SECTION 870 Materials Testing and Acceptance - Concrete

Standard spec references to concrete testing and sampling methods contained in this chapter:

Standard spec 701.3 ..... concrete testing

CMM provisions mobilized by the contract:

CMM 870.4.8 ..... strength/maturity relationship development

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 quality requires control of the component materials.

870.2.1 Component Materials

The four basic component materials in concrete are:

- Cementitious materials
- Mixing Water
- Aggregates (fine and coarse)
- Admixtures

Acceptance of the component materials are by various methods of department-approved sources (listed on the APL), prequalified sources by the department, and/or project engineer approval prior to use.

870.2.1.1 Cementitious Materials

Cement, fly ash, slag, silica fume, blended SCM's and ASCM's are cementitious materials. The quantity and percentages required or allowed depend on the product specified.

See listing of approved sources on the APL for Portland cement and fly ash class F.

Cementitious materials must conform to standard spec 501.2.4, as shown below.

Portland cement ..... standard spec 501.2.1
Supplementary Cementitious Material (SCM) ..... standard spec 501.2.4.2
Fly Ash Class C ..... standard spec 501.2.4.2.2.2
Fly Ash Class F ..... standard spec 501.2.4.2.2.3
Slag ..... standard spec 501.2.4.2.3
Silica Fume ..... standard spec 501.2.4.2.4
Blended SCM's ..... standard spec 501.2.4.2.5
Alternative Supplementary Cementitious Material (ASCM) ..... standard spec 501.2.4.3

870.2.1.2 Mixing Water

Update 870.2.1.2 to refer to WisDOT's Test Procedure (WTP) methods. Remove reference to former Attachment 870-1.

Test procedures described in this section are conducted for acceptance of concrete water under standard spec 501.2.6. Concrete mixing water acceptance testing is conducted by department staff at the BTS central laboratory per frequency in CMM 850. Water source approval is required prior to placing concrete.

Water from non-municipal sources must conform to the following:

Acidity ..... WTP C-001
Alkalinity ..... WTP C-001
Sulfate ..... WTP C-001

Chloride ..... WTP C-001

Total Solids & Inorganic Matter..... WTP C-001

Water is tested during the concrete plant inspection. The engineer may test water on the project site for compliance.

It is a best practice for the engineer to visually inspect surface water prior to concrete production on the project. During the project, if there is a major rain event, revisit the water source and visually inspect to determine if there is a visible change from the initial visit due to runoff. Take note of the surrounding area to determine if there has been any land disturbance nearby that would increase the sediment or if manure has been recently applied to nearby fields as that can increase the sulfates. If there is a concern with the water source, talk with the contractor and monitor the other concrete properties being tested. If there are inconsistencies, the engineer may take a water sample to ensure the water properties have not changed.

870.2.1.3 Aggregates

870.2.1.3.1 General

Contractors must use aggregates from a source(s) on the approved products list (APL.) Requirements for contractors adding/renewing aggregate sources to the APL are defined in standard spec 106.3.4 and CMM 860. The APL specifically needs to state concrete under the source for inclusion in concrete mixtures as shown on Figure 870-1.

FIGURE 870-1 Sample View of Approved Product List for Aggregate Testing

* = Not Certified	Location Description													Coarse				
Source Name	P/Q	Qrt	Qrt	Sect	Town	Range	County	Test Number	% Light weight Pieces	Freeze Thaw %	% SDS	LA Wear (%) 100	LA Wear (%) 500	Sp. Gravity OD	Sp. Gravity SSD	Absorp. % Crse	Absorp. % Fine
BADGERLAND X PIT	P		SW	9	17N	22E	Manitowoc	0-225-278-2018	0.1	0.0	1.3	6.0	27.5	2.774	2.799	0.870	
55-36-039-PIT	Approved Use : HMA<MT, HMA>=MT, CONCRETE, Base Aggregate																
Created On: 08/28/18																	

Aggregates used on department projects must also conform to specific contract requirements. Most of the required aggregate properties are specified in standard spec 501.2.7.

Aggregate acceptance is specified in standard spec 710.5.6. All aggregate testing is completed during concrete production and tracked by the cubic yards of concrete placed, not the actual quantity of aggregate used.

870.2.1.3.2 Contractor Aggregate Testing Responsibilities

Contractors are required to submit aggregate control charts for each mix design used on the project. The frequency for contractor control charts is defined in standard spec Table 710-1 and Table 710-2. For testing purposes, each bid item will need to be converted to the cubic yardage of concrete.

The monitoring of aggregates is for troubleshooting issues with the mix and provide the contractor an opportunity to control the process before corrective action would need to be taken.

870.2.1.3.2.1 Contractor Small Quantity Requirements

Small quantities are defined in standard spec 710.2. Small quantities are determined by the LET quantity.

Contractor can provide one of two options listed in the spec for fulling the contractual requirements for small quantity concrete aggregates. To utilize the documented previous testing, the placement of concrete must start within the timeframe specified in the standard spec. The non-random start up gradation test is to be performed on the first day of concrete placement for that aggregate source. The requirements for small quantity are required for each aggregate source that is used for those items.

870.2.1.3.2.2 Contractor Requirements

A gradation report is required before placement of a given mix design for both Class I and Class II concrete. If the anticipated date of placement is postponed, another test is not required to be taken. The reason for the test being outside of the prior to placement window needs to be documented in the final QC plan and also in the department material records. The preplacement test is the start of the contractor control chart information for each mix design.

The frequencies for Class I concrete are found in standard spec Table 710-1. The testing frequency is dependent on the amount of concrete that is produced the day of the concrete placement. When two tests are required per day, it is preferred that one test is taken in the morning and one in the afternoon.

The frequency for Class II concrete is found in standard spec Table 710-2. The contractor's test is not required to be completed on a day of concrete placement.

A contractor test is allowed to be used for multiple mix designs and on multiple projects. The contractor is allowed to take an aggregate test and then mathematically combine/proportion for each mix design.

Example:

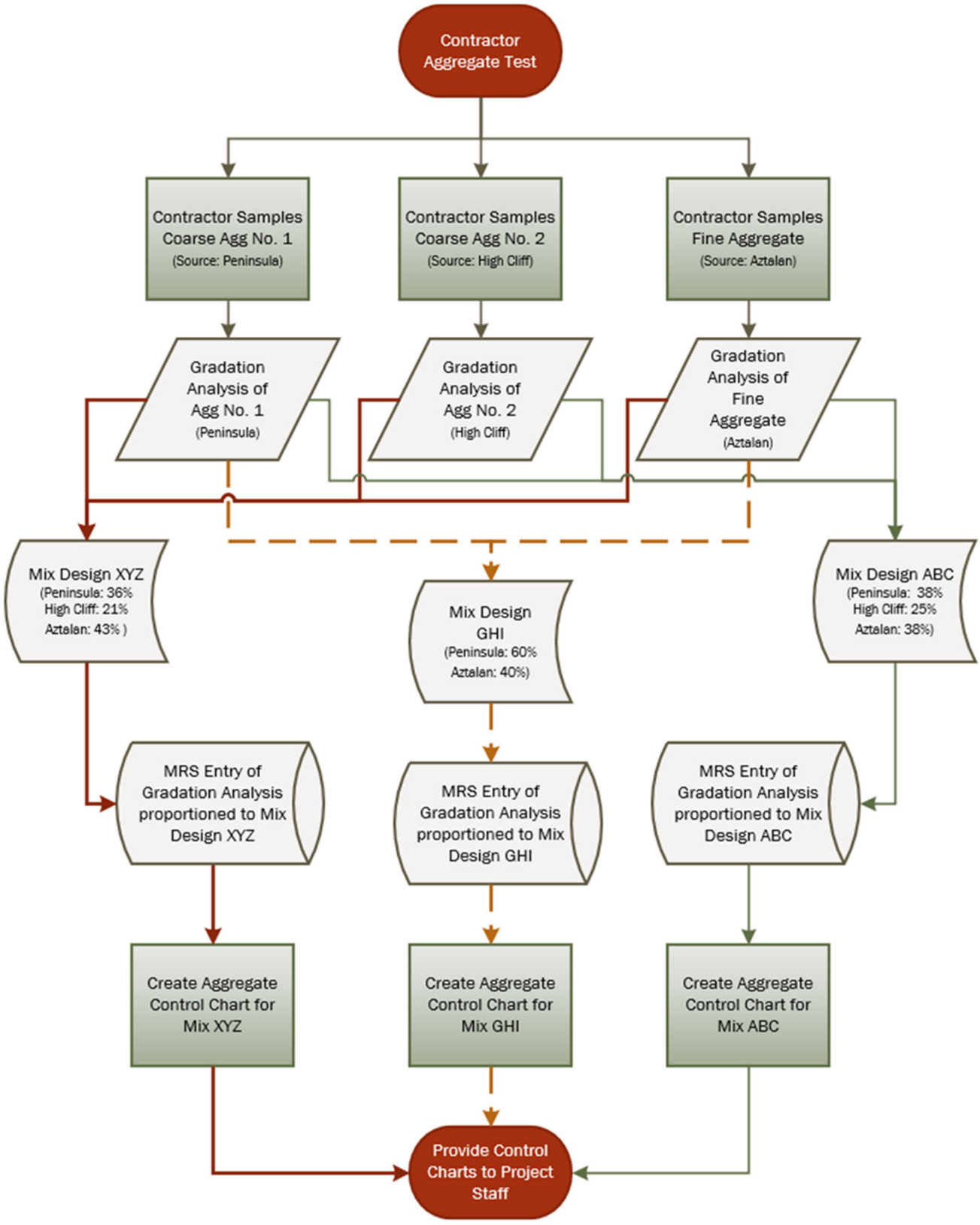
Contractor has 3 different concrete mixtures being poured all the mixtures contain the exact same aggregate sources. Table 870-1 is a summary of the mixes to be placed by the contractor.

