870 Materials Testing and Acceptance - Concrete

870.1 General
Portland cement concrete (PCC) is a major component for a number of bid items used on highway construction projects. The various properties of the component materials, the unhardened mixture, and the finished concrete product as well as required construction techniques are specified throughout parts 4, 5, and 6 of the standard specifications and in the contract special provisions, the plans, and other elements of the contract. These contract requirements can vary widely from contract to contract. The contractor is responsible for producing and delivering material that conforms to all the contract requirements.

The contract references this and other portions of the CMM to describe required sampling and testing procedures. These procedures apply equally to sampling and testing performed by the department, contractor, material supplier, or consultants performing work under the contract for the contractor or administering the contract for the department.

870.2 Concrete Mixtures and Materials
The properties of fresh concrete and the finished concrete product depend on the properties of the component materials. While all materials must meet the threshold, properties specified in the contract, a good mix design can yield quality concrete even if some of the component materials are less than perfect. Once a mix design is selected that optimizes the use of the available materials, consistent production of that design mix is key to concrete quality. Maintaining that quality requires control of the component materials.

870.2.1 Component Materials
Ensure that the contractor uses aggregates, cement, fly ash, pozzolans, slag, and admixtures from a department-approved source. Make sure that other components are either prequalified by the department or from sources the project engineer specifically approves before use.

870.2.1.1 Cementitious Materials
Cement, fly ash, slag, and pozzolans are cementitious materials. The quantity and percentages required or allowed depend on the product specified.

See listing of approved sources on the APL.

Cementitious materials are required to meet specifications set forth in standard spec 501.2, as shown below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Standard Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement</td>
<td>501.2.1</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>501.2.6</td>
</tr>
<tr>
<td>Slag</td>
<td>501.2.7</td>
</tr>
<tr>
<td>Pozzolans</td>
<td>501.2.8</td>
</tr>
</tbody>
</table>

870.2.1.2 Provide testing requirements, previously in AASHTO T 26, for water used in concrete.

870.2.1.2 Mixing Water
Test procedures described in this section are conducted for acceptance of concrete water under standard spec 501.2.4. Concrete water test procedures replace the discontinued AASHTO T26 Standard Method of Test for Quality of Water to Be Used in Concrete. The full AASHTO T26 procedure can be found in any AASHTO standard test method edition before 2014. Acceptance testing is conducted by department staff at the BTS central laboratory.

Tests for maximum sulphate (SO4) and chloride percentages are done according to ASTM D516 and ASTM D512, respectively.

Acidity and Alkalinity testing is determined either by the electrometric or colorimetric method in conjunction with the necessary indicator and is expressed in pH units. When the pH of the water is less than pH 4.5 or more than pH 8.5, further tests should be made.

The procedure for securing pH values is regulated entirely by the method used; that is, either by electrometric or colorimetric methods. The testing procedures are based on the type of apparatus used and conforming to the methods and instruction the apparatus manufacturer furnishes. The apparatus used, either colorimetric or electrometric, must have a working range suitable for the test being performed.
Total solids are determined by evaporating water samples in a 100-200 ml platinum dish on an analytical balance. The platinum dish is filled with 100 ml of water. The contents of the dish are evaporated and then placed on a pan in an oven at 100 C for one hour. Sample and dish are weighed after one hour in the oven. The platinum dish with evaporated sample is then placed in a 550 C oven for one hour. The sample and dish are weighed after one hour in the 550 C oven.

- Total inorganic solids content is determined by dividing the final mass of sample without dish after removal from the 550 C oven by the initial mass of the water sample multiplied by 100 percent.
- Total organic solids content is determined by subtracting the mass of the sample and dish after removal from the 100 C oven from the mass of the sample and dish after removal from the 550 C oven, dividing the difference by the mass of the initial water sample, and multiplying that quotient by 100 percent.

### 870.2.1.3 Aggregates

Contractors and aggregate suppliers submit test results for specific source pits and quarries to the department. The department maintains a list of approved sources for aggregates used in concrete production on the APL. Contractors must use aggregates from a source on this approved list. The department will work with contractors to add new sources, but it is primarily the contractor’s responsibility to provide the required test results and submit the required information to get a new source approved.

Aggregates used on department projects must also conform to specific contract requirements. Most of the required aggregate properties are specified in standard spec 501.2.5.

Under the QMP special provisions the contractor is given somewhat greater freedom to use marginal materials if the quality of the aggregate blend in the resultant concrete is maintained. Contractor mix designs can use a combined aggregate approach. Here the gradation of the individual fine and coarse aggregates is combined mathematically and compared to the total gradation used in a department-approved mix design. This calculation, and the calculation to determine appropriate combined gradation specification limits, can be done using department form WS3012, Combined Concrete Aggregate Gradation.

The department allows contractor mix designs under the QMP specifications to encourage innovation and optimization of existing sources of materials. The contractor may be exempted from meeting the 1-inch sieve requirement in standard spec 715.2.2 if an optimized mix design is submitted that meets the approval of the project engineer. Until specification details and training are available that define satisfactory mix optimization, this approval will be handled centrally through BTS. If your project receives a request for approval of an optimized concrete aggregate gradation or mix design, please forward to Jim Parry via e-mail (james.parry@dot.wi.gov) for review and approval.

### 870.2.1.4 Admixtures

A well-designed concrete mixture may include admixtures to impart desired properties to the fresh or hardened concrete. Approved admixtures are on the APL.

The most common type of admixture used for department concrete is an air entrainment agent. Air entrainment agents introduce microscopic air bubbles into a concrete mixture to enhance durability, reduce permeability, and increase workability. Air entrainment admixtures must conform to standard spec 501.2.2.

Other admixtures include retarding, water reducing, and non-chloride accelerating admixtures. These admixtures must conform to standard spec 501.2.3.

