ATM 501 Sampling Freshly Mixed Concrete

Following are guidelines for the use of WAQTC FOP for WAQTC TM 2 by the State of Alaska DOT&PF.

1. Under required Apparatus, Apparatus for wet sieving, add the following clarification:

Mixes with aggregates larger than 1.5 inch apparatus for wet sieving, including: a sieve(s), conforming to AASHTO M 92 (ASTM E11), minimum of 2 ft^2 (0.19 m^2) of sieving area, 1.5 inch screen openings, and conveniently arranged and supported so that the sieve can be shaken rapidly by hand.

Delete and Replace Procedure 3.

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

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

  With

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

  The Department will take all samples from the delivery truck discharge. Obtain sample after a minimum of 1/2 m^3 (1/2 yd^3) of concrete has been discharged. Do not obtain samples from the very first or last portions of the batch discharge.

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SAMPLING FRESHLY MIXED CONCRETE
WAQTC TM 2

Scope

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

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

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

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

Apparatus

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

Procedure

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

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

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

   - **Sampling from stationary mixers**

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

- **Sampling from paving mixers**

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

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

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

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

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

- **Sampling from pump or conveyor placement systems (SEE GUIDANCE PAGE- AK only)**

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

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

Wet Sieving

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

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

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

Report

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

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ATM 502 Temperature of Freshly Mixed Portland Cement Concrete

Following are guidelines for the use of WAQTC FOP for AASHTO T 309 by the State of Alaska DOT&PF.

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

Scope

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

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

Apparatus

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

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

Standardization of Thermometer

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

Sample Locations and Times

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

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

Procedure

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

Report

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

ATM 503 Slump of Hydraulic Cement Concrete

Following are guidelines for the use of WAQTC FOP for AASHTO T 119 by the State of Alaska DOT&PF.

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SLUMP OF HYDRAULIC CEMENT CONCRETE
FOP FOR AASHTO T 119

Scope

This procedure provides instructions for determining the slump of hydraulic cement concrete in accordance with AASHTO T 119-18. It is not applicable to non-plastic and non-cohesive concrete.

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

Apparatus

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

Procedure

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

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

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

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

7. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in.) into the bottom layer. Distribute the strokes evenly.

8. Use the scoop to fill the mold to overflowing.

9. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in.) into the second layer. Distribute the strokes evenly. If the concrete falls below the top of the mold, stop, add more concrete, and continue rodding for a total of 25 strokes. Keep an excess amount of concrete above the top of the mold at all times. Distribute strokes evenly as before.

10. Strike off the top surface of concrete with a screeding and rolling motion of the tamping rod.

11. Clean overflow concrete away from the base of the mold.

12. Remove the mold from the concrete by raising it carefully in a vertical direction. Raise the mold 300 mm (12 in.) in 5 ±2 seconds by a steady upward lift with no lateral or torsional (twisting) motion being imparted to the concrete.

    Complete the entire operation from the start of the filling through removal of the mold without interruption within an elapsed time of 2 1/2 minutes.

13. Immediately measure the slump:

    a. Invert the slump mold and set it next to the specimen.

    b. Lay the tamping rod across the mold so that it is over the test specimen.

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

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

14. Discard the tested sample.

Report

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

ATM 504 Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

Following are guidelines for the use of WAQTC FOP for AASHTO T 121 by the State of Alaska DOT&PF.

1. Report the volume of the measure to 0.000001 m3 (0.0001 ft3).
2. Calculate aggregate free water mass as follows (use decimal form):

$$Free\ Water\ Mass = Total\ Aggregate\ Mass - Aggregate\ SSD\ Mass$$

$$Aggregate\ SSD\ Mass = \frac{Total\ Aggregate\ Mass}{1 + (Aggregate\ Moisture\ Content)} \times (1 + Percent\ Absorption)$$

3. Free water percentage = Total moisture content of aggregate – absorbed moisture

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

Scope

This method covers the determination of density, or unit weight, of freshly mixed concrete in accordance with AASHTO T 121-19. It also provides formulas for calculating the volume of concrete produced from a mixture of known quantities of component materials and provides a method for calculating cement content and cementitious material content – the mass of cement or cementitious material per unit volume of concrete. A procedure for calculating water/cement ratio is also covered.

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

Apparatus

- Measure: May be the bowl portion of the air meter used for determining air content under the FOP for AASHTO T 152. Otherwise, it shall be a cylindrical metal container meeting the requirements of AASHTO T 121. The capacity and dimensions of the measure shall conform to those specified in Table 1.
- Balance or scale: Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) longer than the depth of the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in.).
- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb) for use with measures of 0.014 m^3 (1/2 ft^3) or less or having a mass of 1.02 ±0.23 kg (2.25 ±0.5 lb) for use with measures of 0.028 m^3 (1 ft^3).

Table 1
Dimensions of Measures*

Capacity m^3 (ft^3)	Inside Diameter mm (in.)	Inside Height mm (in.)	Minimum Thicknesses mm (in.) Bottom	Minimum Thicknesses mm (in.) Wall	Nominal Maximum Size of Coarse Aggregate*** mm (in.)
0.0071	203 ±2.54	213 ±2.54	5.1	3.0	25
(1/4)**	(8.0 ±0.1)	(8.4 ±0.1)	(0.20)	(0.12)	(1)
0.0142	254 ±2.54	279 ±2.54	5.1	3.0	50
(1/2)	(10.0 ±0.1)	(11.0 ±0.1)	(0.20)	(0.12)	(2)
0.0283	356 ±2.54	284 ±2.54	5.1	3.0	76
(1)	(14.0 ±0.1)	(11.2 ±0.1)	(0.20)	(0.12)	(3)

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

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

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

Procedure Selection

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

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

Procedure

Sampling

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

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

Rodding

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

6. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.
8. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
9. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
10. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
11. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
12. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
13. Continue with 'Strike-off and Determining Mass.'

Internal Vibration

1. Determine and record the mass of the empty measure.
2. Dampen the inside of the measure and empty excess water.
3. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Insert the vibrator at three different points in each layer. Do not let the vibrator touch the bottom or side of the measure. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
5. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
6. Slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
7. Insert the vibrator at three different points, penetrating the first layer approximately 25 mm (1 in.). Do not let the vibrator touch the side of the measure.
8. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
9. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
10. Continue with 'Strike-off and Determining Mass.'

Self-Consolidating Concrete

1. Determine and record the mass of the empty measure.
2. Dampen the inside of the measure and empty excess water.

3. Use the scoop to slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Continue with 'Strike-off and Determining Mass.'

Strike-off and Determining Mass

1. Press the strike-off plate flat against the top surface, covering approximately 2/3 of the measure.
2. Withdraw the strike-off plate with a sawing motion to finish the 2/3 originally covered.
3. Cover the original 2/3 again with the plate; finishing the remaining 1/3 with a sawing motion (do not lift the plate; continue the sawing motion until the plate has cleared the surface of the measure).
4. Final finishing may be accomplished with several strokes with the inclined edge of the strike-off plate. The surface should be smooth and free of voids.
5. Clean off all excess concrete from the exterior of the measure including the rim.
6. Determine and record the mass of the measure and the concrete.
7. If the air content of the concrete is to be determined, ensure the rim (flange) is clean and proceed to 'Strike-off and Air Content' Step 3 of the FOP for AASHTO T 152.

Calculations

Mass of concrete in the measure

$$concrete\ mass = M_c - M_m$$

Where:

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

Density

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

Where:

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

Yield m^3

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

Where:

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

Yield yd^3

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

Where:

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

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

Cement Content

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

Where:

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

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

Water Content

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

– water added at batch plant

– water added in transit

– water added at jobsite

– free water on coarse aggregate*

– free water on fine aggregate*

– liquid admixtures (if required by the agency)

*Mass of free water on aggregate

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

Table 2
Liquid Conversion Factors

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

Mass of free water on aggregate (See Guidance Page)

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

Where:

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

Water/Cement Ratio

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

Where:

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

Example

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

From batch ticket:

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

Other

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

Density

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

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

Given:

concrete mass = 16.920 kg (36.06 lb)

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

Yield m^3

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

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

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

Yield yd^3

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

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

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

Cement Content

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

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

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

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

Free water

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

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

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

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

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

Given:

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

Water Content

Total of all water in the mix.

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

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

Given:

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

Water/ Cement Ratio

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

Report 0.46

Report

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

ANNEX A – STANDARDIZATION OF MEASURE

(Mandatory Information)

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

Apparatus

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

Procedure

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

Calculations

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

Where:

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

Example

Mass of water in Measure = 7.062 kg (15.53 lb)

Density of water at 23°C (73.4°F) (ρw) = 997.54 kg/m3 (62.274 lb/ft3)

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

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

°C	(°F)	kg/m^3	(lb/ft^3)	°C	(°F)	kg/m^3	(lb/ft^3)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Report

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

ATM 505 Air Content of Freshly Mixed Concrete by the Pressure Method

Following are guidelines for the use of WAQTC FOP for AASHTO T 152 by the State of Alaska DOT&PF.

- An alternate calibration procedure may be used as found in Standard Practice 8.
- Correction Factors should be checked for each new aggregate source and for sources that have a history of a correction factor in excess of 0.4 percent.
- If the slump is 1 in or less, consolidate by vibrator. If the slump is above 1 in, consolidate by rodding. Concrete for curb and gutter shall be rodded regardless of slump.

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

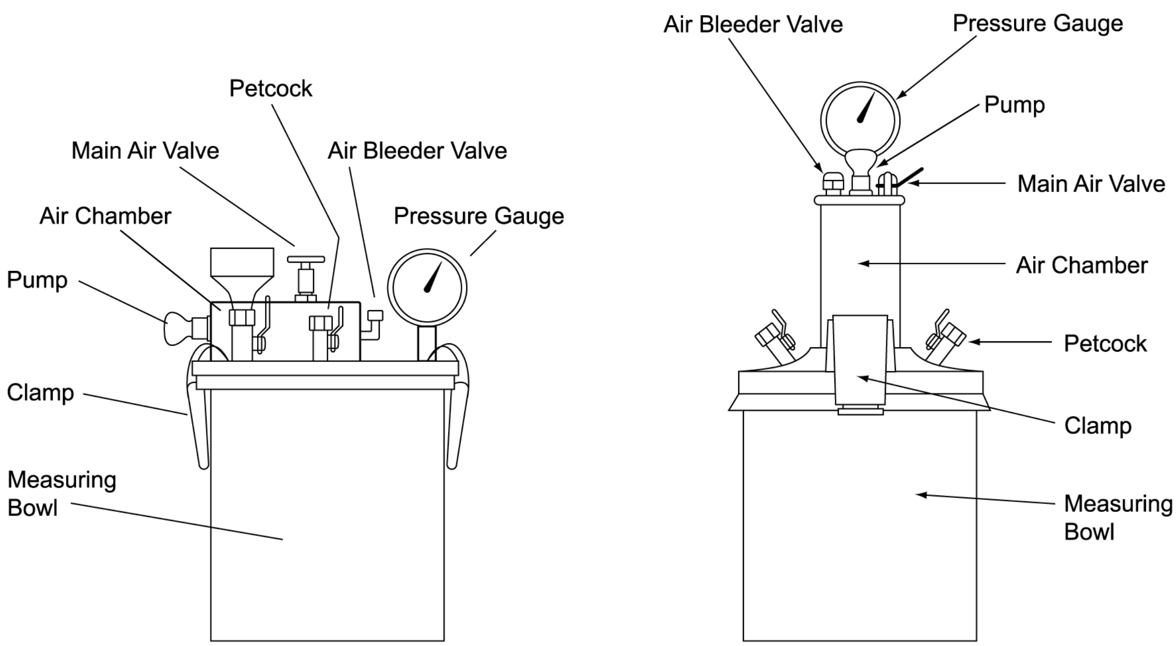
Scope

This procedure covers determination of the air content in freshly mixed Portland Cement Concrete containing dense aggregates in accordance with AASHTO T 152-19, Type B meter. It is not for use with lightweight or highly porous aggregates. This procedure includes standardization of the Type B air meter gauge, Annex A.

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

Apparatus

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



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

Type B Meter

- Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use (for Method 1 standardization only)
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) than the depth of the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Container for water: rubber syringe (may also be a squeeze bottle)

- Strike-off bar: Approximately 300 mm x 22 mm x 3 mm (12 in. x 3/4 in. x 1/8 in.)
- Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in.).

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

Procedure Selection

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

Procedure

Sampling

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

Testing shall begin within five minutes of obtaining the sample.

Rodding

1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to fill the measure approximately 1/3 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.
4. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.
5. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.
7. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
8. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
9. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
10. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
11. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the trowel or scoop. If the measure is under full, add a small

quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.