TABLE 870-1 CONTRACTOR MIX AND PLACEMENT SCHEDULE EXAMPLE

Project ID	Concrete Mix ID	Aggregate Source	Testing Frequency	Placement Schedule	No of Samples
1234-56-78	XYZ Class I Barrier	Coarse Agg No. 1 – Peninsula Coarse Agg No 2 – High Cliff Fine Aggregate - Aztalan	1 test / day	Placing on: Tuesday (750 CY) Wednesday (550 CY) Friday (625 CY)	3
9876-54-71	GHI Class II	Coarse Agg No. 1 – Peninsula Fine Aggregate - Aztalan	1 test per calendar week	Placing on: Thursday (45 CY)	0
1234-56-78	ABC Class I Pavement	Coarse Agg No. 1 – Peninsula Coarse Agg No 2 – High Cliff Fine Aggregate - Aztalan	1 test / day	Placing on: Tuesday (775 CY) Friday (825 CY)	0

In total, 6 test reports need to be created for the aggregate control charts. However, only 3 samples are needed. The contractor will need to sample aggregates on Tuesday, Wednesday and Friday. One of the aggregate samples from Tuesday, Wednesday or Friday can be used to create the test reports for the 1234-56-78 Class II concrete. Figure 870-2 shows the flow of contractor aggregate sampling.

FIGURE 870-2 Contractor Aggregate Testing



870.2.1.3.3 Department Aggregate Testing Responsibilities

870.2.1.3.3.1 Department Small Quantity Requirements

Small quantities are defined in standard spec 710.2. Small quantities are determined by the LET quantity.

The department is required to test each aggregate source for a small quantity placement according to the standard spec Table 710-3 frequency. The requirements for small quantity are required for each mix design/aggregate source that is placed for those items.

870.2.1.3.3.2 Department Requirements

The department is required to randomly sample the concrete aggregates according to standard spec. 710, Table 710-3.

870.2.1.3.3.3 Class I - Department

870.2.1.3.3.3.1 Small Quantity Aggregate Testing

Determining random samples for small quantity can be done a number of different ways. One way to determine the testing for small quantity is by time of day. See Table 870-2 for an example based on a 10-hour workday.

TABLE 870-2 EXAMPLE RANDOM NUMBER CORRELATION

Random Number (X)	Time of Day
X <= 0.1000	6:00 am to 6:59 am
0.1000 <= X <0.2000	7:00 am to 7:59 am
0.2000 <= X < 0.3000	8:00 am to 8:59 am
0.3000 <= X < 0.4000	9:00 am to 9:59 am
0.4000 <= X < 0.5000	10:00 am to 10:59 am
0.5000 <= X < 0.6000	11:00 am to 11:59 am
0.6000 <= X < 0.7000	12:00 pm to 12:59 pm
0.7000 <= X < 0.8000	1:00 pm to 1:59 pm
0.8000 <= X < 0.9000	2:00 pm to 2:59 pm
0.9000 <= X < 1.0000	3:00 pm to 3:59 pm

870.2.1.3.3.3.2 Concrete Pavement Aggregate Testing

Concrete pavement is allowed to reduce testing frequency if the initial amount of department tests are all satisfactory. The days of placement do not have to be consecutive placement days. The placement can start and then gap over a few calendar days and then restart the placement.

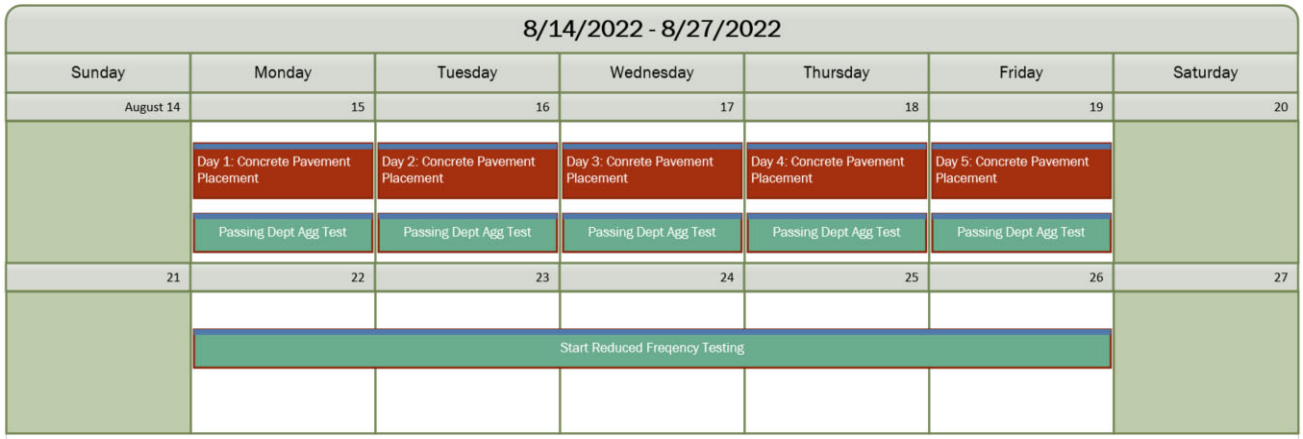
Random sampling for the initial frequency can be done similar to Table 870-2 Example Random Number Correlation. The reduced frequency random sampling can be accomplished multiple ways. One example of random sampling for the reduced frequency is detailed in Table 870-3. In addition, the sample time should be random.

TABLE 870-3 EXAMPLE REDUCED FREQUENCY RANDOM NUMBER CORRELATION

Random Number (X)	Day of Week
X <= 0.2000	Monday
0.2000 <= X <0.4000	Tuesday
0.4000 <= X < 0.6000	Wednesday
0.6000 <= X < 0.8000	Thursday
0.8000 <= X < 1.0000	Friday

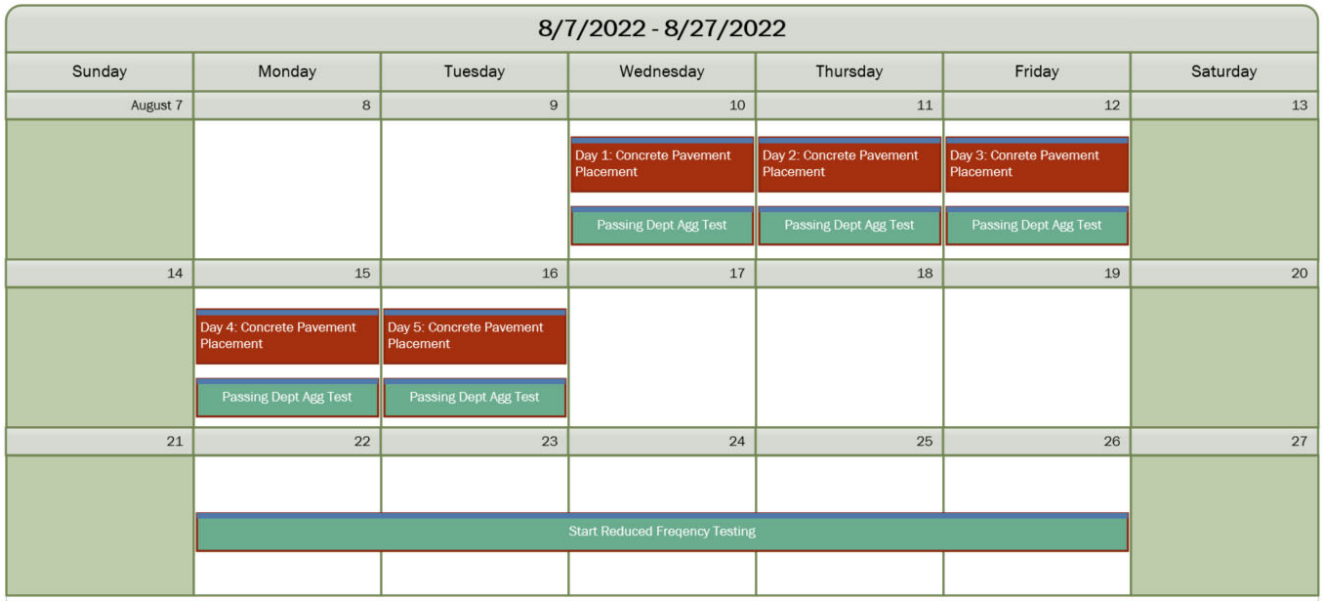
Scenario 1: If concrete placement is performed on Monday, Tuesday, Wednesday, Thursday and Friday of the same calendar week AND all department aggregate samples are satisfactory, the following calendar week, the department would begin the reduced frequency testing. Figure 870-3 visually represents Scenario 1.