Admixtures not on the approved list need to be approved by the project engineer before use. It is the responsibility of the contractor and concrete producer to ensure that the admixtures used produce the desired properties in the concrete. Some admixtures may have compatibility issues, and test batches should be made to ensure that the admixtures are compatible and produce the desired properties in the concrete.

### 870.2.2 Mix Design

#### 870.2.2.1 Mix Design Submittal and Approval

Details of the contractor mix design and approval process vary somewhat between QMP specifications. Be sure to check the contract special provisions for the specific requirements under your contract. Guidance is also provided in 835. Generally, contractors can use either a new mix design supported by laboratory tests, previously accepted designs supported by field history and recent test results, or use the prescriptive mix designs specified in standard spec 501.3.2.

When assessing mix design test results and history it is essential to consider source specific variability. Even the most consistent source materials vary over time. Test results based on old production are no guarantee that current production will perform similarly.
Air void system analysis is required under standard spec 715.2.3.1 for new lab-qualified concrete paving mixes. Testing procedures and interpretation of the super air meter (SAM) number are described in attachment 870-4, Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method.

During the mix design phase if the mix has a SAM number >0.25 the contractor's mix designer should consider modifying the following and rerunning the test:

1. Add more air within the limits of the specifications.
2. Change mixture proportions.
3. Change mixing/batching operations.

If the contractor's mix designer is still unable to achieve a SAM number ≤ 0.25 after considering the above-mentioned items and all user errors have been eliminated, contact BTS.

870.2.2.2 Determining Batch Weights
Mix designs are required to be submitted in terms of weights based on saturated surface dry aggregates (SSD). The SSD moisture condition is neutral to the net water available for hydration of the cementitious material. SSD aggregates neither contribute extra water to the mix nor do they absorb extra water from the mix.

The single most important measure of concrete quality is the water/cementitious material ratio (W/Cm). Since the aggregates used in the field contain moisture that varies over time, field batch weights must be monitored and adjusted periodically to adjust for changes in aggregate moisture content in order to maintain the design W/Cm ratio.
Field staff can download department form **DT2220**, Determination of Field Batch Weights for Concrete to adjust batch weights for aggregate moisture. Keep completed forms in the project field files.

**FIGURE 870-1  Determination of Field Batch Weights for Concrete, Form DT2220**

<table>
<thead>
<tr>
<th>AGGREGATE DATA</th>
<th>BATCH SIZE DATA</th>
</tr>
</thead>
</table>

**PROJECT DESCRIPTION**

<table>
<thead>
<tr>
<th>Contract</th>
<th>Concrete Grade</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A-FA</td>
<td>4.2 bags</td>
</tr>
</tbody>
</table>

**CONCRETE DESCRIPTION**

<table>
<thead>
<tr>
<th>Name of Road</th>
<th>Concrete Mix Water in Gal. per Cubic Yard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holmen - Antigo</td>
<td>32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Computations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>395</td>
</tr>
<tr>
<td>Fly A./Slag</td>
<td>170</td>
</tr>
<tr>
<td>Fine Agg.</td>
<td>1227</td>
</tr>
<tr>
<td>No. 1 C.A.</td>
<td>1196</td>
</tr>
<tr>
<td>No. 2 C.A.</td>
<td>644</td>
</tr>
<tr>
<td>No. 3 C.A.</td>
<td></td>
</tr>
</tbody>
</table>

**AGGREGATE DATA**

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Source</th>
<th>Test No.</th>
<th>Specific Gravity</th>
<th>% Absorp.</th>
<th>% Total Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Agg.</td>
<td>Z. Holmes</td>
<td>456-87</td>
<td>2.70</td>
<td>1.42</td>
<td>4.9</td>
</tr>
<tr>
<td>No. 1 C.A.</td>
<td>G. Zuehy</td>
<td>473-87</td>
<td>2.60</td>
<td>1.16</td>
<td>2.5</td>
</tr>
<tr>
<td>No. 2 C.A.</td>
<td>G. Zuehy</td>
<td>473-87</td>
<td>2.60</td>
<td>1.16</td>
<td>2.0</td>
</tr>
<tr>
<td>No. 3 C.A.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Balance Average Specific Gravity**

= 2.639 (D) = 3067 (E)

Max. allow. mix water which may be added to batch

\[(\text{max. allow. gal/C.Y.}) \times (\text{batch volume})\]

- No. 1: 65
- No. 2: 35
- No. 3: 243 C.F.

**Computed by**

RUM 2/13/06

**Checked by**

MJH 2/13/06

Total free moisture in gallons -

7.7 gal.

Total 64.1
870.2.2.3 Optimized Concrete Mixtures
The following is guidance for contractors:

1. The paste system consists of the cementitious materials, water, w/cm ratio, chemical admixtures and air.
2. Recommended paste to void ratio, \( V_{\text{paste}}/V_{\text{voids}} \), is 1.25 to 1.75. However, it may be necessary to use as high as a 2.00 to achieve a minimum cementitious content of 520 lbs.
3. Enough paste should be provided to not only fill the voids between aggregate but also to cover the aggregates and separate them to reduce inter particle friction when the mixture is in the fresh state.
4. Use of polycarboxylate high range water reducing admixtures are recommended.

The project engineer should review the mix design to assure:

1. The aggregate gradations are within table 870-1.
2. The \( V_{\text{paste}}/V_{\text{voids}} \) ratio is at least 1.25.
3. The minimum cement content requirements are met.
4. Verify that mix design flexural and compressive strengths meet specifications.
5. Verify that the fly ash or slag does not exceed 30% for binary mixes. Verify that the combination of fly ash plus slag does not exceed 30% for ternary mixes.

