.			
3. Specimen centered in loading system.			
4. Apply approximately 3-6% of estimated ultimate load.			
5. Check for gaps with feeler gauges.			
• Grind or cap if gaps > 0.015 in. (0.10 mm) over 1 inch.			
• Leather shims suitable if gaps between 0.004 in. and 0.015 in. (0.10 to 0.4 mm).			
6. Load smoothly without shock, increasing load between 125 and 175 psi/min (25-35 lbs/sec for 6 by 6 beam), to the breaking point.			
7. Determine average width and depth at a fracture face (3 measurements each – each edge and center) as tested.			
8. Calculate modulus of rupture using correct formula.			
9. Disregard results if appropriate (outside of middle third by >5% of span length).			
10. Report all required information.			
Signature of examiner observing OVERALL			

I attest that the tests results reported above are accurate and testing was conducted and proctored in accordance with WACEL requirements.

_____
Signature

_____
PRINTED NAME OF WACEL Examiner