FIGURE 870-3 SCENARIO 1: REDUCED AGGREGATE FREQUENCY TESTING



Scenario 2: If concrete placement spans over 2 calendar weeks. For example, placement starts on Wednesday and continues into the next week, the following week (3rd week of placement) would start the reduced frequency. Figure 870-4 visually represents Scenario 2.

FIGURE 870-4 SCENARIO 2: REDUCED AGGREGATE FREQUENCY TESTING



870.2.1.3.3.3.3 Structure Aggregate Testing

When quantities for structure concrete are over the small quantity amount, the department testing has a requirement to test once per concrete lot and to have a minimum of one test for the substructure concrete and one test for the superstructure concrete. The tests are to be representative of the cumulative concrete for the contract, regardless of the number of structures on the project.

The following scenarios help to understand the specification that is written.

Scenario 1: The two structures for the contract have a total of 654 CY of concrete. Structure 1 has 174 CY of substructure concrete and 286 CY of superstructure concrete. Structure 2 has 74 CY of substructure concrete and 120 CY of superstructure concrete. The department will need 3 tests for this contract. A minimum of one test is needed during placement of substructure concrete. A minimum of one test is needed during superstructure concrete.

For this scenario, the random numbers were calculated for the 250 CY increment required for testing and one test was for the substructure and two tests were taken for the superstructure. Table 870-4 portrays the number of department aggregate tests required.

TABLE 870-4 SCENARIO 1: DEPARTMENT STRUCTURE AGGREGATE TESTS

Pour Date	Pour Location	Qty Poured (CY)	Cumulative Qty (CY)	Test Increment (CY)
3/29/2022	Bridge 1: S Abutment (substructure)	33	33	
4/7/2022	Bridge 1: N Abutment (substructure)	33	66	42 CY
4/27/2022	Bridge 1: Pier 1 (substructure)	62	128	
5/7/2022	Bridge 1: Pier 2 (substructure)	46	174	
5/12/2022	Bridge 1: Deck (superstructure)	143	317	
5/13/2022	Bridge 1: Deck (superstructure)	143	460	460 CY
5/20/2022	Bridge 2: W Abutment (substructure)	37	497	
5/25/2022	Bridge 2: E Abutment (substructure)	37	534	
6/10/2022	Bridge 2: Deck (superstructure)	120	654	567 CY

Scenario 2: This one structure has 295 CY of concrete. 271 CY of superstructure concrete and 24 CY of substructure concrete.

For the following example, the random numbers were calculated for the 250 CY increment required for testing and one test was for the superstructure and one test was taken for the substructure as shown in Table 870-5.

TABLE 870-5 SCENARIO 2: DEPARTMENT STRUCTURE AGGREGATE TESTS

Pour Date	Pour Location	Qty Poured (CY)	Cumulative Qty (CY)	Test Increment (CY)
6/29/2022	Abutment Wings (substructure)	12	12	
7/6/2022	Deck (superstructure)	210	222	79
7/11/2022	Parapet (superstructure)	30	252	
7/13/2022	Parapet (superstructure)	30	282	
7/20/2022	Parapet Repair (superstructure)	1	283	
9/7/2022	Wing Repair (substructure)	3	286	
9/12/2022	Wing Repair (substructure)	1	287	
9/15/2022	Wing Repair (substructure)	5	292	292
9/18/2022	Wing Repair (substructure)	3	295	

870.2.1.3.3.3.4 Cast-In-Place Barrier Aggregate Testing

Cast-in-place barrier concrete aggregate testing frequency equates to one test per concrete lot. Follow normal procedures for determining random numbers and collecting samples.

870.2.1.3.3.4 Class II - Department

Class II concrete does not require a specified frequency of testing for concrete aggregate. The department may want to take a sample if there seems to be concerns with the concrete mixture. Staff should be monitoring the contractors aggregate control charts to help determine if the aggregate gradation could be a cause for a change in air content, workability or pumpability to name a few.

870.2.1.3.3.5 Department Sampling

The department test is allowed to be used for multiple mix designs using the same aggregates within the same contract. The frequency of the testing must be maintained for each type of concrete. The department is allowed to take an aggregate test and then mathematically combine/proportion for each mix design. The following depicts the department testing for the contractor example in CMM 870.2.1.3.2.2.

Example: Contractor has 3 different concrete mixtures being placed. The three mixes contain the exact same aggregate sources. Table 870-6 is a summary of the department's sampling requirements for the contractor's mix placement.

TABLE 870-6 DEPARTMENT SAMPLING REQUIREMENT EXAMPLE

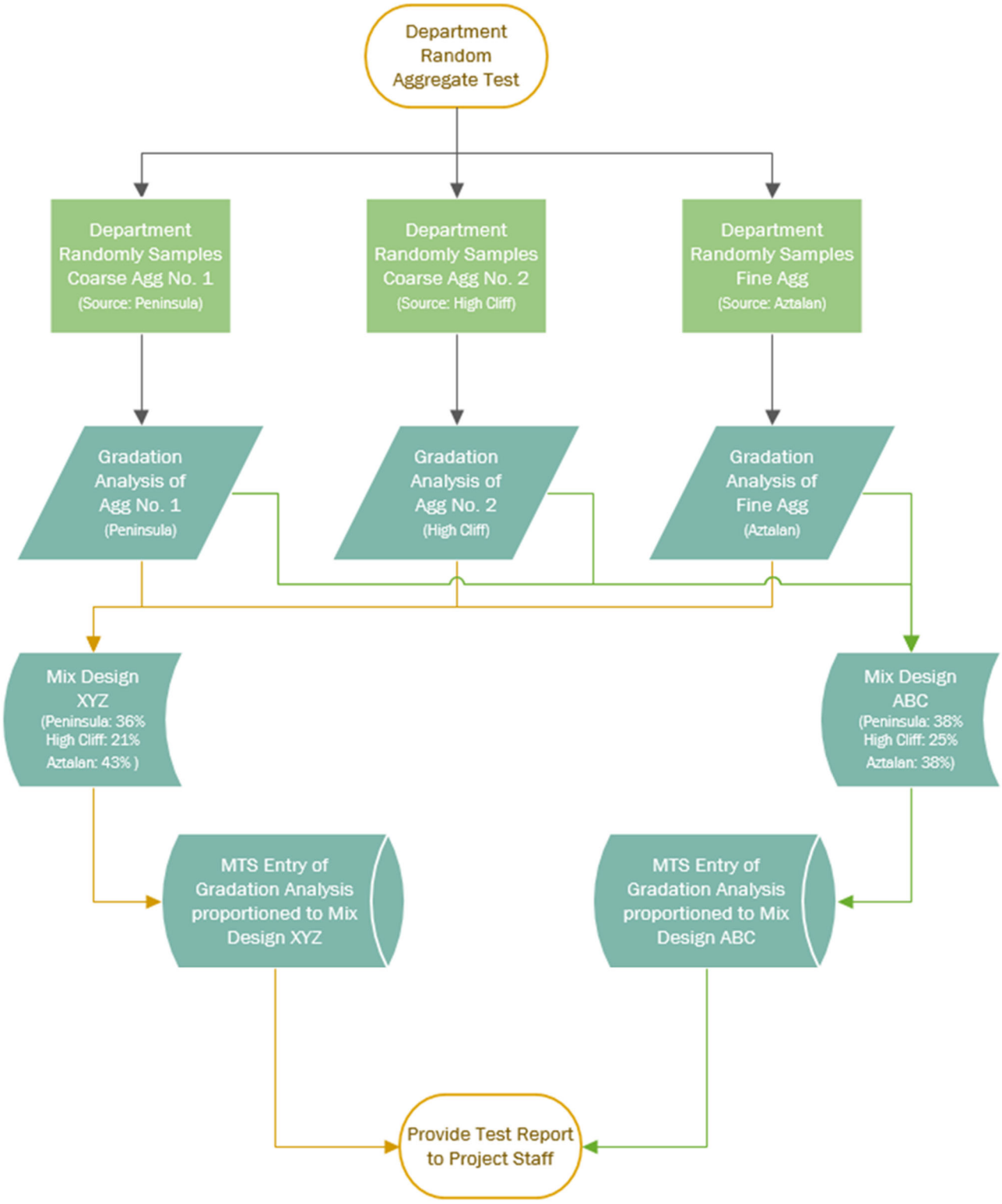
Project ID	Concrete Mix ID	Aggregate Source	Dept. Testing Frequency	Placement Schedule	No of Dept Samples
1234-56-78	XYZ Class I Barrier	Coarse Agg No. 1 – Peninsula Coarse Agg No 2 – High Cliff Fine Aggregate - Aztalan	1 test / 500 CY	Placing on: Tuesday (750 CY) Wednesday (550 CY) Friday (625 CY)	4
9876-54-71	GHI Class II	Coarse Agg No. 1 – Peninsula Fine Aggregate - Aztalan	No minimum testing	Placing on: Thursday (45 CY)	0
1234-56-78	ABC Class I Pavement	Coarse Agg No. 1 – Peninsula Coarse Agg No 2 – High Cliff Fine Aggregate - Aztalan	1 test / day for 5 days	Placing on: Tuesday (775 CY) Friday (825 CY)	0