<table>
<thead>
<tr>
<th>TABLE 870-1  Tarantula Curve Gradation Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIEVE SIZES</td>
</tr>
<tr>
<td>2 in.</td>
</tr>
<tr>
<td>1 1/2 in.</td>
</tr>
<tr>
<td>1 in.</td>
</tr>
<tr>
<td>3/4 in.</td>
</tr>
<tr>
<td>1/2 in.</td>
</tr>
<tr>
<td>3/8 in.</td>
</tr>
<tr>
<td>No. 4</td>
</tr>
<tr>
<td>No. 8</td>
</tr>
<tr>
<td>No. 16</td>
</tr>
<tr>
<td>No. 30</td>
</tr>
<tr>
<td>No. 50</td>
</tr>
<tr>
<td>No. 100</td>
</tr>
<tr>
<td>No. 200</td>
</tr>
</tbody>
</table>

\[1\] Minimum of 15% retained on the sum of the #8, #16, and #30 sieves.

\[2\] Conform to 24-34% retained of fine sand on the #30-200 sieves.

870.3 Concrete Production and Equipment

870.3.1 General
It is very important that plants producing concrete mixtures are capable of producing a consistent, quality mixture that meets specification requirements. It is the responsibility of the concrete producer and contractor to make sure that the plant used to produce a concrete mixture is fully functional and adequate to produce the required mixture.

870.3.2 Plant Inspection
Annual approval of permanent, commercial ready-mixed concrete plants may be accomplished by on-site inspection or by review of records at the region office.

Upon request of the region staff, the ready-mix producer shall submit a copy of the following current documentation to the region office:

- Certificate of calibration for plant scales, water meter, and admixture meters if used.
- List of source and type of all materials planned for use in WisDOT work for the upcoming season.
- Latest mill test reports for cement, fly ash, slag, and pozzolans in use.
Approval of portable concrete plants erected especially for production of concrete pavement and other related items on a WisDOT project will be made by the project engineer. Upon request of the project engineer, the contractor shall submit a copy of the following documentation to the project engineer.

- Certificates of calibration for plant scales, water meter, and admixture meters if used in set-up on current project site.
- Completed Form DT1926 for initial checkout of plant on the current site.

The controls and tolerance check sheet must be completed the first time a check-out of the automatic controls and interlocks of the concrete batching plant is performed by the contractor during the first week of production, and weekly thereafter. The completed form should be kept in the project field file. Field staff can download department form DT1926, Automatic Controls and Tolerance Check Sheet for Portland Cement Concrete Plants.

870.4 Concrete Sampling and Testing

870.4.1 General

All personnel performing acceptance testing must be certified through the WisDOT Highway Technician Certification Program (HTCP) administered by the University of Wisconsin, Platteville. All laboratory testing must be performed at a laboratory that is qualified through the WisDOT Laboratory Qualification Program.

870.4.2 Portland Cement Sampling

Portland cement is evaluated for approval under the “Certification Method of Acceptance for Portland Cement.” The central laboratory maintains a list of approved cement types from specific manufacturers. The list of approved cement types from approved Portland cement manufacturers on the APL.

Sampling and acceptance is detailed in attachment 870-3 - Certification Method of Acceptance for Portland cement.

870.4.3 Concrete Sampling and Testing Standard Procedures

Perform sampling and testing of concrete mixtures in accordance with the following AASHTO procedures:

- AASHTO T141, Sampling Freshly Mixed Concrete.
- AASHTO T119, Slump of Hydraulic Cement Concrete.
  - Use a ruler or tape that starts at "zero" inches.
  - Do not use a piece from a metal roll-up tape.
- AASHTO T152, Air Content of Freshly Mixed Concrete by the Pressure Method.
  - Except for lightweight concrete mixtures, WisDOT allows only type B meters be used, that air meters be calibrated at three points within the expected range of testing, that calibration be performed every three months with calibration records kept with the meter, and that periodic checks with a calibration canister be performed with records available. Comply with the air meter calibration procedure as detailed in AASHTO T152.
  - All air meters must have a means of identification so that calibration records and calibration canister check tests records can be related to the specific air meter those records represent. How to use a calibration canister to perform calibration check tests on an air meter is detailed in attachment 870-1 - Field Check Test of Air Meters Using Calibration Canister.
- AASHTO TP 118, Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method.
- AASHTO T23, Making and Curing Concrete Test Specimens in the field.
- AASHTO T212, Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete.
  - This test is not required by WisDOT at this time but is generally used in the mix design process to ensure that a concrete mix design is producing the yield or volume that it was designed to produce.
- AASHTO T22, Compressive Strength of Cylindrical Concrete Specimens.

870.4.3.1 Sampling During Pumping Operations

When pumping concrete, there is a potential for a loss of entrained air. According to the specifications, the contractor is to ensure that the discharge end of the hose is kept higher than the lowest point of the hose. This can be accomplished by laying a portion of the flexible hose on the bridge deck, tying a partial loop in the end of the hose, or any other method approved by the project engineer. The project engineer may approve alternate methods if the contractor can demonstrate that the air loss in the concrete created by the pumping process does not exceed 1.0 percent in any boom orientation.
Due to the potential for air loss, it is important to sample the mix from the point of placement, which is the discharge end of the pump line. This will ensure that the test results are a true representation of the in-place material. Due to the loss of air being dependent on the variable location or configuration of the pumping hose, it is generally not acceptable to use a correlation between the truck discharge and the end of the pump hose.

870.4.3.1.1 Dispute Resolution
If entrained air loss is >1.0 percent the contractor can request that the department have a hardened air analysis conforming to ASTM C457 performed at the contractor's expense. If requested, the contractor must notify the project engineer and the QC staff will cast a cylinder from the same load of concrete as the failing test. The cylinder must be immediately taken into possession by department staff for initial curing and transport to a third-party department qualified lab. A report containing the hardened air content test results signed by a professional engineer registered in the state of Wisconsin must be submitted to the project engineer. If the results of the hardened air analysis are within specifications, take no action. If the results are outside the specifications, apply a price reduction as outlined in 810.5.1.2.