12. Continue with 'Strike-off and Air Content.'

Internal Vibration

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

Self-Consolidating Concrete

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

Strike-Off and Air Content

1. Strike off the surface of the concrete and finish it smoothly with a sawing action of the strike-off bar or plate, using great care to leave the measure just full. The surface should be smooth and free of voids.
2. Clean the top flange of the measure to ensure a proper seal.
3. Moisten the inside of the cover and check to see that both petcocks are open, and the main air valve is closed.
4. Clamp the cover on the measure.
5. Inject water through a petcock on the cover until water emerges from the petcock on the opposite side. Jar the meter gently until all air is expelled from this same petcock.
6. Verify that water is present in both petcocks.
7. Close the air bleeder valve and pump air into the air chamber until the needle goes past the initial pressure determined for the gauge. Allow a few seconds for the compressed air to cool.

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

Report

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

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

  (See AASHTO T 152 for more information.)

ANNEX A
STANDARDIZATION OF AIR METER GAUGE

(Mandatory Information)

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

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

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

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

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

11. Remove the curved tube. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
12. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle is stabilized. The gauge should now read 5.0 ±0.1 percent. If the gauge is

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

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

Report

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

ATM 506 Making and Curing Concrete Test Specimens in the Field

Following are guidelines for the use of WAQTC FOP for AASHTO R 100 by the State of Alaska DOT&PF.

- Under "Apparatus" add:

  Shims

  Bubble Level

- When Concrete test specimens are made in conjunction with other testing, (WAQTC FOP for AASHTO T 121 and WAQTC FOP for AASHTO T 152), the same method of consolidation must be used for all tests.

- When cylinders must be transported, transportation time shall not exceed 8 hours. If this transportation time requirement cannot be met, the transportation time must be approved by the Engineer in writing prior to transporting.

- Acceptance testing may be done with either 150 mm by 300 mm (6 in by 12 in) cylinders or 100 mm by 200 mm (4 in by 8 in) cylinders.

- For "Method 1- Initial cure in a temperature controlled chest-type curing box" between step 1 and step 2 insert:

  Place the curing box in an area that will not be disturbed by construction activities. Ensure curing box is level, use shims if needed.

- For "Method 2 - Initial cure by burying in earth or by using a curing box over the cylinder" before step 1 add:

  Choose a curing location that will not be disturbed by construction activities.

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

Scope

This practice covers the method for making, initially curing, and transporting concrete test specimens in the field in accordance with AASHTO R 100-22.

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

Apparatus

- Concrete cylinder molds: Conforming to AASHTO M 205 with a length equal to twice the diameter. Standard specimens shall be 150 mm (6 in.) by 300 mm (12 in.) cylinders. Mold diameter must be at least three times the maximum aggregate size unless wet sieving is conducted according to the FOP for WAQTC TM 2. Agency specifications may allow cylinder molds of 100 mm (4 in.) by 200 mm (8 in.) when the nominal maximum aggregate size does not exceed 25 mm (1 in.).
- Beam molds: Rectangular in shape with ends and sides at right angles to each other. Must be sufficiently rigid to resist warpage. Surfaces must be smooth. Molds shall produce length no more than 1.6 mm (1/16 in.) shorter than that required (greater length is allowed). Maximum variation from nominal cross section shall not exceed 3.2 mm (1/8 in.). Ratio of width to depth may not exceed 1:5; the smaller dimension must be at least 3 times the maximum aggregate size. Standard beam molds shall result in specimens having width and depth of not less than 150 mm (6 in.). Agency specifications may allow beam molds of 100 mm (4 in.) by 100 mm (4 in.) when the nominal maximum aggregate size does not exceed 25 mm (1 in.). Specimens shall be cast and hardened with the long axes horizontal.
- Standard tamping rod: 16 mm (5/8 in.) in diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 150 mm (6 in.) x 300 mm (12 in.) cylinders.
- Small tamping rod: 10 mm (3/8 in.) diameter and 305 mm (12 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 100 mm (4 in.) x 200 mm (8 in.) cylinders.
- Vibrator: At least 9000 vibrations per minute, with a diameter no more than ¼ the diameter or width of the mold and at least 75 mm (3 in.) longer than the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Trowel or float
- Mallet: With a rubber or rawhide head having a mass of 0.57 ±0.23 kg (1.25 ±0.5 lb.).
- Rigid base plates and cover plates: may be metal, glass, or plywood.
- Initial curing facilities: Temperature-controlled curing box or enclosure capable of maintaining the required range of 16 to 27°C (60 to 80°F) during the entire initial curing period (for concrete with compressive strength of 40 Mpa (6000 psi) or more, the temperature shall be 20 to 26°C (68 to 78°F). As an alternative, sand or earth for initial cylinder protection may be used provided that the required temperature range is maintained, and the specimens are not damaged.

- Thermometer: Capable of registering both maximum and minimum temperatures during the initial cure meeting the requirements for FOP for AASHTO T 309.

Procedure – Making Specimens – General

1. Obtain the sample according to the FOP for WAQTC TM 2.
2. Wet Sieving per the FOP for WAQTC TM 2 is required for 150 mm (6 in.) diameter specimens containing aggregate with a nominal maximum size greater than 50 mm (2 in.); screen the sample over the 50 mm (2 in.) sieve.
3. Remix the sample after transporting to testing location.
4. Begin making specimens within 15 minutes of obtaining the sample.
5. Set molds upright on a level, rigid base in a location free from vibration and relatively close to where they will be stored.
6. Fill molds in the required number of layers, attempting to slightly overfill the mold on the final layer. Add or remove concrete before completion of consolidation to avoid a deficiency or excess of concrete.
7. There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 25 mm (1 in.), consolidation may be by rodding or vibration. When the slump is 25 mm (1 in.) or less, consolidate the sample by internal vibration. Agency specifications may dictate when rodding or vibration will be used.

Procedure – Making Cylinders –Self-Consolidating Concrete

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

Procedure – Making Cylinders – Rodding

1. For the standard 150 mm (6 in.) by 300 mm (12 in.) specimen, fill each mold in three approximately equal layers, moving the scoop or trowel around the perimeter of the mold to evenly distribute the concrete. For the 100 mm (4 in.) by 200 mm (8 in.) specimen, fill the mold in two layers. When filling the final layer, slightly overfill the mold.
2. Consolidate each layer with 25 strokes of the appropriate tamping rod, using the rounded end. Distribute strokes evenly over the cross section of the concrete. Rod the first layer throughout its depth without forcibly hitting the bottom. For subsequent layers, rod the layer throughout its depth penetrating approximately 25 mm (1 in.) into the underlying layer.
3. After rodding each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Procedure – Making Cylinders – Internal Vibration

1. Fill the mold in two layers.

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

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

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

4. After vibrating each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).

5. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.

6. Immediately begin initial curing.

Procedure – Making Flexural Beams – Rodding

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

2. Consolidate each layer with the tamping rod once for every 1300 mm^2 (2 in^2) using the rounded end. Rod each layer throughout its depth, taking care to not forcibly strike the bottom of the mold when compacting the first layer. Rod the second layer throughout its depth, penetrating approximately 25 mm (1 in.) into the lower layer.

3. After rodding each layer, strike the mold 10 to 15 times with the mallet and spade along the sides and end using a trowel.

4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.

5. Immediately begin initial curing.

Procedure – Making Flexural Beams – Vibration

1. Fill the mold to overflowing in one layer.

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

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

4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.

5. Immediately begin initial curing.

Procedure – Initial Curing

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

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

- Prevent loss of moisture.

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

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

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

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

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

Procedure – Transporting Specimens

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

Final Curing

- Upon receiving cylinders at the laboratory, remove the cylinder from the mold and apply the appropriate identification.
- For all specimens (cylinders or beams), final curing must be started within 30 minutes of mold removal. Temperature shall be maintained at 23° ±2°C (73 ±3°F). Free moisture must be present on the surfaces of the specimens during the entire curing period. Curing may be accomplished in a moist room or water tank conforming to AASHTO M 201.

- For cylinders, during the final 3 hours before testing the temperature requirement may be waived, but free moisture must be maintained on specimen surfaces at all times until tested and ambient temperature is between 20 to 30°C (68 to 80°F).
- Final curing of beams must include immersion in lime-saturated water for at least 20 hours before testing.

Report

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

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ATM 507 Field Sampling and Fabrication of 50 mm (2 in.) Cube Specimens using Grout (Non-Shrink) and or Mortar

Following are guidelines for the use of FOP for AASHTO R 64 by the State of Alaska DOT&PF.

1. Three specimens shall be cast for each test age required.
2. Applicable sections of AASHTO T 106 shall be followed for final curing, testing compressive strength and reporting test results.

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FIELD SAMPLING AND FABRICATION OF 50 MM (2 IN.) CUBE SPECIMENS USING GROUT (NON-SHRINK) AND OR MORTOR
WAQTC FOP FOR AASHTO R 64

1. Scope

This method covers field sampling and fabrication and initial curing of 50 mm (2 in.) cube specimens of non-shrink grout and/or mortar materials.

The values stated in either SI or inch-pound units shall be regarded separately as standard. The inch-pound units are shown in brackets. The values stated might not be exact equivalents; therefore, each system must be used independently of the other.

Note 1: Unit weight was the previous terminology used to describe the property determined by this test method, which is mass per unit volume.

The text of this test method references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this test method.

Warning—This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

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

2. Referenced Documents

- ASTM C 1107 Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Non-shrink)
- AASHTO T 106 / ASTM C 109 Test method for Compressive Strength of Hydraulic Cement Mortars (Using 50 mm or 2 in. Cube Specimens.)

3. Definitions

Fluid mix: Material fluid enough that little or no indentation will be left in the surface after puddling.

Plastic mix: Material viscous enough that an indentation will be left in the surface of the grout after tamping.

4. Apparatus

- Specimen Molds including cover plate (s): The 2 in. (50 mm) cube specimen molds shall be tight fitting and made of brass or other suitable material. This material shall not be susceptible to attack by the cement mortar. The molds shall have not more than three (3) cube compartments and shall be separable into not more than two (2) parts. The parts of the molds, when assembled, shall be positively held together. The cover plate(s) working surface shall be plane and shall be positively attached to the side walls of the mold. The interior faces of the molds shall conform to the tolerances of Table 1.

Table 1

Permissible Variations of Specimen Molds				
2 in. Cube Molds			50 mm Cube Molds	
Parameter	New	In Use	New	In Use
Planeness of Sides	<0.001 in.	<0.002 in.	<0.025 mm	<0.05 mm
Distance Between Opposite Sides	2 in .± 0.005 in.	2 in. ± 0.02 in.	50 mm ± 0.13 mm	50 mm ± 0.50 mm
Height of Each Compartment	2 in. + 0.01 in. to -0.005 in.	2 in + 0.01 in. to -0.015 in.	50 mm + 0.25 mm to -0.13 mm	50 mm + 0.25 mm to -0.38 mm
Angle Between Adjacent Faces [A]	90 ± 0.5°	90 ± 0.5°	90 ± 0.5°	90 ± 0.5°

[A] Measured at points slightly removed from the intersection. Measured separately for each compartment between all the interior faces and the adjacent face and between interior faces and top and bottom planes of the mold.

- Tamper: A non-absorptive, nonabrasive, non-brittle material such as a hard rubber compound having a Shore A durometer hardness of 80 ± 10. The tamper shall have a cross section of about 1/2 in. × 1 in. (13 mm × 25 mm) and a length of 5 in. to 6 in. (125 mm to 150 mm). The tamping face shall be flat and at right angles to the length of the tamper.
- Trowel: Steel bladed 100 to 150 mm (4 in to 6 in) in length, with straight edges.
- Water tight container: a 150 mm × 300 mm (6 in × 12 in) concrete cylinder mold with lid
- Other Equipment: Rubber gloves, scoop, clamps to secure the cover plate, light release oil for oiling the molds, small brush or lint-free cloth for applying and removing excess release oil, burlap or wrapping cloth capable of retaining moisture.

5. Sampling

1. Samples shall be obtained in accordance with WAQTC TM 2 when the batch equals or exceeds 1 m^3 (1 yd^3). When the batch is less than 1 m^3 (1 yd^3) sample from the batch after discharge. If remixing is required sample after remixing. Begin molding the specimens within an elapsed time of not more than 2 1/2 minutes from completion of the mixing.

   Note 2: Use this test for grouts with 100% passing the 9.5 mm (3/8 inch) sieve.

2. Obtain a representative sample of the mix. Samples shall be a minimum size of 2000 g (4 lb) for each set of three (3) cubes to be fabricated.

6. Procedure

1. Assemble both portions of the mold and the bottom cover plate. All joints shall be water tight. If not water tight, seal the surfaces where the halves of the mold join by applying a coating of light cup grease (non water soluble). The amount should be sufficient to extrude slightly when the halves are tightened together. Repeat this process for attaching the mold to the bottom cover plate. Remove any excess grease. Apply a thin coating of release agent to the interior faces of the mold and the bottom cover plate. Wipe the mold faces and base plate as necessary to remove any excess release agent and to achieve a thin, even coating on the interior surfaces. Adequate coating is that which is just sufficient to allow a distinct fingerprint to remain following light finger pressure.
2. Place a layer of grout about 25 mm (1 in) (approximately one-half of the depth of the mold) in all of the cube compartments. Consolidated according to the consistency (plastic or fluid) of the mix.

a. For plastic mixes, tamp the lift in four rounds of 8 tamps for a total of 32 tamps with the rubber tamper in 10 seconds. See Figure 1 for tamping sequence of each round. Rounds 1 and 3; and rounds 2 and 4 shall be the same.

b. For fluid mixes, puddle the lift 5 times with a gloved finger. See Figure 2 for puddling sequence.