In total, 6 test reports need to be created for the aggregate control charts. However, only 4 random samples are needed. The barrier total is 1925 cy. The randoms for the barrier require a test on Tuesday (433 CY placed), Wednesday (676 CY placed) and two tests on Friday (1364 CY & 1652 CY placed). The samples taken for the barrier randoms can then be used for the daily aggregate tests required for the Class I Pavement because the following are true:

1. The mix designs are being placed on the same contract.
2. The mix designs are using the exact same aggregate sources.

Figure 870-5 shows the flow of aggregate sampling for this example project.

FIGURE 870-5 DEPARTMENT RANDOM AGGREGATE TESTING

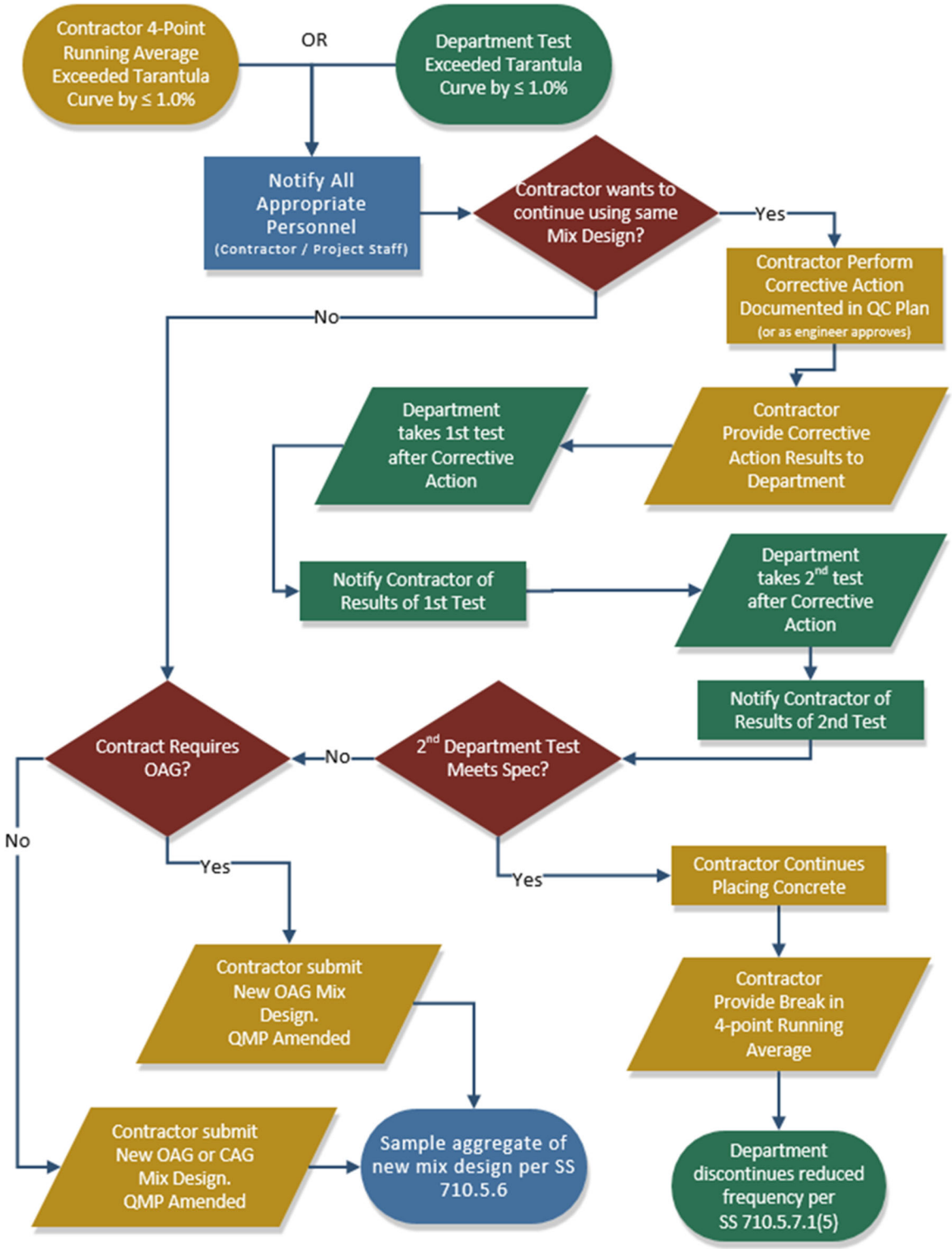


870.2.1.3.4 Corrective Action

870.2.1.3.4.1 Optimized Aggregate Gradation (OAG)

The corrective action for OAG is defined in standard spec 710.5.7.1. Figure 870-6 is a diagram of the sequence of actions for the contractor and department to follow if a new mix design is not required to be used.