870.4.3.2 Sampling During Conveyor Belt Placement
When placing concrete with the use of conveyor belts, there is a potential for air loss due to the movement of the mix from belt to belt and from the belt to the point of placement. It is important to have test results that truly represent the in-place material. The specified air content is for the point of placement location and it is intended that sampling take place at the point of placement.

870.4.3.3 Sampling During Underwater Placement
It is not possible to obtain a sample at an underwater point of placement. The contractor and project engineer should agree on a method and location of sampling. The sampling point should be as close as possible to the placement location, while ensuring the safety of testing personnel. It is important to document the sampling methods when not being performed at the point of placement.

870.4.4 Testing Equipment
All testing equipment used must be in good condition with documentation available showing that the equipment has been verified to be in compliance with specification requirements.

870.4.5 Identification and Shipping Specimens
Concrete cylinders must be plainly marked for identification with the project number, cylinder numbers, and the date on which the cylinders were cast. Sets of cylinders shall be numbered consecutively with individual cylinders in each set designated by letters. Since the majority of cylinders are made to be tested at 28 days, and to promote uniformity among the regions, the 28-day cylinders should be lettered "A" and "B", respectively. All others should be lettered consecutively beginning with the Letter "C."

All QMP verification cylinders must be identified and tested at the end of the curing period indicated in the applicable QMP specification.

Cards for submitting data relative to test cylinders are furnished by the laboratory. These cards shall be filled out and submitted with the specimens and shall contain complete representative data correlated with the information on the cylinder for proper identification by the laboratory. Download department form DT1308 "Concrete Cylinders Test Data Card."
870.4.6 Concrete Cylinder Test Results

An example of the concrete test results reported in Materials Information Tracking (MIT) is shown below in figure 870-3. A system called the Materials Reporting System (MRS) is available for contractor entry of QC cylinder results for structures, and is being developed for other concrete QMP specifications.
When cores are required to determine concrete strength, entrained air content, or pavement thickness they shall be obtained according to AASHTO T24.

- AASHTO T24, Obtaining and Testing Drilled Cores and Sawed Beams.

**870.4.7 Concrete Pavement Thickness by Magnetic Imaging Tomography Scan (MIT Scan)**

This section discusses the application of magnetic imaging tomography, to determine the thickness of freshly placed concrete. Use this process for acceptance testing during construction of new non-reinforced concrete pavements.

**870.4.7.1 Pavement Units**

Standard spec 415.3.16.2 requires the contractor to determine the basic and special paving units. Basic units are generally slip-formed pavements including mainline, shoulders, and ramps 10’ wide or wider. Special units are typically fillet areas, intersections, gaps, tapers, and shoulders and ramps less than 10’ wide. There is no lower boundary on the size of a special unit.

Requirements for locating test plates are mobilized into the contract in standard spec 415.3.16.3.
870.4.7.2 Test Plate Locations for Basic and Special Units

The standard specification requires the contractor to place two test plates at random locations in each pavement unit. Longitudinal and transverse test plate locations are determined randomly by the contractor using ASTM D3665, department approved spreadsheet, calculator equipped to provide random numbers, or other approved method. When slip forming multiple lanes simultaneously, the plates can be placed at the same longitudinal random location within adjacent units. The plates should be relocated to a new random location if the original location is:
- Over an active loop detector.
- Where the depth will not be representative (such as a rut in the base).

Plates should be relocated to the center of the panel if the original location is within 3-feet of steel or an object containing steel.

The contractor shall enter the following plate data into the Material Reporting System (MRS) PCC module:
1. Sequential test plate number.
2. The location of the test plate by one of the following methods:
   a. Station and offset (Needs to be entered manually.)
   b. Latitude and Longitude (Can be manually inputted or uploaded with a tab delimited .txt file.)
   c. Northing and Easting (Can be manually inputted or uploaded with a tab delimited .txt file.)

For special units where the project engineer employs alternate methods of measuring, the department will measure slip form pavement thicknesses using probing. For non-slip form pavements, the department will measure the thickness before placement by measuring the top of adjacent concrete slabs and top of forms to the base aggregate surface. The project engineer will measure interior areas by stretching a string-line across the top of forms and adjacent slabs, and measure from the string to the grade. Thickness corrections should be made by reshaping the base aggregate before the pavement is placed.

Requirements for acceptance testing of concrete thickness are in standard spec 415.3.16.4

870.4.7.3 Department-performed MIT Scan acceptance testing

See attachment 870-2 for the process to perform pavement thickness acceptance testing. For pavement thickness acceptance of special units using alternate testing methods see 870.4.7.2.

870.4.7.4 Materials Information Tracking (MIT) Thickness Entry

The department enters all thickness measurements into the department’s MIT system, using test report 136 as outlined in attachment 870-2. If both plates are required to be measured under standard spec 415.3.16.4, then all six thickness measurements will be averaged for that unit. If the average plate measurement falls within the 80 to 50 percent pay range specified in standard spec 415.5.2, the department shall notify the contractor immediately.

If an alternate measurement method is used on special units the following information should be entered into form 136:
- Provide descriptions of each pavement piece contained in each special unit. Include station and offset if they are available. Also provide the method of measurement of each piece, for example probing, adjacent slab, form height, string line, etc. Because the thickness of handwork areas can be directly measured and corrected before placement, there should not be thickness deficiencies in these areas. The project engineer must enter the final acceptable thickness measurements for these areas into MIT.

Upon completion of the project thickness testing, the department shall provide the test results to the contractor within 5 business days.