3. Place the second lift in each of the cube compartments, slightly over-filling each compartment Consolidate the material in the same fashion as the first lift with the additional requirement that during consolidation of the second lift any grout forced out onto the top of the mold after each round will be pushed back onto the compartment by means of the tamper and/or gloved fingers before the next consolidation round. When consolidation of the grout is completed, material should extend slightly above the top of the mold. Push any grout forced out onto the top of the mold after the last round back onto the compartment with the trowel.

4. Smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mold. Then, for the purpose of leveling the mortar and making the mortar that protrudes above the top of the mold of more uniform thickness, draw the flat trailing edge of the trowel (with leading edge slightly raised) once lightly along the length of the mold. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion over the length of the mold. The material shall be flush with the top of the mold.

5. Immediately secure the top cover plate to the cube mold.

6. *Initial Curing* - Place the molds in a secure location away from vibration and as close as possible to the structure for initial curing. Cover with wet burlap, towels, or rags, seal it in a plastic sack in a level location out of direct sunlight, and record the time. These samples shall remain undisturbed and protected from freezing or overheating for a period of 24 to 28 hours.

7. At the end of the initial curing period as required by the agency either;

   a. Place the sealed plastic sack into a water tight container. Transport the cube samples immediately to the location of final curing. During transport, the cube samples shall be protected from jarring, freezing, and moisture loss.

   b. Disassemble the mold and carefully remove the cube samples. Using a permanent marker, identify the cube samples. Handling the cube samples very carefully, wrap them in wet burlap or wet towels and place them into a water tight container. Transport the cube samples immediately to the location of final curing. During transport, the cube samples shall be protected from jarring, freezing, and moisture loss.

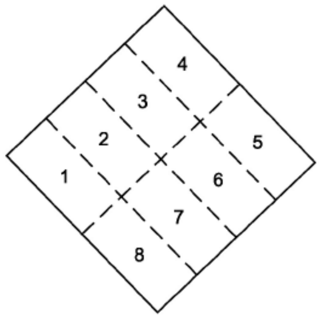
Final curing shall consist of immersing the cube samples in a lime-saturated water storage tank at a temperature of 23.0 ± 2.0°C (73.5 ± 3.5°F). They are to remain in the storage tank until time of test. (Curing cube samples of material other than hydraulic cement shall be in conformance with the manufacturer's recommendations.) The storage tank shall be made of non-corroding materials.

7. Report

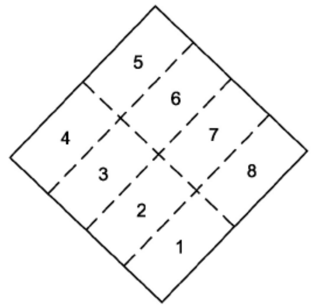
- On forms approved by the Department
- Date
- Time
- Location, source and sampling method

- Quantity represented

Figure 1 – Plastic Mixes

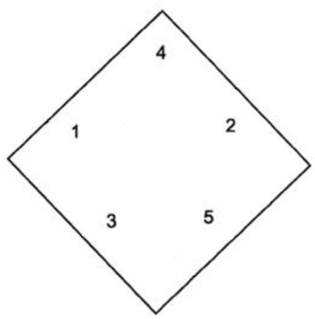


Rounds 1 and 3



Rounds 2 and 4

Figure 2 – Fluid Mixes



Puddling sequence

ATM 508 Slump Flow of Self-Consolidating Concrete

1. Scope

This procedure provides instructions for determining the slump flow of self-consolidating concrete (SCC) in accordance with ASTM C1611/C1611M.

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

2. Apparatus

- Cone: The SCC shall be placed in a slump cone mold conforming to the applicable requirements of ATM 503.
- Sample receptacle: Pan or wheel barrow that is water tight, has a non-absorbent surface, and large enough to retain a volume of concrete sufficient to perform all necessary testing and to fill all necessary sample specimen containers.
- Base plate: Flat, rigid, non-absorbent moistened surface having a minimum diameter of 915 mm (36 in.).
- Scoop or Pouring Vessel: A water tight container having a volume such that concrete is not spilled during placement in the mold.
- Strike-off bar: A flat straight steel bar, at least 3mm x 20 mm x 300 mm (1/8 x3/4 x 12 inches), or plastic bar twice as thick as the steel bar.
- Tape measure or ruler with at least 5 mm or 1/4 in. graduations.

3. Procedure

1. Obtain the sample in accordance with ATM 501.

   Note 1: Testing shall begin within five minutes of obtaining the sample.

2. Remix sample using shovel or scoop.
3. Dampen the inside of the cone and the base plate.
4. Place cone in center of leveled base plate, in the inverted position, as shown in Figure 1.

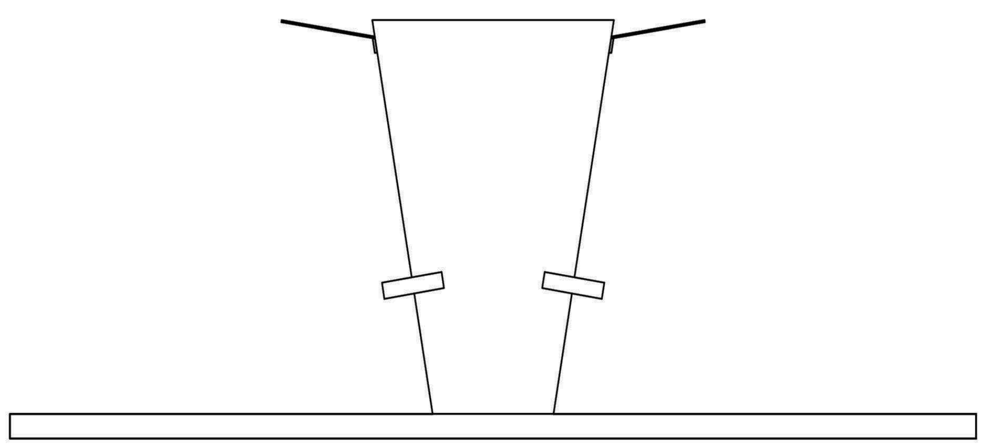


Figure 1

5. Fill the cone in one lift with a representative sample of concrete. Allow the concrete to flow into the cone without dropping the concrete from more than 5 inches above the inverted cone. Fill the cone slightly over full.

   Note 2: Do not rod concrete. Do not tap or vibrate the cone. If concrete has been rodded, tapped, or vibrated discard sample, the test is invalid.

6. Strike off the top surface of concrete level with the top of the cone with a screeding motion of the strike-off bar.

7. Remove any spilled or struck off concrete from around the base of the cone so it does not inhibit the flow of the SCC mix.

8. Raise the cone vertically with a smooth fluid motion, without twisting or jerking, in 3 ± 1 seconds.

   Note 3: Complete the entire test from the start of filling through removal of the cone without interruption within an elapsed time of 2 ½ minutes.

9. Wait for the concrete to stop flowing and then measure the largest diameter (d_1) of the resulting spread of concrete. When a halo is observed in the resulting circular spread of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter (d_2) of the circular spread of concrete at an angle approximately perpendicular to the first measured diameter (d_1). Measure the diameters to the nearest 5mm [1/4 in].

4. Calculation

Calculate the Slump Flow as follows:

$$\text{Slump flow} = (d_1 + d_2)/2$$

Where:

d_1 = the largest diameter of the circular spread of the concrete, and
d_2 = the circular spread of the concrete at an angle perpendicular to d_1.

1. If the measurement of the two diameters differs by more than 50 mm [2 in.], the test is invalid and shall be repeated.

2. Record the average of the two diameters to the nearest 10 mm [1/2 in.].

5. Report

1. On forms approved by the Department

2. Date

3. Time

4. Location, source and sampling method

5. Quantity represented

6. Report the slump flow to the nearest 10 mm [1/2 in.].

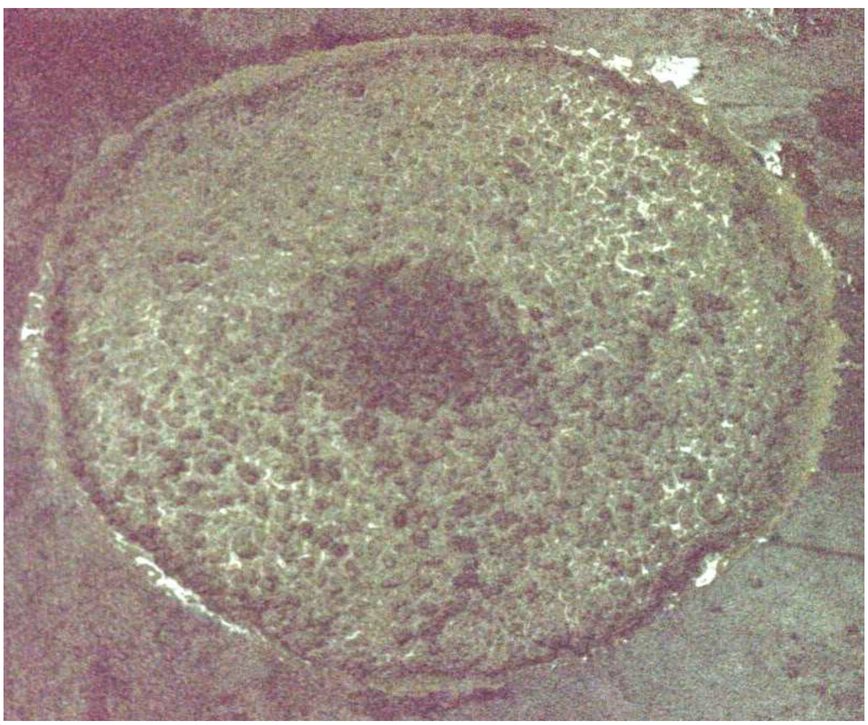
7. Report visual segregation index (VSI) based on photos below; matching nearest photo.

Figure 2: Examples for visual inspection of slump flow.

VSI 0: Stable mix, no evidence of segregation or bleeding.

VSI 1: Stable mix, only slight bleeding.

VSI 2: Unstable mix, visible separation around edges (halo) and bleeding.



VSI 3: Unstable mix, visible halo around edges, segregation in middle, excessive bleeding.

ATM 509 Fabricating Test Specimens with Self-Consolidating Concrete

1. Scope

This procedure provides instructions for fabricating test specimens in the laboratory or field using a sample of freshly mixed self-consolidating concrete (SCC). This practice is applicable to SCC with a nominal maximum aggregate size of 25 mm [1 in.] and a slump flow of 500 mm [20 in.] or greater. If the slump flow is less than 500 mm [20 in.] follow the fabrication procedures described in the standard for which the test specimen is required.

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

2. Apparatus

- Cylinder Molds: Molds for casting SCC specimens shall conform to the requirements of ATM 506.
- Beam Molds: Molds for casting SCC specimens shall conform to requirements of ATM 506.
- Scoop or Pouring Vessel: A water tight container having a volume such that concrete is not spilled during placement in the mold.
- Strike-off bar, trowel or float.

3. Procedure

1. Obtain the sample in accordance with ATM 501.
2. After transporting sample to testing location remix sample using shovel or scoop.
3. Begin making specimens within 15 minutes of obtaining the sample.
4. Fill the mold with a representative sample of concrete. Slightly overfill by tilting the scoop and pouring the sample around the perimeter of the mold to allow the SCC to flow into the mold and to ensure an even distribution of concrete.

   Note 1: Do not rod the concrete or tap the sides of the specimen mold.

   Note 2: If slump flow is below 500 mm [20 in.] follow standard procedures for fabricating test specimens found in ATM 506.

5. After filling, strike off the mold with either the strike off bar, trowel or float. Cover specimens and immediately place on a flat, level surface for initial curing in accordance with ATM 506.
6. After initial curing, follow transporting and final curing procedures listed in ATM 506.

4. Report

- On forms approved by the Department
- Date and Time
- Location, source and sampling method
- Quantity represented

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ATM 520 Certified Precast Concrete Plant Program

1. Scope

This procedure covers the requirements for listing precast concrete products (products) on the Alaska Department of Transportation & Public Facilities (DOT&PF) Qualified Products List (QPL).

Note: QPL link: www.dot.state.ak.us/qploracle/#stage/advancesearch

2. References

Retain copies of the most recent AASHTO and ASTM test methods on file in the precast plant for each product produced and for the applicable quality control tests.