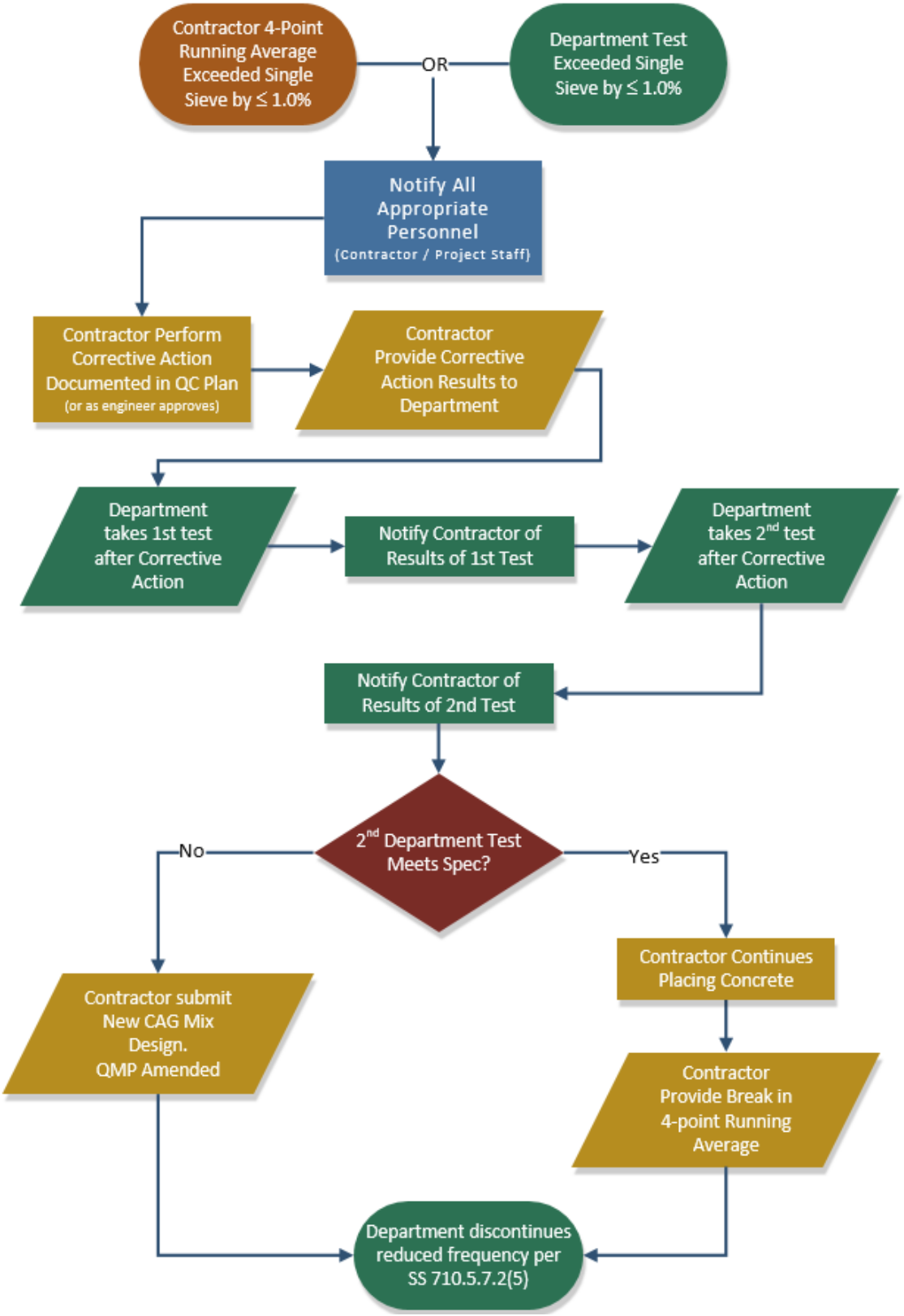
FIGURE 870-6 CORRECTIVE ACTION: OPTIMIZED AGGREGATE GRADATION



870.2.1.3.4.2 Combined Aggregate Gradation (CAG)

The corrective action for CAG is defined in standard spec 710.5.7.2. Figure 870-7 is a diagram of the sequence of actions for the contractor and department to follow if a new mix design is not required to be used.

FIGURE 870-7 CORRECTIVE ACTION: COMBINED AGGREGATE GRADATION



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 501.2.5.

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.

BTS will approve concrete mixtures that contain a superplasticizer. Submit the concrete mix design and the intended use to the BTS Concrete unit for approval.

870.2.2 Mix Design

Details of the contractor mix design and approval process are defined in CMM 871.

870.3 Concrete Production and Equipment

870.3.1 General

It is very important that plants producing concrete mixtures can produce 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 must 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 must 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 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 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 attachment 870-1 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.

870.4.3 Concrete Sampling and Testing Standard Procedures

Update 870.4.3 to refer to various WisDOT Test Modified (WTM) procedures. Remove reference to former Attachments 870.2, 870.8, 870.9, 870.10, 870.11, 870.12, 870.13, 870.14, and 870.15.

Perform sampling and testing of concrete mixtures in accordance with the following WisDOT Manual of Test Procedures, WisDOT Test Modified (WTM):

- WTM R60, Sampling Freshly Mixed Concrete.
- WTM 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.
- WTM T152, Air Content of Freshly Mixed Concrete by the Pressure Method.
- WTM T395, Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method.
- WTM R100, Making and Curing Concrete Test Specimens in the field.
- WTM T121, 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.
- WTM T22, Compressive Strength of Cylindrical Concrete Specimens.
- WTM T97, Flexural Strength of Concrete (using simple beam with third-point loading).
- WTM T24, Testing Drilled Cores and Sawed Beams.
- WTM T358, Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration

870.4.3.1 Interferences for Air Content and Air Void Spacing

870.4.3.1.1 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.

870.4.3.1.2 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 CMM 810.5.1.2.

870.4.3.2 Conveyor Belt Placement

When placing concrete with 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 must 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 must be filled out and submitted with the specimens and must contain complete representative data correlated with the information on the cylinder for proper identification by the laboratory (as shown in Figure 870-8). Download DT1308 Concrete Cylinders Test Data Card.

FIGURE 870-8 Concrete Cylinders Test Data, DT1308

CONCRETE CYLINDERS TEST DATA

DT1308 1097

County: Dane		Project ID: 0617-32-10	
Contractor: CAPE		Cylinder Nos.: 1-1 A & B	
Test Age: 28 DAYS		Made By: JAMES COOL	
Concrete Grade: A-FA	Class: AE	Date Made: 1-1-01	
(Lbs) (kg) Cement/Cy (m3): 450	Cement Brand/Mill Location: LONESTAR/OGLESBY		Type: I
(Lbs) (kg) Fly Ash/Cy (m3): 150	Fly Ash Brand/Plant Location: MINERAL SOLUTIONS/COL.		Class: C
Lbs (kg) Slag/Cy (m3)	Slag Brand/Plant Location		Grade

Admixtures - Type	Amount Per (100 lb) (Kg) Cement
No. 1 DARAVAIR 1000	1.0 (Fl. Oz) (ml)
No. 2 WRDA-82	3.0 (Fl. Oz) (ml)
No. 3	Fl. Oz. (ml)
No. 4	Fl. Oz. (ml)

Aggregate Source(s)	Aggregate Test No(s).
FOX RIDGE PIT	0-162-0028-2001
Coarse ROCK SPRINGS QUARRY	0-162-0028-2001

Total Dry Agg/Cy (m3)	Sand - % of Total Dry Agg
3092 (Lbs) (Kg)	40 %

Net Water	Slump	Air Content
24 (Gal/Cy) (L/m3)	1.5 (In.) (mm)	7.0 %

Sample Location: STH 62 N.B. STA. 121+07

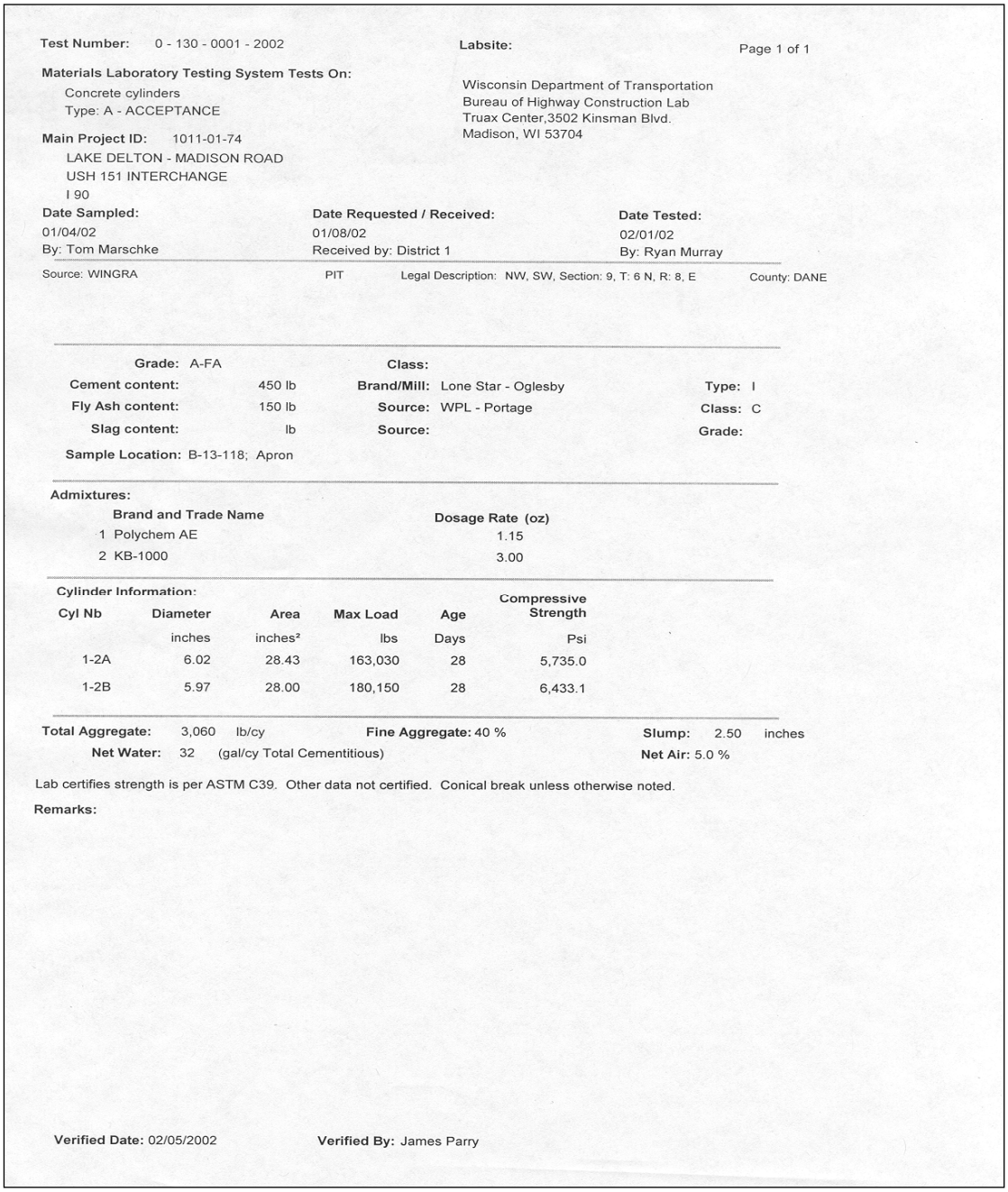
Remarks	DO NOT WRITE HERE
SLIP FORM	T

Wisconsin Department of Transportation

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 870-9. 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.