Requirements for developing a strength/maturity relationship are mobilized into the contract by standard spec 502.3.10.1.3.

870.4.8 Concrete Maturity Testing

If using the maturity method for determining concrete strength, either standard spec 502.3.10.1.3 or the special provisions require the contractor to follow the procedures defined in this section.

Maturity testing is an alternative to compressive strength tests for administering timing of job control functions such as ending the curing period or cold-weather protection periods, opening to service, or removal of forms or false work. Use data-encrypted sensor devices permanently embedded in the field-placed concrete. Data-encrypted sensors have a chip that records both temperature and time information that can be downloaded to a reading device not permanently attached to those sensors.
870.4.8.1 Calibration Curve
Develop a calibration curve representing the strength-maturity relationship for the concrete before using maturity testing for job control functions. A separate calibration curve is required for each concrete mix design for which maturity testing is to be used. This is to be based on those calibration curves on comparative compressive strength and maturity data from field samples of concrete of the same mix design that is being incorporated into the work. The contractor shall submit the maturity test results to the project engineer for approval before use for job control functions on the project. Develop a new calibration curve every time the mix changes or if project engineer verification cylinder strength varies from the expected value from the current calibration curve by more than 10 percent.

870.4.8.2 Calibration Procedure
Cast at least 15 standard 6x12 inch cylinders in accordance with AASHTO T23 from a single composite sample taken in accordance with AASHTO T141. Embed maturity sensors at the center of at least two cylinders. Cure concrete cylinders in conditions similar to which the field concrete will be exposed. Protect the cylinders from moisture loss. Perform compression tests in accordance with AASHTO T22, at 1, 3, 7, 14 and 28 days, or other intervals as determined appropriate for the mix design. Develop data points for the strength/maturity relationship up to at least 120 percent of the highest required opening strength for each mix design. Test two specimens at each age and compute the average strength. If the strength of the lower strength cylinder is less than 90 percent of the higher strength cylinder, also break a third cylinder. Discard the lowest of the three cylinder strengths, and calculate the strength as the average of the two higher strength cylinders. At each test age, record the average maturity index for the instrumented cylinders.

Calculate the maturity index using the temperature-time factor maturity function as defined in ASTM C1074. Use a default datum temperature of 32 F (0 C) or use a mix-specific datum temperature per Annex A1 of ASTM C1074.

870.4.8.3 Field Procedures for Use of Maturity
Place at least one maturity sensor for each 2000 square yards of concrete pavement, and at least one sensor for each 100 cubic yards of concrete placed under non-pavement bid items. Embed the sensor in the fresh concrete as soon as practicable after concrete placement. When using this practice to allow critical operations to begin, install sensors in locations that are critical in terms of exposure conditions and structural requirements. Connect the sensors to maturity instruments and activate the recording devices as soon as practicable. When the strength at the location of a sensor is to be estimated, read the value of the maturity index from the maturity instrument. Using the strength-maturity calibration curve for that mix design, read off the value of compressive strength corresponding to the measured maturity index. Before performing critical operations such as false work removal or post-tensioning, supplement determination of concrete maturity with other tests to verify that the concrete has the necessary strength.

870.4.8.4 Verification Cylinders
Each workweek the contractor shall provide a set of three verification cylinders to the project engineer for each strength/maturity field calibration curve currently in use on the project. The project engineer will designate the sampling location for these verification cylinders. Provide two cylinders for compressive strength testing, and one with a data-encrypted maturity sensor embedded in its center. Cast and cure these cylinders on-site as the project engineer directs, and in accordance with the requirements of AASHTO T23 for field curing. Deliver them to the project engineer promptly after attaining 50 percent of their opening maturity so the project engineer can perform verification testing as close as possible to the opening maturity level.

870.5 Acceptance
870.5.1 Portland Cement
Acceptance of Portland cement is discussed in Appendix 3 - Certification Method of Acceptance for Portland cement.

870.5.2 Hardened Air Content Testing As a Referee Test
The project engineer will consider the results of hardened air content tests conducted in accordance with ASTM C457 as a referee test for acceptance of concrete with nonconforming pressure air test results. A report containing the hardened air content test results signed by a registered professional engineer shall be submitted to the project engineer. Cores shall be obtained in accordance with AASHTO T24.

870.5.2.1 Frequency
For each day of concrete production with nonconforming pressure air test results that are disputed by the contractor, the following minimum hardened air content test frequencies will be required. Where the quantity of concrete with nonconforming pressure air test results consists of three or more truckloads of material, three hardened air tests will be required. When the quantity of concrete with nonconforming pressure air test
results consists of less than three truckloads of material, one hardened air test will be required for each truckload of material.

Where a large quantity of concrete is involved and results of hardened air content tests are mixed, after review of the hardened air content test results the project engineer may request additional hardened air content testing to more closely define the true limits of the nonconforming material.

870.5.2.2 Location
Coring locations for removing samples for hardened air content testing will be selected in areas of the in-place concrete item represented by the nonconforming pressure air test results. As well as can be determined, each core should be located in an area representing a separate truckload of concrete. If nonconforming pressure air test results are available for multiple individual loads of concrete, the core locations for hardened air content testing will be established to represent the three loads of concrete with the lowest pressure air test results. Otherwise, random core locations should be established which represent the area of nonconforming material. The project engineer must approve all coring locations before removing cores. Care should be taken to not hit reinforcement or appurtenances buried in the concrete.

870.5.2.3 Cost
When the contractor is disputing pressure air test results from QC testing on a QMP project, the contractor shall pay traffic control, core hole filling, hardened air content analysis, and all costs for coring. When the contractor is disputing pressure air test results from department testing, the above costs shall be the responsibility of the party found to be in error.