AASHTO Standards

- M 86M Concrete Sewer, Storm Drain, and Culvert Pipe
- M 170 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
- M 199 Precast Reinforced Concrete Manhole Sections
- R 60 Sampling Freshly Mixed Concrete
- R 81 Static Segregation of Hardened Self-Consolidating Concrete (SCC) Cylinders
- T 22 Compressive Strength of Cylindrical Concrete Specimens
- T 23 Making and Curing Concrete Test Specimens in the Field
- T 24 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- T 119 Slump of Hydraulic Cement Concrete
- T 121 Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
- T 152 Air Content of Freshly Mixed Concrete by the Pressure Method
- T 196 Air Content of Freshly Mixed Concrete by the Volumetric Method
- T 280 Concrete Pipe, Manhole Sections, or Tile
- T 309 Temperature of Freshly Mixed Portland Cement
- T 347 Slump Flow of Self-Consolidating Concrete (SCC)
- T 351 Visual Stability Index (VSI) of Self-Consolidating Concrete SCC)

ASTM Standards

- A615 Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
- C31 Making and Curing Concrete Test Specimens in the Field
- C39 Compressive Strength of Cylindrical Concrete Specimens
- C42 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- C138 Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
- C143 Slump of Hydraulic Cement Concrete
- C172 Sampling Freshly Mix Concrete

- C173 Air Content of Freshly Mixed Concrete by the Volumetric Method
- C231 Air Content of Freshly Mixed Concrete by the Pressure Method
- C478 Circular Precast Reinforced Concrete Manhole Sections
- C497 Concrete Pipe, Concrete Box Sections, Manhole Sections
- C825 Precast Concrete Barriers
- C858 Underground Precast Concrete Utility Structures
- C913 Precast Concrete Water and Wastewater Structures
- C1064 Temperature of Freshly Mixed Hydraulic-Cement Concrete
- C1611 Slump Flow of Self-Consolidating Concrete
- C1758 Fabricating Specimens with Self-Consolidating Concrete
- C1776 Wet-Cast Precast Modular Retaining Wall Units
- D4101 Polypropylene Injection and Extrusion Materials

ATMM Test Methods

- ATM 530 Concrete Mix Designs by ACI & Packing Density Methods

3. Abbreviations and Definitions

Definitions for terms and abbreviations shall be according to the Department's Standard Specifications for Highway Construction, Section 101 and the following:

Abbreviations

- **ACPA.** American Concrete Pipe Association
- **ATM.** Alaska Test Method
- **ATMM.** Alaska Test Method Manual
- **NTPEP.** National Transportation Product Evaluation Program
- **NPCA.** National Precast Concrete Association
- **PCI.** Precast/Prestressed Concrete Institute
- **QA.** Quality Assurance
- **QAI.** Quality Assurance Inspector
- **QAE.** Quality Assurance Engineer
- **QC.** Quality Control
- **QCP.** Quality Control Plan
- **QPL.** Qualified Products List

Definitions

Addenda. Any addition or deletion to the QCP.

Audit. An inspection conducted by an independent party selected by the ACPA, NPCA, PCI or DOT&PF that verifies compliance with the Department's Certified Precast Plant Program

Plant. A precast concrete plant certified by ACPA, NPCA, PCI or DOT&PF according to ATM 520.

Quality Control Plan (QCP). Quality Control Plan for the plant that is site-specific and specifies the production, policies and procedures used by the plant. QCP includes materials testing frequencies of Table 1 & 2 items.

Qualified Products List (QPL). Qualified Products List is a compilation of products, sources, equipment, or other specified items approved for use on a Department Contract. The QPL includes the manufacturer (Certified Precast Concrete Plant) and date of the last audit for each product.

4. Significance and Use

Precast concrete products, meeting Contract requirements, along with the certified precast concrete plant (manufacturer) are included on the QPL.

5. Plant Personnel

Management Representative. The liaison with the Department responsible for all aspects of production and quality control required by the ATM 520.

Quality Control Technician. Certified as an ACI Concrete Field Testing technician, Grade I, or a WAQTC Concrete Testing Technician.

6. Materials

Provide materials incorporated into precast concrete products meeting the specifications of Table III and the following criteria:

a. Chemical admixtures approved by the State Quality Assurance Engineer.

b. Aggregates meeting requirements of ATM 530, Section 4. Aggregates.

c. Cement approved by the State Quality Assurance Engineer.

d. Manhole steps meeting the requirements of ASTM C478 and AASHTO M 199 with polypropylene conforming to ASTM D4101 and #4 (1/2") Grade 60 reinforcing bar conforming to ASTM A615.

e. Pozzolans approved by the State Quality Assurance Engineer.

f. Reinforcing steel sourced from a NTPEP Certified Manufacturer and meeting Buy America (FHWA funded projects) and Buy American (FAA and FTA funded projects) requirements.

g. Welded wire reinforcement sourced from a NTPEP Certified Manufacturer and meeting Buy America (FHWA funded projects) and Buy American (FAA and FTA funded projects) requirements.

h. Repair materials according to the QCP.

Materials Testing

Test aggregates used to make concrete for precast products at the frequencies required in the QCP and according to **Table 1**.

Table 1
Aggregate Tests

Test	Alaska Test Method	AASHTO Test Method	ASTM Test Method
Fine Aggregate			
Sticks and Roots Content	ATM 201		
Sodium Sulfate Soundness		T 104	C88
Material finer than #200 sieve by washing	ATM 304	T 11	C117
Organic Impurities		T 21	C40
Sieve Analysis of Aggregate	ATM 304	T 27	C136
Specific Gravity of Fine Aggregate		T 84	C128
Coarse Aggregate			
Sticks and Roots Content	ATM 201		
Sodium Sulfate Soundness		T 104	C88
Clay Lumps and Friable Particles		T 112	C142
Lightweight Pieces in Aggregate (Chert)		T 113	C132
Material finer than #200 sieve by washing	ATM 304	T 11	C117
Sieve Analysis of Aggregate	ATM 304	T 27	C136
Specific Gravity of Coarse Aggregate	ATM 308	T 85	C127
Los Angeles Abrasion		T 96	C131

The Plant shall test the precast products at the frequencies required in the QCP and according to **Table 2**.

Table 2
Precast Product Tests

Test	AASHTO Test Method	ASTM Test Method
Absorption	T 280	C497
Air Content (Pressure Method)	T 152	C231
Air Content (Volumetric Method)	T 196	C173
Super Air Meter (SAM) Number	T 395	
Compressive Strength	T 22	C39
Concrete Cores	T 24	C42
Making and Curing Concrete Specimens	T 23	C31
Sampling Concrete	R 60	C172
Slump	T 119	C143
Unit Weight	T 121	C138
Temperature	T 309	C1064
Slump Flow of Self-Consolidating Concrete (SCC)	T 347 & T 351	C1611
Fabricating Specimens with Self-Consolidating Concrete		C1758

Products

Table 3
Design Specifications for Certified Precast Concrete Plant Products

Products	Highway Specifications	Airport Specifications
Minor and Incidental Structure Products:	**Section 550 Commercial Concrete[a]**	**Item D-751 Manholes, Catch Basins, Inlets, and Inspection Holes**
Curb and Gutter	Section 609[a,b], Subsection 550-2.03[b]	
Manhole Sections	Section 604[a,b], Subsection 712-3.05[a] Subsection 550-2.03[b] ASTM C478, AASHTO M 199	Section 751-3.4[c] Precast Concrete Structures
Headwall	Subsection 550-2.03[b]	
Modular Retaining Wall Units	Subsection 550-2.03[b] ASTM C1776	
Noise Wall Panels and Posts	Subsection 550-2.03[b]	
Portable Barriers	Section 614[a,b] Subsection 550-2.03[b] ASTM C825	
Utility Structures; Cabinet Base (1) Load Center Base/Foundation, (2) Controller Base/Foundation, Junction Box, Similar Structures	Section 660[a,b] Section 662[b], Subsection 550-2.03[b] ASTM C858	
Water and Waste Water Structures; Catch Basin, Inlet Box, Outlet Box, Similar Structures	Subsection 550-2.03[b], ASTM C913	Section 751-2.8[c] Precast Inlet Structures

a. Standard Specifications for Highway Construction
b. Central Region Special, Project Special
c. Standard Specifications for Airport Construction

Product Marking

Precast concrete products shall be marked with the date of manufacturing, product identification number, ACPA, NPCA, PCI, or DOT&PF-approved supplier certification identification marking, and the applicable Standard Specification required marking.

- The ACPA product marking shall be the "QCast" emblem or the words "ACPA Certified Product".
- The NPCA marking shall be the words "NPCA Certified Product".
- The PCI marking shall be the "PCI certification" emblem or the words "PCI Certified Product".

Quality Control Plan

Each Plant providing precast concrete products under the ATM 520 shall have a plant-specific written QCP that is the basis of control. The QCP shall contain, but not be limited to, the methods of production and quality control policies and procedures used by the plant. The QCP shall be according to ACPA, NPCA, or PCI Plant Certification requirements and ATM 520.

7. Certification

The Certified Precast Concrete Plant Program is a program whereby the Plant takes responsibility for the production of quality precast concrete products according to contract requirements, and the Department performs quality assurance inspections and audits the Plant's quality control procedures.

The Certified Precast Concrete Plant Program currently uses the **Auditor Checklist** from the **NPCA Quality Control Manual 15th Edition** as the basis for initial qualification of the products made by a precast plant that may be listed on the Qualified Products List (QPL).

Note: ACPA and PCI Auditor Checklists are also acceptable. The Auditor must meet NPCA, ACPA or PCI qualifications or be a Registered Professional Civil or Structural Engineer with a minimum of three years of experience in precast concrete design, quality assurance, or production.

Provide the DOT&PF State Quality Assurance Engineer:

a. Copy of the compliance certificate issued by the auditing agency

b. Copy of the completed Auditor Checklist

c. Copy of the response to deficiencies of the audit (if applicable)

d. Copy of the QCP

e. List of products to be certified

f. Management Representative name and contact information

The State Quality Assurance Engineer will notify the Management Representative of any deficiencies and provide instruction for listing approved products on the QPL.

The Plant shall provide a certificate of compliance with each shipment to a DOT&PF project meeting the contract requirements.

Change of Ownership

In the event of a change in ownership of the Certified Precast Concrete Plant, the certification shall expire on the date of such change. The new ownership may avoid expiration by submitting a statement to the State Quality Assurance Engineer, before legal transfer, indicating recognition of the details of the Program and verification that the plant is according to the ACPA, NPCA, PCI, or DOT&PF certification program requirements.

Independent Audit

Each Certified Precast Concrete Plant is required to submit to State Quality Assurance Engineer a copy of the annual independent party audit and their response to deficiencies of the audit, if applicable, to verify compliance with the ACPA, NPCA, PCI, or DOT&PF certification programs.

Submit the annual audit documents before the end of the calendar year or within 16 months of the last audit date for the product(s). Include the manufacturer (Certified Precast Concrete Plant) and date of the last audit for each product submitted for listing on the QPL.

All products produced by a plant will be removed from the QPL if the ACPA, NPCA, PCI, or DOT&PF audit documents are not submitted within 16 months. The products will be removed from the Qualified Products List for a minimum of 12 months.

- Disqualified precast products may be submitted for listing after 12 months of compliance to the ACPA, NPCA, PCI, or DOT&PF Certification program by the plant.
- Product listing is subject to review and compliance with ATM 520 Item 7, Certification.

8. Department Responsibilities

DOT&PF reserves the right to inspect, sample, test, conduct random audits and review documentation at any time to ensure compliance with this Program.

Plants shall grant QAI(s) access to all portions of the plant and storage area. The QAI will check compliance to ATM 520, the Plant's QCP and ACPA, NPCA, PCI, or DOT&PF program requirements, and DOT&PF specifications. The QAI will document any noncompliance items and report them in writing to the Plant.

Non-compliance items include material control, quality control inspection, final product testing and records documentation that do not conform to the Plant's QCP and ACPA, NPCA, PCI, or DOT&PF program requirements, or DOT&PF specifications.

The Department will conduct comprehensive annual audits of plants renewing DOT&PF Certification and will review annual audits done by other national plant certification agencies such as; ACPA, NPCA and PCI.

The Department will conduct bi-monthly Quality Assurance inspections of plants during their production season. Bi-monthly inspections include; an annual absorption test for manholes (ASTM C497), QA testing that parallels QC testing of fresh concrete by plant personnel, verification of correct steel grade, size, placement, and Buy America or Buy American records, concrete QC records since the previous inspection, safety meeting minutes, batch tickets, housekeeping records, current test standards, and aggregate management. QC test results that vary from QA test results by more than the tolerances listed in Table 11-1 of the current Alaska Construction Manual will be reported, investigated and the cause corrected by the QAI during the inspection when possible. Unresolved disputes between test results will be resolve by third party testing in an accredited laboratory with certified technicians.

The Department may conduct QA Inspections at the project site where precast products are installed.

When an inspection identifies deficiencies, and or changes to the QCP, submit a plan detailing methods to correct the deficiencies within 30 days of receiving the inspection report. Submit a revised QCP if the changes require it.

A Plant's product(s) may be removed from the QPL for failure to correct deficiencies identified by Quality Assurance Inspections.

The removal of a product from the QPL will be the responsibility of the State Quality Assurance Engineer. The product manufacturer may appeal removal of a product from the Department's Qualified Products List to the State Materials Engineer.