FIGURE 870-9 Concrete Cylinders Test Data



Test Number: 0 - 130 - 0001 - 2002 **Labsite:** Page 1 of 1

Materials Laboratory Testing System Tests On:
Concrete cylinders
Type: A - ACCEPTANCE

Wisconsin Department of Transportation
Bureau of Highway Construction Lab
Truax Center,3502 Kinsman Blvd.
Madison, WI 53704

Main Project ID: 1011-01-74
LAKE DELTON - MADISON ROAD
USH 151 INTERCHANGE
I 90

Date Sampled:	Date Requested / Received:	Date Tested:
01/04/02	01/08/02	02/01/02
By: Tom Marschke	Received by: District 1	By: Ryan Murray

Source: WINGRA PIT Legal Description: NW, SW, Section: 9, T: 6 N, R: 8, E County: DANE

Grade:	A-FA	**Class:**			
Cement content:	450 lb	**Brand/Mill:**	Lone Star - Oglesby	**Type:**	I
Fly Ash content:	150 lb	**Source:**	WPL - Portage	**Class:**	C
Slag content:	lb	**Source:**		**Grade:**	

Sample Location: B-13-118; Apron

Admixtures:

	Brand and Trade Name	Dosage Rate (oz)
1	Polychem AE	1.15
2	KB-1000	3.00

Cylinder Information:

Cyl Nb	Diameter	Area	Max Load	Age	Compressive Strength
	inches	inches²	lbs	Days	Psi
1-2A	6.02	28.43	163,030	28	5,735.0
1-2B	5.97	28.00	180,150	28	6,433.1

Total Aggregate: 3,060 lb/cy **Fine Aggregate:** 40 % **Slump:** 2.50 inches
Net Water: 32 (gal/cy Total Cementitious) **Net Air:** 5.0 %

Lab certifies strength is per ASTM C39. Other data not certified. Conical break unless otherwise noted.

Remarks:

Verified Date: 02/05/2002 **Verified By:** James Parry

Cores required to determine concrete strength, entrained air content, or pavement thickness must be obtained according to WTM T24.

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

870.4.7 Concrete Pavement Thickness

Revise 870.4.7 to refer to WTM or WTP test methods. Remove references to former Attachments 870-3, 870-4, and 870-5.

Test procedures described in this section are conducted for acceptance of concrete pavement under standard spec 415.3.16. Concrete pavement thickness acceptance testing is conducted by department staff.

Thickness testing must conform to the following:

Magnetic Pulse Induction..... WTM E3209

Probing ..... WTP C-002

Preplacement Measurement..... WTP C-003

870.4.7.1 Magnetic Imaging Tomography Scan (MIT Scan)

This section discusses the application of magnetic imaging tomography, to determine the thickness of freshly placed concrete. This is the preferred method for testing concrete pavement for both basic and special units.

870.4.7.1.1 Test Plates

870.4.7.1.1.1 Obtaining Testing Plates

Construction staff will obtain test plates by contacting the regional materials section.

Each regional materials section is responsible for ordering test plates for the region's construction projects. Contact BTS Concrete Section for ordering process.

870.4.7.1.1.2 Project Reference Plate Locations

The purpose of a project reference plate is to have a location that the operator tests each day before taking thickness measurements for the project to ensure the MIT Scan is operating properly.

Any MIT Scan machine used on the project needs to perform the project reference plate readings.

A project reference plate is established at the first plate of each paving stage. A paving stage can be any phase in the construction where a new project reference plate needs to be defined due to the following circumstances:

- Previous project reference plate is under live traffic.
- Traffic switch made accessing first plate for testing unsafe.
- If the initial plate is greater than 5 miles from where testing needs to occur.

A project reference plate data sheet, DT3209, is needed for each project reference plate location established. Completed DT3209 forms are to be included in the material archive records.

870.4.7.1.1.3 Project Plate Locations

Department will randomly select the plate to read in the paving unit. Random numbers for plate readings are to be included in the material archive records.

870.4.7.1.1.4 Materials Information Tracking (MIT) Thickness Entry

The contractor enters the locations of all the test plates into the MRS system.

The department downloads the locations from the MRS system into MIT. The department enters all the MIT Scan thickness measurements into the department's MIT system, using test report prefix 136.

870.4.7.1.1.5 Troubleshooting

Things to consider if the MIT Scan is not within the project reference plate or test plate tolerance:

- Is the pavement wet?
  - Wet pavement can cause inaccurate readings. Let pavement dry out before testing.
- Pavement surface is dirty?
  - Tined pavements can have surface irregularities that are a result of the tining operation. Sweep and scrape the pavement until the surface is free of debris and anomalies.
- Cold weather?
  - Colder temperatures can have an affect on the MIT Scan reading. Best practice to take readings above 32 F.
- Utilities in the area?
  - Check around for underground or overhead utilities. Underground utilities can impact the readings if they contain metal.
- Nearby equipment?
  - The metal on equipment that is within the immediate vicinity of the MIT Scan can affect the readings.
- MIT Scan Unit?
  - Make sure the battery is charged before performing readings.
  - Try turning the machine off and back on. Sometimes computers need a fresh restart.
  - Ensure proper handling and storage of the MIT Scan unit. Repeated mishandling of the machine can cause damage to the unit. MIT Scan should never be thrown, shoved, or dropped. Properly case the unit and place in the backseat of the vehicle. Avoid transporting machine in the bed of a truck.

- Ensure that all wheels are in contact with the surface during measurement. If all wheels are not in contact, false thickness readings will result.

- Measurements?
  - If measurements seem to have thickness irregularities along the pavement, contact BTS Concrete Unit to assist in troubleshooting.

870.4.7.1.1.6 Calculations

The department enters individual MIT Scan depth readings in whole numbers into the test prefix 136 report. The readings are reported in millimeters.

Example for a Pavement Design of 9-inch plan thickness:

Step 1: Enter individual MIT Scan depth reading in whole numbers into the test prefix 136 report. Readings are reported in millimeters.

Raw Data

Unit ID	Plate ID	Station	Depth Measurements (mm)			Plate Average (mm)	Unit Average (mm)	Unit Average (in)
			Reading 1	Reading 2	Reading 3			
29	A	7+67	228	229	229			
	B							
30	A	10+34	229	229	229			
	B	12+34	215	214	214			
31	A	12+88	199	200	199			
	B	13+82	209	210	210			
32	A							
	B	17+07	230	229	230			

Step 2: The average plate readings are defined by adding the three individual readings and dividing by three. The average result is rounded to the nearest hundredth. This is the plate average in millimeters.

Plate Average

Unit ID	Plate ID	Station	Depth Measurements (mm)			Plate Average (mm)	Unit Average (mm)	Unit Average (in)
			Reading 1	Reading 2	Reading 3			
29	A	7+67	228	229	229	228.67		
	B							
30	A	10+34	229	229	229	229.00		
	B	12+34	215	214	214	214.33		
31	A	12+88	199	200	199	199.33		
	B	13+82	209	210	210	209.67		
32	A							
	B	17+07	230	229	230	229.67		

Step 3: The unit average reading (mm) is defined by adding the six individual readings and dividing by six. The average result is rounded to the nearest hundredth. This is the unit average in millimeters.

Unit Average

Unit ID	Plate ID	Station	Depth Measurements (mm)			Plate Average (mm)	Unit Average (mm)	Unit Average (in)
			Reading 1	Reading 2	Reading 3			
29	A	7+67	228	229	229	228.67	228.67	
	B							
30	A	10+34	229	229	229	229.00	221.67	
	B	12+34	215	214	214	214.33		
31	A	12+88	199	200	199	199.33	204.50	
	B	13+82	209	210	210	209.67		
32	A							
	B	17+07	230	229	230	229.67	229.67	

Step 4: The unit average reading (in) is defined by converting the unit average (mm) by dividing the unit average (mm) by 25.4. The unit average (in) is rounded to the nearest hundredth. This is the unit average in inches.