870.5.2.4 Acceptance Criteria
Concrete represented by hardened air content tests will be deemed to be acceptable if one or both of the following are true:

- The total air content equals or exceeds the lower control limit for the in-place concrete item.
- The spacing factor is less than or equal to 0.0080 inches (0.200 mm.).

870.6 Department Defined Testing and Acceptance Methods for Concrete
The department defines it's own methods for the following:

- Air Meter Field Check
- Concrete Pavement Thickness
- Portland Cement Acceptance
- Concrete Air-Void System
Attachment 870-1  Field Check Test of Air Meters Using a Calibration Canister

The calibration canister check test should never be used to calibrate an air meter. Air meter calibration must be performed by the water method prescribed in AASHTO T 152 (WisDOT Modified) at three points within the anticipated range of testing.

Since the calibration canister only gives one point of reference in checking the accuracy of an air meter it is suggested that a check on the accuracy of the Initial Pressure Line also be performed in conjunction with the check performed using the calibration canister. This should be performed per AASHTO T152 requirements to ensure that introducing the pressure to the air meter bowl from the air chamber pumped up to the initial pressure would result in a zero reading on the air pressure gauge. For checking the accuracy at the high end of possible air test results, two calibration canisters may be used, and the results should be consistent with the total air percentage represented by the calibration canister used. The procedure for testing the accuracy of the air meter using a calibration canister is as follows:

1. Locate the air meter bowl on a firm horizontal (level) surface.
2. Fill the bowl with clean water. It is recommended that the water sit for several minutes before use. This will permit air entrained in the water to dissipate.
3. Place the calibration canister upright at the bottom of the water filled air meter bowl.
4. Add water to the bowl to the point of just overflowing.
5. Place the cover (lid assembly) on the bowl and latch it down. Make certain the main air valve is closed.
6. Add water through the funnel or petcock until the meter is completely full. Gently jar the meter and tap on the sides of the bowl until no air bubbles come out the petcock.
7. Pump up pressure until the gauge needle comes to the vicinity of the red line.
8. Stabilize the gauge hand at the initial pressure line (yellow/red hand on Soil Test or White type meters, gauge line on Forney type). This is done by using the air bleeder valve.
9. Close both petcocks on the lid. Open the main air valve, tap the gauge and permit the gauge hand a few seconds to stabilize. The gauge reading should be that established for the calibration canister (see below). A reading +/- 0.2% is considered to be acceptable.
10. If the reading exceeds the suggested tolerances a second trial should be done. Meters that read over +0.2% after a second trial or under -0.2% on the first trial should be removed from service and repaired and recalibrated as appropriate.

The calibration canisters are suitable for use with any 1/4 cubic foot (0.007 m³) air meter. The manufacturer usually establishes the canister to be equal to 5% by volume, but experience has shown the actual value to be slightly different. It is suggested that the actual percentage of each calibration canister be determined on a meter that has been water-calibrated according to AASHTO T 152 (WisDOT Modified) at three different percentage points within the anticipated range of testing through at least three repetitive tests using a calibration canister that indicate a repeatable result. An equivalent volume can be determined based on the actual volume of the meter that the calibration canister percentage was based on. Calculate the equivalent volume of the calibration canister by multiplying the volume of the bowl by the determined calibration canister percentage divided by 100. When testing is repeated using a calibration canister the canister must be removed and any water that has remained in the canister must be removed before any subsequent tests.

Example 1:

| Volume of the air meter bowl = 7050 mL |
| Indicated calibration canister results = 4.8% |
| Calibration canister equivalent volume = 7050 X 4.8/100 =338.4 mL |

When a calibration canister is used in a meter with a different volume, the percentage of the calibration canister for that meter can be determined by dividing the equivalent volume calculated for the calibration canister by the volume of the air meter bowl being checked.

Example 2:

| Volume of air meter bowl being checked = 7075 mL |
| Equivalent volume of the calibration canister = 338.4 mL |
| Percent of volume of meter tested = 338.4mL/7075mL X 100 = 4.78% |

Volume variations between air meter bowls would need to be significant to show a 0.1% difference in the indicated results compared to the calculated results using the equivalent volume.
Attachment 870-2  Field Determination of Concrete Pavement Thickness

Scope
This test method covers measuring concrete pavement thickness using magnetic pulse induction (MIT Scan).

Interferences
This test method produces misleading results when near metal, like equipment, vehicles, dowel, and tie bars. During normal operation, steel-toe shoes shouldn’t affect results unless the operator steps too close to the gauge head.

Active loop detectors can produce misleading results. Relocate plates to a new random location if their original location falls over an active loop detector.

Apparatus
MIT Scan is an electromagnetic pulse induction device that generates a variant magnetic field that creates an eddy current that is reflected from a metal plate on the base that measures pavement thickness.

Before measuring, charge the battery if the voltage is less than 12 volts.

Procedure
1. Obtain the contractor's plate locations from the Material Information Tracking (MIT) System.
2. Follow the instructions located in the MIT-Scan case for proper operation of the device.
3. Locate and mark the actual position of the plate center using the gauge search mode.
4. Remove debris from the gauge wheel paths using a scraper and broom.
5. Place the front wheel approximately 1.5 feet before the plate center. Press the measure button and slowly push the gauge over the plate. After the gauge head has traveled approximately 6 feet, the gauge processor will calculate the pavement thickness above the plate.
6. Repeat step #5 two additional times in the same direction. For a valid test, all three measurements must be within 3mm of each other.
7. Record the three thicknesses on report 136 in the MIT System for each plate. Report 136 automatically averages the three readings at each test plate location.