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ATM 530 Concrete Mix Designs by ACI & Packing Density Methods

1. Scope

This method describes Optimization of concrete aggregate blends and Volumetric Mix Design procedures for flowable and slip-formed Portland Cement concrete mixtures. This method is appropriate for design of concrete mixtures classified by STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION under Section 501 Concrete for Structures as Class A or Class AA concrete and for all mixtures under Section 550 Commercial Concrete. This method conforms to the mix design process required by ACI 301, Specifications for Structural Concrete, Section 4, Concrete Mixtures. Flowable concrete applications include traditional ready-mix concrete such as sidewalks, floor slabs, fixed formed pavements, parking lots, walls, and pumpable concrete applications. Slip-formed paving includes curb and gutters, pavements, and highways that use a slip-formed paving machine. Combined Aggregate gradation bands are specified for flowable and slip-formed concrete mixtures. Self-consolidating concrete combined aggregate gradation band is included for reference. ACI 211 and Packing Density proportioning procedures are included in this method.

2. Significance

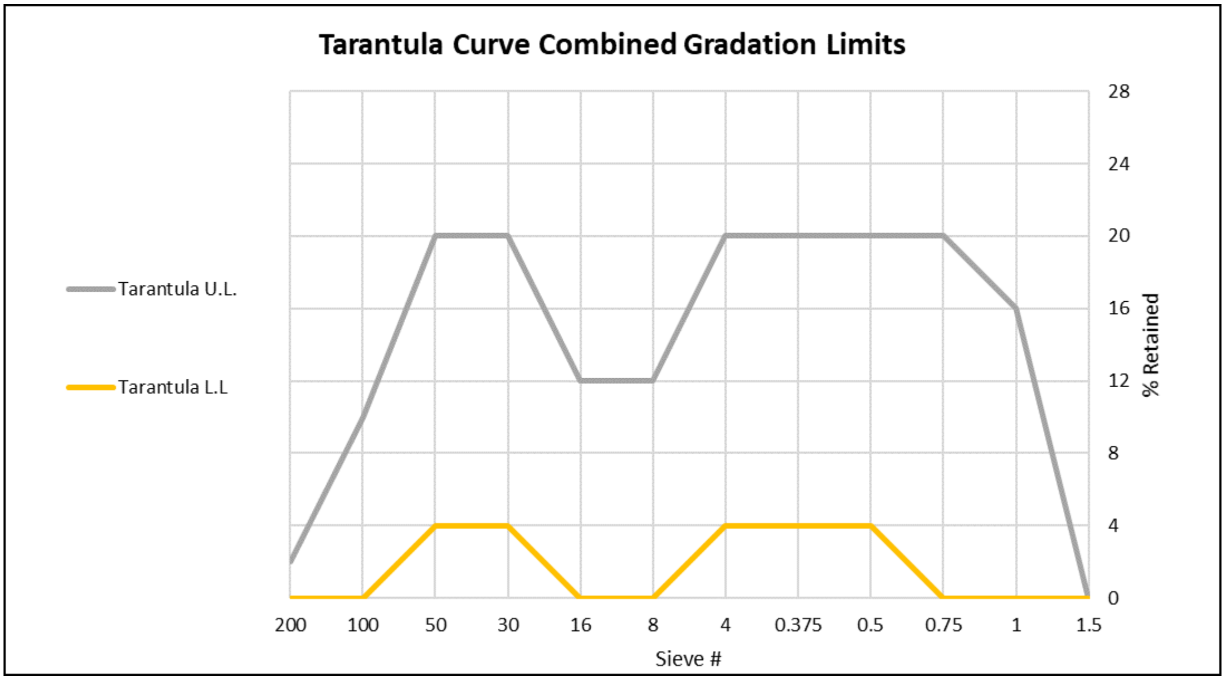
Concrete proportions, properties and performance are determined by the aggregate that forms most of the matrix of this composite material. For each sieve size the Tarantula Curve provides a recommended maximum retention limit and a suggested minimum retention limit. An adequate amount of coarse sand (#8 to #30) provides the cohesion properties of the concrete and reduces segregation. An adequate amount of fine sand (#30 to #200) provides the finishability, consolidation, and richness of a mixture. Historically many proportioning methods have been used to produce concrete. This method includes historic ACI 211 and newer Packing Density proportioning procedures.

3. Apparatus

- Ovens and hot plates thermostatically controlled to maintain the various required temperatures within ± 3°C (5°F).
- Fresh Concrete Testing equipment for Slump, Air, Unit Weight, and Temperature, AASHTO T 119, T 152, T 121, and ASTM C1064/C respectively.
- Water tank with temperature at 23.0 ± 1.7°C (73.4 ± 3.0°F) per AASHTO T 85.
- Balance or scale: Capacity sufficient for the principal sample mass, readable to 0.1 g or 0.1 percent of the total sample mass and meeting the requirements of AASHTO M 231.
- Sieve shaker meeting the requirements of WAQTC FOP for AASHTO T 27/T 11.
- Specimen molds with lids, either 4x8” or 6x12” that conform to ASTM C470.
- Compression testing machine meeting the requirements of ASTM C39 and referenced documents.
- Surface Resistivity testing apparatus meeting the requirements of AASHTO T 358.
- Shrinkage testing apparatus meeting the requirements of ASTM C157.
- Air-entrained concrete maximum bubble spacing factor of 0.008 inch by ASTM C457 or AASHTO T 395, Sequential Air Method (SAM) number ≤ 0.20 on fresh concrete.

4. Aggregates

Combined Aggregate gradations must be within the Tarantula Curve boundary limits for each sieve size.as follows:



4.1. Perform gradations in accordance with AASHTO T 11 and T 27

4.1.1. Flowable Concrete Combined Gradation

Specified Aggregate Gradation for Flowable Concrete:

Sieve #	1.5	1	0.75	0.5	0.38	4	8	16	30	50	100	200
Tarantula U.L. (% retained)	0	16	20	20	20	20	12	12	20	20	10	2
Tarantula L.L (% retained)	0	0	0	4	4	4	0	0	4	4	0	0

Flowable Concrete Sand Limits:

Coarse Sand % (#8-30) =	(Minimum is 20%)
Fine Sand % (#30-200) =	(Allowable range is 25-40%)

4.1.2. Slip-Formed Concrete Combined Gradation

Specified Aggregate Gradation for Slip-Formed Concrete:

Sieve #	1.5	1	0.75	0.5	0.38	4	8	16	30	50	100	200
Tarantula U.L. (% retained)	0	16	20	20	20	20	12	12	20	20	10	2
Tarantula L.L (% retained)	0	0	0	4	4	4	0	0	4	4	0	0

Slip-Formed Concrete Sand Limits:

Coarse Sand % (#8-30) =	(Minimum is 15%)
Fine Sand % (#30 - 200) =	(Allowable range is 24-34%)

4.1.3. Self-Consolidating Concrete Combined Gradation

Specified Aggregate Gradation for Self-Consolidating Concrete:

Sieve #	1.5	1	0.75	0.5	0.38	4	8	16	30	50	100	200
Tarantula U.L. (% retained)	0	1	2	17	17	30	20	14	13	13	7	4
Tarantula L.L (% retained)	0	0	0	10	10	23	13	6	5	5	3	0

Self-Consolidating Concrete Sand Limits:

Coarse Sand % (#8-30) =	(Minimum is 20%)
Fine Sand % (#30 - 200) =	(Allowable range is 25-40%)

4.2. Determine duplicate specific gravities (bulk, bulk SSD, apparent) and absorption values of each fine & coarse aggregate in accordance with AASHTO T 84 and T 85 respectively. Perform additional testing if duplicate values do not agree within 1s Single operator precision. The average of the duplicate test values shall be used in the mix design. (For "Example Calculations" see Appendix D worksheets for *"Duplicate Coarse Aggregate Specific Gravities and Absorption"* and *"Duplicate Fine Aggregate Specific Gravities and Absorption"*)

4.3. Perform Sodium Sulfate Soundness testing on both coarse (retained on #4 sieve) and fine (passing #4 sieve) aggregates or on coarse and fine fractions of the combined aggregate in accordance with AASHTO T 104. Maximum loss for coarse aggregate is 12% for sodium sulfate and 18% for magnesium sulfate. Maximum allowable loss for fine aggregate is 10% for sodium sulfate and 12% for magnesium sulfate.

4.4. Limit flat or elongated coarse aggregate to a maximum of 15% at a ratio of 1:3 according to ASTM 4791.

4.5. Limits for deleterious materials must conform to AASHTO M 80, Table 2, Class A, for coarse aggregates and AASHTO M 6, Table 2, Class A, for fine aggregates.

5. Cementitious Materials

Cementitious materials acceptable for concrete include, but are not limited to; Portland Cement, Calcium Sulfoaluminate Cement, Class C and F fly ash, micro-silica, nano-silica, natural pozzolans, ground granulated blast furnace slag (GGBF), silica fume, and meta-kaolin.

6. Admixtures

Admixture materials acceptable for concrete include, but are not limited to: water-reducers, surfactants, viscosity modifiers, air-entrainment agents, crack reducers, shrinkage reducers, accelerators, retarders, surface sealers, hardeners and finishing aides.

7. Fibers

Fiber materials acceptable for reinforcement, shrinkage and crack control in concrete include, but are not limited to; steel, stainless steel, synthetic, and alkali-resistant cellulose fibers.

8. Internal Curing

Internal curing may be used to increase tensile and compressive strength, reduce internal stresses and reduce shrinkage in concrete. Internal curing materials include, but are not limited to; expanded shale, clay or slate fine aggregates, alkali-resistant cellulose, super-absorbent polymers, multi-crystalline enhancer, specialty admixtures, and naturally occurring aggregates of volcanic origin meeting ASTM C1761.

9. Determination of Concrete Proportions by ACI 211.1 (See Appendix B)

1. Select slump appropriate for the type of construction
2. Select maximum size of aggregate so concrete can be placed without excessive segregation or voids.
3. Blend available aggregates to optimize the combined gradation as evaluated by gradation guidelines in section 4.1.1. or section 4.1.2
4. Estimate mixing water and entrained-air content for exposure class, selected slump and maximum aggregate size.
5. Select water-cementitious materials ratio needed to provide required durability and compressive strength.
6. Calculate the cementitious materials content based on steps 3-4 above.
7. Estimate coarse aggregate content using ACI 211.1 Table 6.3.6 - Volume of coarse aggregate per volume of concrete.

8. Calculate fine aggregate content. At the end of step 7 all ingredients of the concrete have been estimated except the fine aggregate. The fine aggregate content is calculated by difference.

10. Determination of Concrete Proportions by Packing Density (See Appendix C)

1. Select maximum size of aggregate so concrete can be placed without excessive segregation or voids.
   a. Blend available aggregates to optimize the combined gradation as evaluated by gradation guidelines in section 4.1.1. or section 4.1.2
2. Determine the volume of voids in the combined aggregate. (AASHTO T 19 / ASTM C29)
3. Estimate the amount of excess paste required to provide desired workability.
4. Calculate volume of paste required to fill the aggregate voids.
5. Calculate volume of aggregates.
6. Calculate weights of each aggregate.
7. Select w/c ratio based on compressive strength requirements
8. Calculate cement content.
9. Calculate water content.
10. Determine required entrained air content for exposure conditions and maximum aggregate size.

11. Trial Batches

See Appendix D, Example worksheets.

ACI 301, Specifications for Structural Concrete, Section 4, Concrete Mixtures states, "*Make at least three trial mixtures for each concrete class with a range of proportions that will produce a range of compressive strengths that will encompass* f'_{cr}."

When designing air-entrained concrete a minimum of six trial mixtures is required. First proportion three NO AIR trial batches to achieve 1000 psi more than the strength required for the air-entrained mix. Appendix D, Example Mix Design, starts with design of a 4" slump, 5000 psi NO AIR mix to get a 4" slump, 4000 psi, 5 ± 1.5% air-entrained concrete mix. Appendix D includes seven sequential Excel worksheets followed by twelve sequential graphs that walk the user through the complete mix design process required by ACI 211 and ACI 301.

1. Aggregate structure is the starting point for good concrete proportions, properties, and performance. Perform gradations on representative samples of each aggregate (or use the average gradation from screening plant control charts). Use worksheet 1-*Combined Aggregate Worksheet, Calcs, Graph*, to develop aggregate blend within the Tarantula Curve limits.
   a. Use worksheet 2-*Duplicate Coarse Aggregate Specific Gravities & Absorption* for these tests.
   b. Use worksheet 3-*Duplicate Fine Aggregate Specific Gravities & Absorption* for these tests.
   c. Use worksheet 4-*Bulk Density and Voids in Aggregate* for these tests.
2. Make a minimum of three trial batches of no-air concrete at three different cement contents and three different w/c ratios to establish w/c ratio vs. compressive strength. The constant paste method works well for preparing these batches. (For example: use 6.0 sack mix at 0.50 w/c, 6.5 sack at 0.45 w/c and 7.0 sack at 0.40 w/c.) Use worksheet 5-*Constant Paste Volume Calculations* for these calculations.
3. Prepare first no-air trial batch with the lowest cement content (highest w/c ratio) that will provide a workable mix that is neither under-sanded nor over-sanded. Use a high water/cement ratio predictive of a

compressive strength just below the minimum required overdesign compressive strength (f'_{cr}). (For compressive strength of f'_c = 5000 psi, $f'_{cr} = f'_c$ +1200 psi or 6200 psi.) Make the first trial batch with the least amount of water-reducing admixture needed to get a 4 ± 1" slump. (Note: Mix all subsequent batches to the same slump by adjusting the amount of water reducing admixture.) See worksheet 6-*Mix Design Volumetric Data – 6 sk Trial 1* for example set of proportions with calculations.