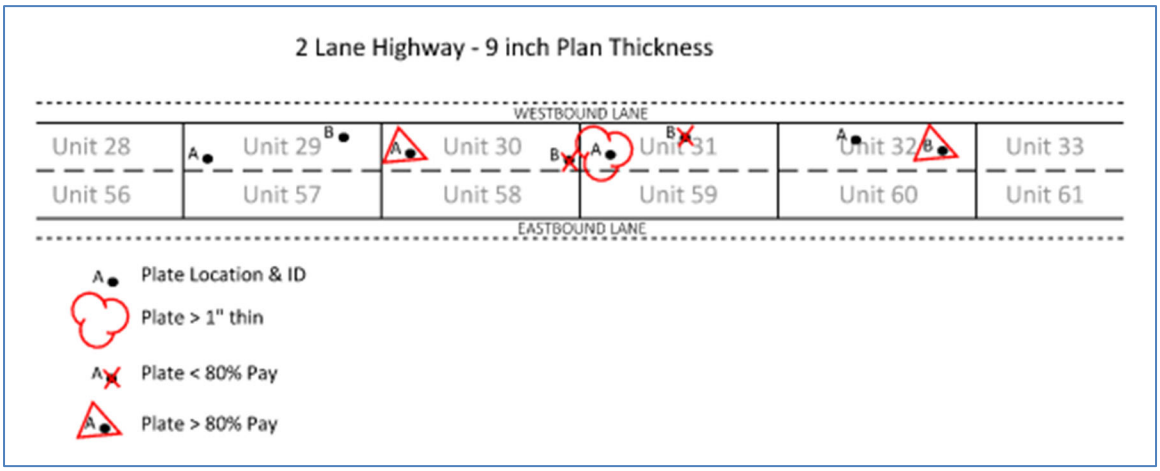
Converting Unit Average to Inches

Unit ID	Plate ID	Station	Depth Measurements (mm)			Plate Average (mm)	Unit Average (mm)	Unit Average (in)
			Reading 1	Reading 2	Reading 3			
29	A	7+67	228	229	229	228.67	228.67	9.00
	B							
30	A	10+34	229	229	229	229.00	221.67	8.72
	B	12+34	215	214	214	214.33		
31	A	12+88	199	200	199	199.33	204.50	8.05
	B	13+82	209	210	210	209.67		
32	A							
	B	17+07	230	229	230	229.67	229.67	9.04

870.4.7.1.1.7 Acceptance Testing

Determining the limits of unacceptable pavement. Refer to Figure 870-10 and the numbers recorded in 870.4.7.1.1.6 Calculations.

Figure 870-10



Scenario:

Plate 31-A is more than 1 inch thinner than contract plan thickness at 199.33 mm (7.85 in). To determine the limits of unacceptable pavement, perform the following:

Step 1: MIT Scan the plates stationed ahead and behind until the thickness test is plan thickness or greater.

- Behind:
  - Plate 30-B: less than plan pavement thickness at 214.33 mm (8.44 in). Continue measuring plates.
  - Plate 30-A: greater than plan pavement thickness at 229.00 mm (9.02 in). Stop measuring plates.
- Ahead
  - Plate 31-B: less than plan pavement thickness at 209.67 mm (8.25 in)
  - Plate 32-A: Need to test with MIT Scan. Plate Average is 218.67 mm (8.61 in). Less than plan thickness, need to continue measuring plates.
  - Plate 32-B: greater than plan pavement thickness at 229.67 mm (9.04 in). Stop measuring plates.

Step 2: Determine limits of unacceptable pavement.

- Behind:
  - Plate 30-B is less than 80% pay according to standard spec 415.5.2. Plate 30-A is greater than plan thickness.
  - Coring needs to be performed between Plate 30-B and 30-A at 20 ft intervals. Measure each core. When core thickness is measured at 8.50 inches or greater, no additional coring is needed for this section.
  - 2 cores were needed. STA 12+14 is the western limit of unacceptable pavement.
- Ahead
  - Plate 32-A is at 80% pay according to standard spec 415.5.2. Since the next plate 30-A is greater than plan thickness, no coring is needed. The ahead station of Plate 32-A is the limit of unacceptable pavement. STA 15+98.
- Limits of unacceptable pavement is STA 12+14 to STA 15+98 (384 FT). Due to being greater than 100 LF, this pavement will be removed and replaced to the nearest joint.

870.4.7.1.1.8 Pay Adjustment

Pay adjustments are determined according to standard spec 415.5.2.

870.4.7.2 Concrete Probing

This section discusses the concrete probing, to determine the thickness of freshly placed concrete. This method is used for testing special unit slip-formed concrete pavement.

870.4.7.2.1 Test Plates

Construction staff will obtain test plates by contacting the regional materials section.

Each regional materials section is responsible for ordering test plates for the region's construction projects. Contact BTS Concrete Section for ordering process.

870.4.7.2.2 Materials Information Tracking (MIT) Thickness Entry

The contractor enters the locations of all the probing test plate locations into the MRS system.

The department downloads the locations from the MRS system into MIT. The department enters all the MIT Scan thickness measurements into the department's MIT system, using test report prefix 136.

870.4.7.2.3 Troubleshooting

Things to consider when probing fresh concrete:

- Top plate not staying in place?
  - When extracting the probe, hold onto the T bar handle when pulling out of the concrete. Don't just pull on the plate.
- Thickness measurement seems inaccurate?
  - Ensure probe is perpendicular to the pavement when inserting into the concrete.
  - When entering the probe in the concrete, make sure that the probe is hitting the plate placed on the grade.

870.4.7.2.4 Calculations

The department enters individual probe depth readings to the nearest 1/8-inch the test prefix 136 report.

The unit average reading is defined by adding the two individual probe readings and dividing by two. The average result is rounded to the nearest thousandth of an inch.

870.4.7.2.5 Pay Adjustment

Pay adjustments are determined according to standard spec 415.5.2.

870.4.7.3 Preplacement Measurement (Stringline)

This section discusses string lining the concrete pavement to determine the thickness of pavement before placing concrete. This method is used for testing special unit hand placed concrete pavement.

Thickness measurements less than plan thickness are required to be corrected before paving according to standard spec 415.3.16.4.2.3.

870.4.7.3.1 Materials Information Tracking (MIT) Thickness Entry

The contractor enters the locations of all the random stringline locations into the MRS system.

The department downloads the locations from the MRS system into MIT. The department enters all final stringline thickness measurements (after any necessary base correction) into the department's MIT system, using test report prefix 136.

870.4.7.3.2 Calculations

The department enters individual stringline depth readings to the nearest 1/8-inch the test prefix 136 report.

The unit average reading is defined by adding the two individual stringline readings and dividing by two. The average result is rounded to the nearest thousandth of an inch.

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. The contractor submits the maturity test results to the project engineer for approval before using for job control 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 WTM R100 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 WTM 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 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

Revise 870.4.8.4 to change test reference from AASHTO to WTM. Update attachment number.

Each workweek the contractor must 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 WTM R100 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 Attachment 870-1 - Certification Method of Acceptance for Portland Cement.

870.5.2 Hardened Air Content Testing As a Referee Test

Revise 870.5.2 to change test reference from AASHTO to WTM.

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 must be submitted to the project engineer. Cores must be obtained in accordance with WTM 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 pays for 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 are 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 its own methods for the following:

- Air Meter Field Check
- Concrete Pavement Thickness
- Portland Cement Acceptance
- Concrete Air-Void System

870.7 Surface Resistivity

870.7.1 Concrete Resistivity

Resistivity (ρ) is the measure of a material's ability to resist an electrical current. It is a function of Ohm's Law, the specimen's geometry, and the method of measuring resistivity. The units of resistivity are expressed in terms of kΩ-cm.

Using resistivity can help identify how permeable concrete is. It is important to know how permeable the concrete is so it can be determined how susceptible structures, pavements and other concrete elements are to outside chemical attack. Knowing this property will lead to better assessment of the concrete's durability and its future life expectancy.

870.7.2 Testing Concrete Resistivity

Revise 870.7.2 to change test reference from AASHTO to WTM. Remove reference to former Attachment 870-8.

Testing concrete resistivity can be performed in one of two methods: bulk resistivity or surface resistivity. The department will be using surface resistivity to measure the concrete's resistivity. This test method is outlined in WTM T358. Surface resistivity utilizes a probe that generates an electric field within the sample. The probe measures the electric field and produces a value known as surface resistivity. Surface resistivity is not the resistivity of concrete. The results from the surface resistivity measurements must be corrected to get the resistivity of concrete. The corrections applied are located in the equations below:

SPECIMEN DIMENSION AND PROBE SPACING CORRECTION

$$k = 1.10 - \frac{0.73}{\frac{d}{a}} + \frac{7.34}{\left(\frac{d}{a}\right)^2}, where \begin{cases} d\ is\ the\ diameter\ of\ the\ cylinder\ (in.) \\ a\ is\ the\ probe\ spacing\ (in.) \end{cases}$$

Note: the correction factor k can only be applied to cylinders.