Interpretation of results
If a test is invalid, rescan the plate until you have three consecutive readings that are within 3 mm of each other. If three consecutive readings within 3 mm of each other can’t be obtained, and all user errors have been eliminated, the plate should be recorded as "Could not be determined". If the first test plate is identified as "Could not be determined" the department will use the second plate within that unit for acceptance. If both plates are identified as "Could not be determined" the department may core the pavement for acceptance.
Acceptance of Portland cement by the certification method provides for acceptance of these materials for use on Wisconsin Department of Transportation (WisDOT) projects upon the manufacturer’s certification that the product as furnished to the contractor or purchaser complies with the pertinent specification and contract requirements.

WisDOT projects include state, county, and municipal federal aid and authorized county and municipal state aid projects. In order to provide Portland cement to WisDOT projects under the certification method, a manufacturer shall comply with the following procedures and requirements.

**Sampling Frequency**

Under the Certification program, minimum sampling frequency will be one sample from each mill for each brand and type of cement per region per calendar year. The region materials section will coordinate sampling.

Routine field sampling of Portland cement types and sources on the certified list is not required at the project level. Project-level sampling is required for Portland cement from non-certified sources, and all fly ash, pozzolans, and slag at the frequencies defined in 850. The contractor should obtain additional samples for all cementitious materials, whether from a certified list or not, when problems with the concrete mixture are suspected or identified. Testing these additional samples will provide valuable information in troubleshooting the problem.

**Sampling Procedures**

The sample submitted for test shall be a composite of several incremental samplings to provide a total weight of four to five pounds (2 - 2.5 kg). The increments may be obtained by means of a scoop or tube device and care shall be exercised to assure that contamination due to the sampling equipment or environmental conditions is not introduced. The composite sample shall be placed in a plastic bag and submitted to the BTS, Truax Center Laboratory in shipping containers provided by the department. A copy of the manufacturer’s certified tests analysis (mill test report) for the production lot sampled shall be furnished by the contractor and submitted with the sample.

**Identifying Samples**

Download department form DT1307, Cementitious Materials Data Card. An example of the completed card is shown below. Information from this card is necessary for the laboratory to identify the sample and to accurately and efficiently report the test results back to the regions. Therefore, it needs to be filled out completely and accurately. Record the railroad car number or the truck transport number of the shipment sampled and any other transports represented by the sample, the total quantity represented by the sample (all loads included), the location where sample was taken (such as on the project or at _____ Ready-Mix Concrete, _____, Wisconsin), and all other pertinent information called for. Place this card inside the shipping carton along with the sample. Also indicate the brand and type of cement on the shipping label on the outside of the carton.

**Cementitious Materials Data Card, Form DT1307**

![Cementitious Materials Data Card, Form DT1307](image)
General Requirements

This procedure provides for the following:

1. Establishing an approved list of manufacturers.
2. Manufacturer testing.
3. Manufacturer certification.
4. Verification sampling at project sites.

The manufacturer shall provide facilities and qualified personnel to perform all specification tests and maintain a quality control program. The manufacturer shall maintain records of all its control testing done in the production of Portland cements. These test records shall be available at all times for possible examination by BTS (or designated representative) and for a minimum period of five (5) years after use on a project. Acceptance of materials by this process will also be contingent upon satisfactory compliance with procedures and conformance of materials to requirements as determined by test results for verification project site samples taken by state project personnel.

Note: Hereinafter in this document, the usual designated representative (contact person) of the Office of Construction for this program is the Physical & Chemical Tests Engineer.

Qualifying for Certification Method of Acceptance

Manufacturers requesting certified status for supplying material from their individual facilities shall make application to BTS, who will arrange for and authorize the use of the Certification Method of Acceptance. Applicants shall provide the following prequalification documentation and information:

1. A manufacturer mill certification for each type and source of cement to be furnished for WisDOT work. The certification shall include a statement that the cement complies with specifications for the brand, type and source indicated. The certification shall be dated and include the signature and title of a person responsible for certifying the product to legally bind the manufacturer.
2. A record of monthly average test results (as on mill certifications) for each type and source of cement furnished for WisDOT work the preceding year.
3. Complete information regarding the manufacturer’s quality control program (control tests, testing frequencies, laboratory facilities, programs for maintaining test and shipment records, etc.).

When the certification approval process is completed, manufacturers will be notified. Approved manufacturers are recorded on the department’s approved list located at:


The listing will specify the brands, types, and sources of cement approved.

Maintenance of Certification

Manufacturers shall request to be recertified annually. The preferred time to do this is early in the year and before construction work starts. The request shall be received in writing within one year of the previous certification date or the certified status will be terminated. The submittal shall include mill certifications, test results, and changes in the manufacturer's quality control program occurring within the one-year period.

Decertification
Certification will be withdrawn from manufacturers and they will be removed from the approved list when one or more of the following conditions exist:

1. Inability to consistently supply material meeting specifications as measured by the department's project site verification sample test results for a specific brand type and source.
2. Inability to maintain satisfactory precision between verification and manufacturer test results according to applicable ASTM or AASHTO specifications.
3. Lack of maintenance of required records.
4. Improper documentation of shipments.
5. Failure to maintain an acceptable quality control program.

Decertification of manufacturers will be by the Director of the Office of Construction. Notification will be in writing. Decertification may be issued for all materials furnished by a manufacturer or limited to a specific type and source of cement. If the manufacturer loses certification, the designated materials will only be accepted according to specific procedures agreed to by the department and manufacturer. Procedures may require pretesting and approval of materials before use in the work and increased frequency of project site verification or acceptance sampling and testing.

The department's costs for pretesting and increased verification or acceptance sampling and testing shall be paid for by the manufacturer or their agent, unless other arrangements are agreed to by the department.

Recertification

If a manufacturer has lost certification and seeks to be recertified, the following is required:

1. Fulfill the requirements for initial certification.
2. Submit documentation to the department's quality management section chief explaining why decertification occurred and the actions the manufacturer has taken to correct the deficient conditions identified by the department.