4. When initial no-air trial batch mix parameters are satisfactory, proceed with two additional trial batches. Use the same aggregate amounts and paste volumes but higher cement contents and lower w/c ratios to obtain progressively higher strengths. In the example 6.0 sk Trial 1 has the highest w/c ratio (0.50) and the 28-day compressive strength of 6130 psi falls below minimum required compressive strength of 6200 psi, as desired. (See worksheet 7-*Mix Design Compressive Strength & Unit Weight Data – 6 sk Trial 1*). Compressive strength of 6.5 sk Trial 2, w/c = 0.45, was 6550 psi, and compressive strength of 7.0 sk Trial 3, w/c = 0.40, was 7700 psi.

5. For air-entrained concrete make 3 additional batches at the highest strength limits (lowest w/c ratio) of the no-air data. Produce batches with air contents at optimum and at a little more than 1.5% above and below optimum to produce data covering the full range of acceptable air contents. This will provide sufficient data to produce a valid Strength vs. Entrained-Air relationship.

Determination of Fresh Concrete Properties
For each trial batch test temperature, slump (or slump flow if SCC mix), wet unit weight, and % air content.

Preparing Concrete Test Specimens
Cast 15 each 4x8" or 10 each 6x12" test cylinders for compressive strength testing of each trial batch. For Type I/II cement break 3 each 4x8" or 2 each 6x12" specimens at 3, 7, 14, 28 days and hold three specimens for possible break at a later age. (Note: High fly ash content concretes may continue to gain significant strength for several years. Additional test specimens should be cast for these mixes as compressive strength at 56 days, 90 days, 1 year and 2 years may be significant.) For Concrete made with Type III cement break 3each 4x8" or 2 each 6x12" specimens at 1, 2, 3, 7 days and hold three specimens for possible break at a later age.

- When flexural strength criteria apply cast one set of three beams for each trial batch per AASHTO T 97 (ASTM C78).
- When maximum shrinkage criteria apply cast one set of shrinkage specimens for each trial batch per ASTM C157. Measure and record all data for each set of specimens and include it in mix design report.

Curing of Specimens
Cure compressive and flexural specimens in fog room or water bath as specified in ASTM C511

Determination of Hardened Concrete Properties
Remove test specimens from molds 24 ± 4 hours after casting. Determine hardened unit weight of all specimens by soaking test specimens in 23^0C water for 15 minutes then weighing in water followed by weighing in air at SSD.

When concrete is subject to exterior environmental conditions, determine the Resistivity of each specimen by AASHTO T 358 no more than 24 hours prior to compression testing. Record specimen age at testing and resistivity for each specimen. Average each set of readings and include data in mix design reports.

When flexural strength is required cast three beams in accordance with ASTM C78, test at the required age and include dimensional, loading, and flexural strength data in mix design report.

When maximum shrinkage criteria apply test one set of restrained shrinkage specimens for each trial batch per ASTM C1581, measure and record required shrinkage data and include it in mix design report.

Graphing, Determination of Optimum w/c Ratio and Analysis of Test Results

1. Graph the 28 day (7 day for Type III cement) compressive strength vs. w/c ratio for the no-air trial batches. Graph the no-air compressive strength on the y-axis vs. w/c ratio on the x-axis and include a linear best-fit line through the data points. (See: *Graph 1-5000 psi NO AIR Strength vs. wc Ratio*).

2. For concrete that is not air-entrained determine the required overdesign and calculate f'_{cr}. Follow the required f'_{cr} value horizontally to the intercept with the strength vs. w/c ratio best-fit line. From this point drop a vertical line down to the w/c ratio on the x-axis and record the value. This is the maximum w/c ratio that will provide the required f'_{cr}. (See: *Graph 2-5000 psi NO AIR w line at f'cr = 6200 psi*).

3. Graph the 28 day (7 day for Type III cement) compressive strength vs. air content for the three air-entrained batches made at the lowest w/c ratio (0.40) of the no-air batches. Provide the best-fit, linear equation for the data such that strength may be calculated as a function of air content. (See: *Graph 3-Compressive Strength vs % Air at 0.40 wc*).

4. On Graph 3, draw a vertical line from the optimum air content (5.0%) on the x-axis up to where it intersects the air vs. strength line. From that point draw a horizontal line across to the strength (y) axis and record the compressive strength (5760 psi) at 5% air. (See: *Graph 4-Compressive Strength at 5% Air*).

5. Plot this point (5760 psi @ 5% air) on Graph 1, the no-air strength vs. w/c ratio graph to create Graph 5. (See: *Graph 5-5760 psi point (0.40 wc, 5% air) w NO AIR line*).

6. On Graph 5 (the no-air strength vs. w/c ratio graph containing the optimum air point compressive strength) draw a line through this point parallel to the no-air strength line to make Graph 6. (See: *Graph 6-Line thru 5760 psi point parallel to NO AIR line*).

7. On the y-axis of Graph 6 draw a horizontal line through 5200 psi, the required over-design strength (f'_{cr}) for the air-entrained concrete, that intersects air-entrained strength vs. w/c ratio line. (See: *Graph 7-f'cr line meets 5% Air Strength vs wc*).

8. From the intersection of the horizontal f'_{cr} = 5200 psi line with the air-entrained strength vs. w/c ratio line on Graph 7, drop a vertical line down to the w/c (x) axis. (See: *Graph 8-Max wc=0.435 for* f'_{cr}*=5200 psi w 5% Air*) Record this w/c ratio (0.435) as the maximum allowed for the air-entrained mix design.

   The point (w/c, f'_{cr}) will provide the critical proportions for the submitted mix design and for a proof batch by the owner agency. (Note: DOT&PF may require materials for a proof batch to verify concrete mixes made from material without a previous history.)

9. Plot Strength vs. Age data for the three NO AIR trial batches as shown on "*Graph 9-NO AIR Strength vs Age - 3 cement contents.*"

10. Plot Strength vs. Age data for the four 5% Air trial batches as shown on "*Graph 10-5% Air Strength vs Age - 4 cement contents.*"

11. Include a graph of Mix Design Unit Weight vs. % Air for the final selected mix proportions. (See: *Graph 11-Mix Design Unit Weight vs % Air w 2s Limits*).

12. Include a graph of 28-day Compressive Strength vs. Gravimetric % Air for the final selected mix proportions. (See: *Graph 12-strength vs, % Air, 7sk, wc 0.41*)

13. Consecutive strength data may provide the basis for reductions or increases in cement content as strength data is accumulated on a new mix design. If 15-30 consecutive strength tests justify reduction in the initial over-design strength (f'_{cr}) according to ACI 301 Sections 4.2.3.2 through 4.2.3.6c then the concrete producer or supplier may submit a request to lower the cement content. Include consecutive strength test data with any request for consideration of cementitious reduction.

Conversely, if strengths are below f'_{cr} or if there is high variability in strength tests, then the engineer may request an increase in the cement content.

Note: Graphs of w/c vs. compressive strength and entrained-air vs. compressive strength provide design and construction personnel with valuable strength information for acceptance/rejection decisions should concrete arrive at the job site that is outside w/c or entrained-air limits. A theoretical percent air vs. unit weight graph provides a good check of pressure type air meter reading.

12. Report

Include the following:

1. Project identification, Source/Supplier of mix and name of the general contractor when mix design is specific for a single project.

2. Aggregate source(s), quality identification(s), target gradation of each aggregate, blend ratio of individual stockpiles, individual aggregate absorption values, apparent, bulk SSD, and bulk specific gravities. For blended Aggregate sources, screen and test Coarse and Fine Fractions. Other properties that may be specified such as; Unit Weight of dry-rodded coarse aggregate, fineness modulus of the blended fine aggregate, percent flat and elongated; sodium sulfate soundness of coarse and fine aggregate fractions, or aggregate-silica reactivity (ASR).

3. Gradation for each aggregate stockpile with graphical representation on Tarantula Curve of the combined aggregate gradation. AASHTO M 6 and M 43gradations for ACI 211.1 mixes. Include Lower Specification Limit (LSL) and Upper Specification Limit (USL) data with both combined and ACI gradations.

4. An orderly presentation of all trial batch data including; type(s) and source certificate with chemical oxide analysis for all cementitious materials, trial batch proportions, complete test cylinder data with unit weight of all cylinders determined immediately after initial curing period and removal from molds, surface resistivity (when required) of test cylinders, with nominal cylinder size indicated, just before compressive testing, compressive strength and average compressive strength at each age.

   Include graphs of Compressive strength vs. w/c Ratio and Compressive strength vs. Air content (for air-entrained mixes). Plot trial batch data points on graph(s) along with best-fit linear trend line. For trial batch nearest to selected mix design proportions plot Strength vs. Age points and the best-fit smoothed curve through the data points.

   Plot the wet unit weight (D) versus air contents of 0% to 10% from the theoretical unit weight (T) using ASTM C138, Sec 7.6, Equation (7), $A = [(T - D)/T] \times 100$, Where: A = % Air, D = Wet Unit Weight, and T = Theoretical Maximum Unit Weight.

5. Identification and address of the laboratory that performed the mix design, mix design identification number, and the signed seal of the professional engineer who reviewed and approved the mix design.

Appendix A

Definitions

Absolute Volume – Solid volume of a material exclusive of all particle void spaces. This is calculated by the following formula:

Absolute Volume (Cubic Feet) = Weight of Material / (Specific Gravity x 62.4)

For example: A sack of Portland cement occupies a bulk volume of approximately 1 cubic foot. The absolute volume is about 0.478 cubic foot.

94 lbs / (3.15 x 62.4 lbs/ft^3) = 0.478 cubic foot

Specific Gravity – A ratio expression of the weight in air of an absolute volume of material to the weight of an equal volume of water.

Fineness Modulus (FM) – An empirical factor obtained by adding the total percentages of a sample of fine aggregate retained on each of the following sieves, that sum divided by 100.

For example:

Sieve numbers 4, 8, 16, 30, 50, 100

Sieve Size	% Passing	% Retained
#4	98	2
#8	90	10
#16	68	32
#30	42	58
#50	20	80
#100	6	94
		Sum = 276

Fineness Modulus calculation: 276 / 100 = **2.76**

Theoretical Density of Concrete (T) - The density of a concrete mixture at 0% air content. Usually determined during the mix design process.

Appendix B

Example Calculations for ACI 211.1 Method

1. Select an appropriate value of slump from ACI Table 6.3.1

   (**Use 3 inch slump for this example**)

2. Choose a nominal maximum size of coarse aggregate based on guidelines in ACI section 6.3.2

   (**Use ¾ inch for this example**.) Include gradation conforming to AASHTO M 43 size 67 for ¾ to #4)

3. Blend available aggregates to optimize the combined gradation as evaluated by gradation guidelines in section 4.11 or section 4.1.2

4. Estimate mixing water and air content per cubic yard of concrete based on ACI section 6.3.3 and Table 6.3.3

   (Use 305 pounds of water for exterior concrete with air-entrainment, and select 6% air for severe exposure)

5. Select w/c ratio to give desired strength per ACI 6.3.4 and Table 6.3.4a

   (Assume 4000 psi required compressive strength and select 0.48 for the w/c ratio)

6. Calculate the cement content in pounds per cubic yard of concrete, ACI 6.3.5, as follows:

   (305 pounds / 0.48 = 635 pounds cement)

7. Estimate coarse aggregate content, ACI 6.3.6 and Table 6.3.6

   a. In this example use FM = 2.76 for fine aggregate with ¾ inch coarse aggregate to get a coarse aggregate bulk volume fraction of **0.62**

   b. Use ASTM C29 to determine Bulk Unit Weight of coarse aggregate. Assume **102 pounds/ft^3** for this example.

   c. For one cubic yard batch proportions coarse aggregate = 0.62 (27 ft^3/yd^3) (102 lbs/ft^3)

      (Weight of coarse aggregate = 1707 pounds/yd^3)

8. At the completion of step 7 all ingredient amounts are known except for the fine aggregate, which is determined by difference, ACI 6.3.7, using the volumetric method. Use specific gravity of 2.68 for coarse aggregate (CA) and 2.71 for fine aggregate (FA). Include FA gradation meeting AASHTO M 6.

   a. Volume of water: = 305 lbs / 62.4 lbs/ft^3 = 4.89 ft^3

   b. Solid Volume of cement: = 635 lbs / (3.15 x 62.4 lbs/ft^3) = 3.23 ft^3

   c. Solid Volume of CA = 1707 lbs / (2.68 x 62.4 lbs/ft^3) = 10.21 ft^3

   d. Volume of air = 0.06 x 27.0 ft3 = 1.62 ft^3

   e. Subtotal of all ingredients except fine aggregate = 19.95 ft^3

   f. Solid Volume of FA = 27 – 19.95 = 7.05 ft^3

   g. Required weight of dry FA =7.05 ft3 x 2.71 x 62.4 lbs/ft3 = 1192 lbs.