CONVERTING SURFACE RESISTIVITY MEASUREMENTS (ρm)TO RESITIVITY MEASUREMENTS (ρ)

$$\rho = \frac{\lambda * \rho_m}{k}, where \begin{cases} \lambda\ is\ the\ leeching\ correction\ factor \\ \rho_m\ is\ measured\ surface\ resistivity \\ k\ is\ the\ probe\ and\ sample\ shape\ correction \end{cases}$$

λ = 1.1 when cured in lime-water tanks

The corrections are applied to the set average rather than the individual measurements. After the corrections are applied to the set average, the resistivity of concrete is rounded to the nearest 0.1 kΩ-cm. DT 2232 performs these calculations automatically and is located on the department's website:

https://wisconsindot.gov/pages/global-footer/formdocs/default.aspx

870.7.3 Accelerated Curing for Surface Resistivity Specimens

Revise 870.7.3 and 870.7.4 to change test reference from AASHTO to WTM.

The reason why the department requires the Accelerated Curing Method for surface resistivity specimens is to account for supplementary cementitious materials (SCMs) in the mixture. In the early stages of concrete's reaction, SCMs remain inert until certain conditions are met within the microstructure that trigger the reaction of SCMs. Placing concrete specimens in a hot lime-water bath, as specified in WTM T358, can cause the SCM reactions to happen faster. This will give the department a better idea of how effective a concrete mixture is when it contains an SCM. In addition, it will also give the department a better idea the permeability performance of concrete without SCMs because the extra heat will cause more of the cement to react. Accelerated cured concrete specimens cannot be used for strength acceptance and concrete strength specimens must not be placed in hot lime-water tanks.

870.7.4 Interferences during Surface Resistivity Testing

There are 3 major interferences that can occur during testing:

1. The temperature of the sample can cause errors during testing. Higher temperatures will decrease surface resistivity measurements while lower temperatures will increase the surface resistivity measurements.
2. Leeching of pore solution from the concrete will affect the surface resistivity measurement. Leeching of ions from the concrete will cause the surface resistivity to go down. A correction factor established by WTM T358 is applied to correct for these ions leeching out of concrete.
3. The surface condition of the sample during measurement does matter. Having a saturated surface will cause the electric current to move through the water on the surface resulting in a lower resistivity. The opposite happens if the surface is too dry. A dry surface condition will increase the surface resistivity measurement or make measurements difficult. The optimum surface condition for surface resistivity measurements is saturated surface dry (SSD).

AASHTO T358 explains other types of minor interferences in Section 5.

870.7.5 Delayed Surface Resistivity Testing

Surface resistivity testing is to be tested on day 28 of the final curing procedure. Due to the length of the final curing procedure, it is possible the 28th day could fall on a weekend or on a holiday. The best practice when this happens is to test at the next available time. Since the concrete specimens are coming out of hot lime-water and need to cool down prior to testing, remove samples from the hot bath and place in a wet/fog room or lime-water tank between 68-77^{o}F before the leaving for the weekend or holiday when the day 28 measurements are supposed to be made. Try to test resistivity specimens no more than 32 days after the final curing process starts. Make a note during testing stating a delay in testing had occurred and the reason for the delay.

Attachment 870-1 Certification Method of Acceptance for Portland Cement

Remove former Attachments 870-1 to 870-5 and 870-8 to 870-15. Renumber former attachment 870-6 to attachment 870-1 and former attachment 870-7 to attachment 870-2. Add references to WisDOT Test Modified (WTM) and WisDOT Test Procedures (WTP).

Refer to the following WisDOT Test Modified (WTM) and WisDOT Test Procedure (WTP) in the WisDOT Manual of Test Procedures for sampling and testing requirements:

- WTP C-001 for concrete mixing water
- WTM T152 for air content of fresh concrete
- WTM E3209 for thickness by magnetic pulse induction
- WTP C-002 for thickness by probing
- WTP C-003 for thickness by preplacement measurement
- WTM T358 for surface resistivity
- WTM T24 for drilled cores for concrete
- WTM T395 for air void system of fresh concrete
- WTM R60 for sampling of freshly mixed concrete.
- WTM R100 for making and curing concrete test specimens.
- WTM T22 for compressive strength of cylinders
- WTM T97 for flexural strength of beams
- WTM 119 for slump

Acceptance of portland cement by the certification method provides for acceptance of these materials for use on 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 must 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 CMM 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.

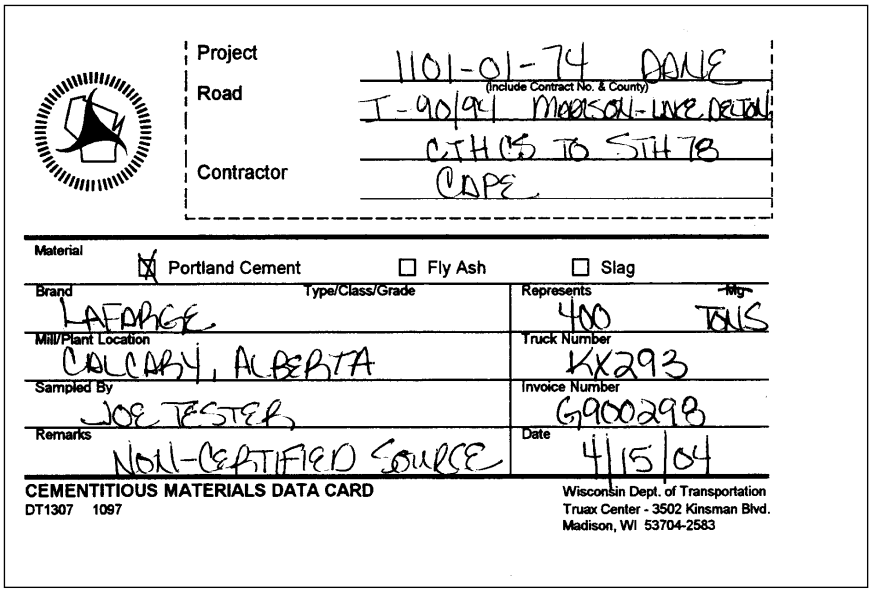
Sampling Procedures

The sample submitted for test must 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 must be exercised to assure that contamination due to the sampling equipment or environmental conditions is not introduced. The composite sample must 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 must be furnished by the contractor and submitted with the sample.

Identifying Samples

Download 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, DT1307



Project: 1101-01-74 DANE (include Contract No. & County)
Road: I-90/94 MADISON-LUCK, INTL
CTHS TO STH 78
Contractor: CAPE

Material: ☒ Portland Cement ☐ Fly Ash ☐ Slag

Brand	Type/Class/Grade	Represents	Mfg
LAFARGE		400	TONS
Mill/Plant Location		**Truck Number**	
CALGARY, ALBERTA		KK293	
Sampled By		**Invoice Number**	
JOE TESTER		G900298	
Remarks		**Date**	
NON-CERTIFIED SOURCE		4/15/04	

CEMENTITIOUS MATERIALS DATA CARD
DT1307 1097

Wisconsin Dept. of Transportation
Truax Center - 3502 Kinsman Blvd.
Madison, WI 53704-2583

(LAB. USE ONLY)

C - No. _____

TEST RESULTS — Date Rec'd.

Autoclave Expansion	Mortar Air Content

Time of Set

COMPRESSIVE STRENGTH — REMARKS:

☐ Satisfactory
☐

- Day		- Day	
Load, lbs (kg)	Stress, psi (MPa)	Load, lbs (kg)	Stress, psi (MPa)
Av. =		Av. =	

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 must provide facilities and qualified personnel to perform all specification tests and maintain a quality control program. The manufacturer must maintain records of all its control testing done in the production of portland cements. These test records must 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 acceptable 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 must make application to BTS, who will arrange for and authorize using the Certification Method of Acceptance. Applicants must 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 must include a statement that the cement complies with specifications for the brand, type and source indicated. The certification must 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:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/appr-prod/default.aspx

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

Maintenance of Certification

Manufacturers must request to be recertified annually. The preferred time to do this is early in the year and before construction work starts. The request must be received in writing within one year of the previous certification date or the certified status will be terminated. The submittal must 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 acceptable 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.

Department costs for pretesting and increased verification or acceptance sampling & testing are paid for by the manufacturer or their agent unless the department agrees otherwise.

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 acceptable 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, is at the department's discretion.

Department Contact Information

Manufacturers must 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, must 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 must also include brand, type, source, and lot of cement. These references will allow verification of test results by the state. The loading document must 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 acceptably monitor test properties of the cement.

A copy of the manufacturer's certified test analysis (mill test report) for the production lot sampled must be furnished by the contractor and submitted with the sample. In addition, ready-mix and on-site plants must 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 unacceptable 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).

Attachment 870-2 Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method - Super Air Meter (SAM)

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 >0.81 will result in a P-Error.
    - Almost always an unintended press of the top lever.