A maximum of three months (of normal production) will be allowed for a manufacturer to regain certified status under this procedure. If, after that time, the department determines that the manufacturer has not attained satisfactory status for certification, the designated materials from that manufacturer will not be accepted for use in WisDOT projects until the brand, type, and source can be recertified. The WisDOT regions will be notified of this action. Decisions regarding the future qualification for certification of a manufacturer, affected by the above process, shall be at the department's discretion.

Department Contact Information

Manufacturers shall submit certification application requests and required documents for this procedure to the department central laboratory at the following address:

Wisconsin Department of Transportation
Truax Center
Attn.: Physical & Chemical Tests Engineer
3502 Kinsman Boulevard
Madison, WI 53704

The laboratory telephone number is (608) 246-3246 and FAX number (608) 246-4669.

Certificates and Documentation

Only material shipped from a certified manufacturer will be accepted as certified material. Mill certified test reports of analysis, for delivered cement, shall provide the manufacturing brand, type and source of cement, complete physical and chemical test results, and a production lot number for the sample test results shown thereon. Transport loading documents shall also include brand, type, source, and lot of cement. These references will allow verification of test results by the state. The loading document shall be submitted to the purchaser (contractor) at the time of delivery of cement to a project.

In addition, ready-mix and on-site plants used by the contractor to produce portland cement concrete for department work must have the following documents available for review by the engineer at all times during production:

- The mill-certified test reports of analysis, as stated above.
- Load documents for each shipment with the manufacturer's certification, as stated above.

Project Site Verification Samples
The department’s project personnel will obtain samples by random selection from shipments of material at the project sites. The sampling rate will be a minimum of one per cement mill, for each brand and type of cement per year in each WisDOT region. Sampling will be accomplished by taking a single sample of material according to the department standard practices for sampling cement. The Materials Section in each region will coordinate sampling. The samples will be sent to the department’s central laboratory for testing. Testing will be according to AASHTO standard methods. The tests to be conducted on individual verification samples will be determined by the department central laboratory personnel as being necessary to satisfactorily monitor test properties of the cement.

A copy of the manufacturer’s certified test analysis (mill test report) for the production lot sampled shall be furnished by the contractor and submitted with the sample. In addition, ready-mix and on-site plants shall have the following documents available for department review at all times during Portland cement concrete production for WisDOT work:

1. A mill-certified test report of analysis.
2. Load documents for each shipment stamped with the manufacturer’s certification for the brand, type, and source of cement.

Sampling will need to be coordinated by the regions and be performed either at the plant or on the project.

Acceptance of Portland Cement Not on the Approved List

It is the intention of WisDOT to encourage manufacturers to become certified according to this procedure. However, if situations occur where a manufacturer’s designated product is not on the WisDOT approved list, materials may be accepted for an interim period not to exceed one year according to specific procedures agreed to by the department and manufacturer. Procedures may require pre-testing and approval of materials before use in the work and increased frequency of project site verification or acceptance sampling and testing.

Department costs for pre-testing and increased verification or acceptance sampling and testing are paid for by the manufacturer or their agent, unless the department agrees otherwise. After one year, the designated product will not be accepted for use in WisDOT projects until the brand, type, and source can be certified.

Verification Samples with Nonconforming Results

Should a verification sample tested by the department show noncompliance with specification requirements, actions will be taken to investigate the sample failure. The purpose of the investigation(s) will be to quickly obtain information to either substantiate the failure data or to provide conclusive evidence that the reported failure is unreliable. Prompt response may help to avoid or reduce additional sample failures. The details of the process to resolve sample failures will include part or all of the following:

1. The department central laboratory will notify the Region Materials Section and request them to investigate all region activities related to procuring, handling, and submitting the sample. Together they will establish the quantity and location of material involved, as well as possible. The region will notify the contractor.
2. The department central lab will conduct additional tests (retests) of the sample and review other pertinent data.
3. The department will work out a program to increase verification sampling frequency for the failed product, if deemed appropriate.
4. The department central laboratory will compile all information and data for the failing sample (including information from the region).
5. The department central laboratory will issue the standard test report for the failing sample and all additional tests (retests) to the region. Copies will also be sent to the manufacturer.
6. The department central laboratory will report the investigation information to the region materials section. The report will include recommendations for the region to resolve the sample problem.
7. The region construction section will make the final decision for resolving the sample problem using input by both the region materials section and central laboratory. This decision will be communicated to the contractor and, if warranted, to the manufacturer for information and possible production adjustments.
8. The department will review the results of the investigation and take action to eliminate reoccurrence of sample failures and use of unsatisfactory cement. These actions may include:
   - Increase verification sampling and testing of the specific cement brand, type, and source statewide.
   - Use the findings to determine the acceptability of the specific cement in WisDOT projects when the manufacturer submits their annual request for recertification.
   - Notify the manufacturer and regions that the brand, type and source of cement in question is being removed from the approved list of certified cements (i.e. decertified).
See the following link for videos on how to adjust, calibrate, and perform the Super Air Meter (SAM) test: www.superairmeter.com

When performing the test special attention should be given to the following:

1. Check the clamp arm tension.
2. Clean the rim of the bucket thoroughly, ensure no sand is present.
3. Ensure all bubbles from the bottom chamber have been removed before each testing sequence.

Although currently there are no contractual specification limits, an acceptable SAM number is ≤0.25. Acceptable SAM numbers typically require a minimum of 4.0% air. Failing SAM numbers typically do not occur above 8.0% air.

Interpretation of low or high SAM results:

1. Negative SAM numbers
   - Any negative SAM number is incorrect & indicates an error
   - Fill with fresh concrete & re-test
   - Check for leaks
   - Make sure you are confident in water testing results before testing concrete

2. SAM numbers >0.83
   - Almost always an unintended press of the top lever.