9. Follow ACI 211.1 Sections 7.2.8 to 7.3.10 for adjustments for aggregate moisture, slump, workability and mix harshness.

Appendix C

Example Calculations for Packing Density Method

1. Select the maximum size aggregate to minimize segregation and voids.
2. Create maximum density aggregate blend from available sources. (see section 4.1.1 or 4.1.2 in method)
3. Use AASHTO T 19 /ASTM C29 to determine Bulk Unit Weight of combined aggregate and then calculate the volume of voids in one cubic yard.

   Packing density = **0.7223**

   Voids content = 1 – 0.7223 = **0.2777**
4. Estimate the amount of excess paste required to provide desired workability.

   Excess paste for 3” slump = **10%**
5. Calculate the total amount of paste required.

   Paste content = 0.2777 + 0.10 x 0.2777 = **0.3054**
6. Calculate Volume of aggregates.

   Volume of aggregates = 1 – 0.3054 = **0.6945**
7. Calculate weights of each aggregate assuming a three-aggregate blend of 42% CA, 18% IA, and 40% FA with specific gravities of 2.712, 2.736, and 2.593 respectively.

   Solid Volumes of Aggregates = 0.42 / 2.712 + 0.18 / 2.736 + 0.40 / 2.593 = **0.3749**

   CA = (0.6945 / 0.3749) x 0.42 x 62.4 lbs/ft^3 x 27 ft^3/yd^3 = **1311 lbs/yd^3**

   IA = (0.6945 / 0.3749) x 0.18 x 62.4 lbs/ft^3 x 27 ft^3/yd^3 = **562 lbs/yd^3**

   FA = (0.6945 / 0.3749) x 0.40 x 62.4 lbs/ft^3 x 27 ft^3/yd^3 = **1248 lbs/yd^3**
8. Select w/c ratio to give desired strength.
9. Calculate cement content:

   (Assume 4000 psi required compressive strength and select 0.48 for the w/c ratio)

   w/c = 0.48; w = 0.48c

   Total paste = c + w = c/3.15 + 0.48c/1 =0.7975c

   Cement content = 0.3054/0.7975 x 62.4 lbs/ft^3 x 27 ft^3/yd^3 = 645 lbs/yd^3
10. Calculate water content:

    Water content = 0.48 x 645 lbs/yd^3 = 310 lbs/yd^3
11. Adjust for aggregate moisture, slump, workability and mix harshness and entrained air.

1. Combined Aggregate Worksheet

Tarantula Curve Data Entry & Graphical Plot: Flowable Concrete

Mix design or batch ID: Flowable Example xyz **Date:** 4/3/2023

Enter Aggregate SSD Weights under BLEND SUPPLIED below.

Note: **Blue font is data entry**, **Red font indicates a calculation cell**

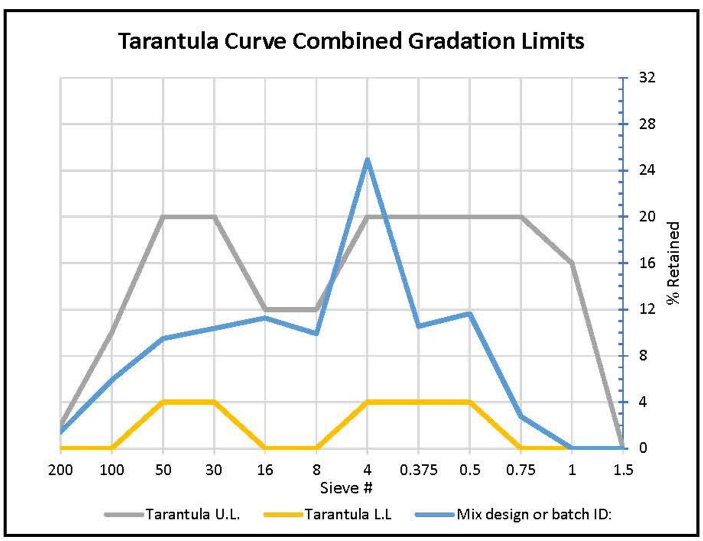
	BLEND SUPPLIED						
Aggregate Sizes:	1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals
SSD Weights (lbs)	0	0	1,762	0	0	1,417	3,179
Mass % Each Size	0.0%	0.0%	55.4%	0.0%	0.0%	44.6%	100.0%

Enter Aggregate Gradations:

SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	**(mm)**	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1.0"	25	0	0	100	100	100	100	100.0	0.0
3/4"	19	0	0	95	100	100	100	97.2	2.8
1/2"	12.5	0	0	74	100	100	100	85.6	11.6
3/8"	9.5	*	0	55	0	100	100	75.1	10.5
#4	4.75	*	0	10	0	0	100	50.1	24.9
#8	2.36	*	0	5	0	0	84	40.2	9.9
#16	1.18	*	*	4	0	0	60	29.0	11.3
#30	0.60	*	*	3	0	0	38	18.6	10.4
#50	0.30	*	*	2	0	0	18	9.1	9.5
#100	0.15	*	*	1	0	0	6	3.2	5.9
#200	0.075	0	0	1.0	0	0	2.8	1.8	1.4
Pan	0.000								1.8
								Total:	100.0

Concrete Sand Limits - Flowable	Coarse/Fine Percentage	Within Limits?
Coarse Sand % (#8-30) = *Minimum is 20%*	**31.5**	**Yes**
Fine Sand % (#30-200) = *Allowable range is 25-40%*	**27.2**	**Yes**

Tarantula Limits - Flowable		
Sieve #	Tarantula U.L.	Tarantula L.L
1.5	0	0
1	16	0
0.75	20	0
0.5	20	4
0.375	20	4
4	20	4
8	12	0
16	12	0
30	20	4
50	20	4
100	10	0
200	2	0



2. Duplicate Coarse Aggregate Specific Gravities & Absorption

AASHTO T 85 (ASTM C127) Duplicate Relative Density, (SpG) and Absorption of Coarse Aggregate

Client:	**Project:** Example	
Client Address:	**Material/Use:**	**Submitted by:**
	Sampled from:	**Field Number:**
Source:	**Sampled by:**	**Date Sampled:**
Test Location:	**Received by:**	**Date Received:**
Depth:	**Testing Tech:**	**Project No:**
Quantity Rep:	**Date Completed:**	**Lab Number:**

Sample Preparation:

Use table below to determine sample size. If more than 15% retained on 1-1/2" sieve, test this portion separately from the smaller material. Multiple fractions may be used. Sieve the reduced sample over a #4 sieve and wash all dust from the sample.

Procedure:

1. Dry to constant mass at 110 ± 5°C. Cool at room temperature for 1-3 hrs. or until sample can be handled comfortably.
2. Completely submerge sample in water at room temperature and soak for 15-19 hrs. (ASTM 24 ± 4 hrs.)
   Note: *AASHTO allows initial drying to be eliminated if aggregate will be used in concrete mixtures in it's naturally wet condition. The 15 hour soaking period may be eliminated if surfaces of the sample have been kept continuously wet until the test was begun.*
3. Tare wire bucket and handling scoop in preparation for submerging sample. Insure water bath is at overflow level.
4. Record temperature of water bath, verifying it is 23 ± 1.7°C (23 ± 2°C for ASTM).
5. Remove sample from water and roll in absorbent towel until no visible water sheen. Place in handling scoop.
6. Immediately record mass of sample in air, at SSD condition, to minimize loss from evaporation. **(B)**
7. Place sample in wire bucket attached to scale in water bath. Shake the bucket to release trapped air bubbles.
8. Record mass of sample while submerged. (Be sure to return handling scoop to top of scale or tare will be off.)**(C)**
9. Dry to constant mass at 110 ±5°C. Cool at room temperature 1-3 hr until sample can be handled comfortably.
10. Record oven dry mass. **(A)**
   Note: *Report Sp.G results to 0.001 (AASHTO) 0.01 (ASTM)*

Formulas:	**Description:**	Trial 1	Trial 2	**Average**
A	Oven dry mass in air (g)	2869.0	2892.6	
B	SSD mass in air (g)	2907.8	2933.5	
C	Mass in water (g)	1820.8	1836.2	
T	Temperature ©	23.4	23	
A/(B-C)	Bulk Sp.G (oven dry)	2.639	2.636	**2.638**
B/(B-C)	SSD Sp.G	2.675	2.673	**2.674**
A/(A-C)	Apparent Sp.G	2.737	2.738	**2.738**
100[(B-A)/A]	% Absorption	1.35%	1.41%	**1.38%**

Sample Size Table

Nominal Max. Size, mm (in.)	**Min. Test Sample Mass, kg (lb.)**
12.5 (1/2) or less	2 (4.4)
19.0 (3/4)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 (1 1/2)	5 (11)
50 (2)	8 (18)
63 (2 1/2)	12 (26)
75 (3)	18 (40)
90 (3 1/2)	25 (55)
100 (4)	40 (88)

Notes:

3. Duplicate Fine Aggregate Specific Gravities & Absorption

AASHTO T 84 (ASTM C128) Duplicate Relative Density, (SpG) and Absorption of Fine Aggregate		
Client:	**Project:** **Example**	
Client Address:	**Material/Use:**	**Submitted by:**
	Sampled from:	**Field Number:**
Source:	**Sampled by:**	**Date Sampled:**
Test Location:	**Received by:**	**Date Received:**
Depth:	**Testing Tech:**	**Project No:**
Quantity Rep:	**Date Completed:**	**Lab Number:**

Sample Preparation:

1. Obtain 2 each, 1kg samples in accordance with T 2 (D 75) and T 248 (C 702) for duplicate tests.
2. Dry to constant mass then add a minimum of 6% moisture after cooling. Allow sample to stand 15-19 hrs. (24 ± 4 hrs. for ASTM).
   a) Initial drying is optional if aggregates will be used for concrete mixtures, and are still in their moist states
3. Decant excess water with care to avoid loss of fines. Spread sample on nonabsorbent surface, and position sample in gently moving warm air. On short table use fan, heat lamp, and spatula to speed up evaporation during the drying process.
4. Press cone mold to a nonabsorbent surface and fill to overflowing, heaping additional material above top of mold by holding it with cupped fingers of hand holding the mold.
   Keep constant pressure on mold, use tamper to deliver 25 blows to aggregate, letting tamper fall under its own weight from approximately 0.2 in. (5mm) above the top surface of the aggregate.
5. Clear the area around the mold and remove the cone, being careful not to agitate the material.
   a) Slight slumping of the material indicates SSD; retention of the molded shape indicates surface moisture.
   b) Slumping after striking the table indicates the cone test should be run again immediately
6. Repeat steps 4-5 until material reaches SSD. Start filling pycnometer immediately after reaching SSD.
   Note: *Angular aggregate, samples containing large proportions of fines may require provisional procedures. To test, drop a handful of material 100-150 mm - airborne fines indicate this situation.*

Procedure: **(Bold letters indicate data entry points)**

1. Partially fill, (1/4), the calibrated pycnometer with water, insert funnel with tube, and tare.
2. Introduce 500 ± 10 grams of prepared SSD material into flask. Record the mass of material to 0.1 g **(S)**.
3. Fill flask to approx 90% capacity with additional water, manually agitate 15-20 min to remove visible air.
   a) Manually agitate by rolling on rubber pad or between your hands.
   Note: *A small amount of isopropyl alcohol may be used to disperse the foam.*
4. Adjust the temperature of the pycnometer and contents to 23.0 ± 1.7°C (23.0 ± 2.0°C for ASTM) **(T)**.
5. Bring the water level to the calibrated mark. The bottom of meniscus should rest on the calibrated line.
6. Record mass of pycnometer, sample, and water to 0.1 g **(C)**.
7. Select the mass of the pycnometer and distilled water from the current calibration sheet **(B)**.
8. Empty the entire sample into a pan and dry to constant mass, (within 0.1 g), using 110°C oven **(A)**.
   a) Use a wash bottle to rinse all the fines from the pycnometer.
   b) Determine the mass of the sample only after it has cooled 1.0 ± 0.5 hrs.

Note: *Report SpG. Results to 0.001 (AASHTO) 0.01 (ASTM)*

Formulas:	Description of data or calculation:	Trial 1	Trial 2	Average
B	Pyc+ Distilled Water	660.7	660.7	
	(from calib) Ave M pw, c (g)			
S	SSD Soil Mass	500.1	500.8	
C	Pyc + Distilled Water + Agg	973.7	974.5	
T	Temperature (23.0 ± 2.0°C)	23.0	22.7	
A	Oven Dry Mass	493.4	495.3	
A/(B+S-C)	Bulk Sp.G. (Oven Dry)	2.637	2.649	**2.643**
S/(B+S-C)	SSD Sp.G.	2.673	2.678	**2.675**
A/(B+A-C)	Apparent Sp.G.	2.735	2.729	**2.732**
100(S-A)/A	Absorption	1.36%	1.11%	**1.23%**

4. Bulk Density and Voids in Aggregate

Bulk Density ("Unit Weight") and Voids in Aggregate
AASHTO T19 / T19 M and ASTM C29 / C 29M

Client:	**Project:** Example	
Client Address:	**Material/Use:**	**Submitted by:**
	Sampled from:	**Field Number:**
Source:	**Sampled by:**	**Date Sampled:**
Test Location:	**Received by:**	**Date Received:**
Depth:	**Testing Tech:**	**R&M Project No:**
Quantity Rep:	**Date Completed:**	**Lab Number:**

Sample Preparation:

Obtain sample 125-200% of quantity required to fill measure. Dry to constant mass at 110 ± 5°C.

Method A - Rodding: (For nominal maximum size 1 1/2" or less)

1. Record weight of measure to 0.1 lb.
2. Fill measure 1/3 full and level surface with fingers. Rod layer 25 times with a 5/8" hemispherical tipped rod. Avoid hitting bottom of measure.
3. Fill measure 2/3 full, level, and rod 25 times. Avoid penetrating the first layer.
4. Fill measure to overflowing and rod again. Avoid penetrating the previous layer.
5. Level aggregate using fingers or straight edge so projections above measure balance surface voids.
6. Record weight of full measure to 0.1 lb.

Method B - Jigging: (For nominal maximum size 1 1/2" to 5")

1. Record weight of measure to 0.1 lb.
2. Fill measure 1/3 full and level surface with fingers. Placing measure on a solid base, compact by raising opposite sides alternately about 2" and dropping. Drop each side 25 times for a total of 50 blows per layer
3. Fill measure 2/3 full, level, and compact as above.
4. Fill measure to overflowing and compact as above.
5. Level aggregate using fingers or straight edge so projections above measure balance surface voids.
6. Record weight of full measure to 0.1 lb.

Method C - Shoveling: (Loose Bulk Density - use only if specified)

1. Record weight of measure to 0.1 lb.
2. Fill measure to overflowing with shovel or scoop, discharging from no more than 2" above measure. Avoid segregation of material.
3. Level aggregate using fingers or straight edge so projections above measure balance surface voids.
4. Record weight of full measure to 0.1 lb.

Bulk Density SSD - For bulk density SSD, use this same procedure but calculate using Mssd formula below.

Note - Absorption and SpG data must be determined using C127 or C128 (fine or coarse SpG tests)

Method Used:	A	Trial Number:			
Formula:	**Description:**	1	2	3	Avg.
G	Wt. of Agg. + T (lb)	39.49			-
T	Wt. Tare (lb):	7.718			-
V	Volume(ft^3):	0.248			-
M = (G-T)/V	Bulk Density (lb/ft^3) **(M)**	128			**128**
A	% Absorption	0.58			-
M[1+(A/100)]	Bulk Density at SSD (lb/ft^3) **(Mssd)**	129			**129**
S	Bulk SpG (dry basis)	2.754			-
W	Water density 62.4 lb/ft^3)	62.4			-
100[(S*W)-M)/(S*W)]	% Void Content	25.5%			**25.5%**

Notes:

5. Constant Paste Volume Calculations

Constant paste volume calculations for high, intermediate and low w/c trial batches :

Blue font indicates data entry points
Red font indicates a calculation, **No** data entry in these cells

1. Start with three w/c ratios 0.05 apart and three cement contents about 1/2 sack of cement apart.
2. For example: Enter w/c = 0.50, 0.45, 0.40 and cement = 6.0, 6.5, 7.0 sack respectively (see below)
3. Enter Cement mass (lb) based on the estimated number of sacks per cubic yard for each of the three mixes.
4. Calculate *Total Paste Volume* at middle w/c ratio of 0.45 (6.5 sack mix) by adding cement and water volumes. (Note: Goal is to match the middle Paste Volume with the High and Low w/c ratio batches. Start with highest w/c ratio in top box below. Follow instructions to the right of Total Paste Volume cell.)
5. From *"Home"* in Excel select *"Data"* tab, then select *"What-If Analysis"*, then *"Goal Seek"* from drop-down menu.
6. To *"Set cell"* select the *"Total Paste Volume"* cell for the high w/c ratio mix.
7. For *"To value,"* type in the *"Total Paste Volume"* of the middle sack mix
8. For *"By changing cell"*, select the blue *"Cement/Mass"* cell. Click *"OK"* to see new Cement and Mixing water data. Click *"OK"* button again to accept and save the new values.
9. Repeat steps 5 through 8 for the low w/c ratio mix.
10. Trial batches with identical aggregate & paste volumes provide valid strength vs. w/c ratio data.

(Note: To maintain consistent slump gradually increase dosage of water-reducing admixture while moving to higher cement contents, as the paste gets thicker. Constant slump is desirable for establishing air-entraining agent dosage. Air-entrainment agents are more effective at higher slumps.)

	Mass (lb)	Vol. (ft^3)
w/c ratio	0.500	
Total free water	282	
Cement, Cell B25>	564	2.87
Silica Fume		
Mixing water	282	4.52

Cement:
94 lbs / sack
6.0 sack = 564.0 lbs
Total Cementitious = 564.0 lbs
Total Paste Volume (ft^3) = 7.389 ← Steps 5-8, with cursor on this cell use Goal Seek to change Cement mass in Cell B25 until paste volume = 7.515

	Mass (lb)	Vol. (ft^3)
w/c ratio	0.450	
Total free water	275	
Cement	611	3.11
Silica Fume		
Mixing water	275	4.41

Cement:
94 lbs / sack
6.5 sack = 611.0 lbs
Total Cementitious = 611.0 lbs
Total Paste Volume (ft^3) = 7.515 ← Step 4 is Goal for all three w/c ratios

	Mass (lb)	Vol. (ft^3)
w/c ratio	0.400	
Total free water	263	
Cement, Cell B39>	658	3.35
Silica Fume		
Mixing water	263	4.22

Cement:
94 lbs / sack
7.0 sack = 658.0 lbs
Total Cementitious = 658.0 lbs
Total Paste Volume (ft^3) = 7.566 ← Step 9, with cursor on this cell use Goal Seek to change Cement mass in Cell B39 until paste volume = 7.515

Reference Data:

Type I cement, Sp G:	3.15
Silica Fume, Sp G:	2.2
Water, unit weight at 20^0 C (pcf):	62.4

6. Mix Design Volumetric Data - 6.0 sk Trial 1

Mix Design Volumetric Data - 6.0 sk Trial (1)

Note: Blue Font = Data Entry, Red Font = Calculation

Type of Concrete:	5000 psi	Date:	
Project Name:	Slabs - Not exposed to Freeze/Thaw	Calculated by:	
		Checked by:	

Mix Design Criteria:

Maximum Nominal Aggregate Size (inches):	3/4	
Cement (Minimum weight per cubic yard):	520 lbs	
Cement Mfg / Type:	Type I/II	
Max Water/Cementitious Materials Ratio (lbs/lb):	0.46	
28 day Design Strength, (f'c):	5000 psi	
28 day Required Strength, (f'cr):	6200 psi	
Slump Range (inches):	4 ± 1.5"	FA, CA Mix Ratios
Entrained Air Content (% by Volume):	1.5 ± 1%	2.47
Mix Ratio by weight (Cementitious:Sand:Gravel)	1:2.47:3.07	3.07
Sand Content (% by Weight of SSD Agg):	44.6%	

Aggregate Moisture (As Received):

	CA	FA
Tare	1012.1	1238.8
T + Wet	2498.4	2534.0
T + Dry	2470.0	2471.3
Water	28.4	62.7
Dry	1457.9	1232.5
%M	1.95%	5.09%

Reference Data:

Type I cement, Sp G:	3.15
Water, unit weight at 20^0 C (pcf):	62.4

Aggregate Characteristics:

Moisture	Size	AASHTO	Bulk Sp G	SSD Sp G	App Sp G	Absorption	Free water
1.95%	Coarse Agg	M-43 #67	2.638	2.674	2.738	1.38%	0.57%
5.09%	Fine Agg	M-6	2.643	2.675	2.732	1.23%	3.86%

Units: 1 gallon = 128 fl oz = 3785.3 milliliter 1 pound = 453.59 grams
1 fl oz = 29.57 ml

Admixtures:	Enter Dose	Trial Batch Amounts			Cubic Yard Amounts		Admixture
	fl oz/100#	fl oz	ml	lbs	fl oz / yd^3	lbs / yd^3	SpG
Polyheed 997	5.00	1.594	**47.1**	0.132	28.7	2.376	1.27
Micro-Air	0.00	0.000	0.00	0.0000	0.0	0.000	1.01
	0.00	0.000	0.0	0.000	0.0	0.000	1

Dry Batch weights for 1.0 yd^3	Weight (lbs.)	Volume (ft^3)	SSD Batch Weights (lbs.)	Field Moist Batch Wts (lbs.)	Aggregate Free Water (lbs.)
w/c ratio	0.500				
Total free water	287				
Cement	574	2.92	574	**574**	
Mixing water	287	4.60	287	**223**	
Coarse Aggregate (Dry)	1738	10.56	1762	**1772**	10
Polyheed 997 Admixture	2.376	0.03	2.4	**2.4**	
Micro-Air Admixture	0.000	0.00	0.0	**0.0**	
	0.000	0.00	0.0	**0.0**	
Air 1.5%		0.41			
Volume Subtotal =		18.51			
Fine Aggregate (Dry)	1400	8.49	1417	**1471**	54
Totals	4001	27.00	4042	4042	64
Unit Weight (pcf)	148.2		149.7	149.7	

Cement:
94 lbs / sack
6 sack = 564.0 lbs
Total Cementitious = 574.0 lbs

Paste Volume (ft^3) = 7.520

Extra Water Record:
Tare ________
Start T+W ________
End T+W ________
Water added ________

Mix Design Volumetric Data - 6.0 sk Trial (1) - Continued

Trial Batch Volumetrics Size (ft^3) 1.5	Weight (lbs.)	Volume (ft^3)
Cement	**31.889**	0.162
	0.000	
Mixing water	**12.392**	0.199
Dry Coarse Aggregate	96.556	0.587
CA Absorption	1.332	
CA Free Water	0.550	0.009
Total Weight Wet CA =	**98.438**	
Polyheed 997 Admixture	0.132	0.002
Micro-Air Admixture	0.000	0.000
	0.000	0.000
Air 1.5%	0.00	0.023
Dry Fine Aggregate	77.763	0.472
FA Absorption	0.956	
FA Free Water	3.002	0.048
Total Weight Wet FA =	**81.721**	
Totals	**224.573**	**1.500**
Calculated Unit Wt w/Admixtures		149.7 pcf

Added water (lbs)	
Total Mixing Water in Trial batch	15.944
Final W/C Ratio	0.500

Use Table below to check Trial Batch % Air Reading.
Use Goal Seek to change the blue % Air number until Unit Weight matches value recorded in "Trial Batch Data" at page bottom.
1. Select red unit weight cell near bottom of table.
2. Select "Data" tab, then "What if?", then "Goal Seek".
3. Set the red Unit Weight cell "To value" in Trial Batch Data
4. "By changing" blue % Air cell. Click OK to solve & to save.

Item	Volume (ft^3)
Cement	2.920
Water	4.599
Coarse Ag	10.558
Poly 997	0.030
Micro-Air	0.000
Pozzutec2	0.000
Fine Agg	8.487
1.50%	0.405
Air was calculated from Unit Weight of **149.7**	
Total Vol.	**27.000**

Theoretical Maximum Unit Wt at 0.0% Air (pcf) = 152.0

Enter % Air here or calculate with Goal Seek →

1. Select this cell, then open "Goal Seek" →

For Sizing Trial Batch:

Note: 6x12 cyl =	0.196	ft^3
4x8 cyl =	0.058	ft^3
Slump cone =	0.204	ft^3
Unit wt bucket =	0.25	ft^3
16 ea 4x8 cyl =	0.93	ft^3
Min Trial batch =	1.38	ft^3

Trial Batch Data:

Temperature	48	°F	Weight of Tare	7.920	lbs
Slump	5.5	inches	Wt of Tare & Concrete	44.725	lbs
Air	2.0%		Weight of Concrete	36.805	lbs
Unit Weight	147.2	pcf	Volume of Tare	0.2500	ft^3
Yield (ft^3/sk)	4.497		Weight of all ingredients as batched	224.573	lbs

(*ASTM C138, Sec 7.6, Equation (7)*)

To calculate % Air from Unit Weight:

A = [(T - D)/T] x 100

Where: A = % Air

D = Wet Unit Weight

T = Theoretical Maximum Unit Weight = 152.0

Calculate % Air (x) from Unit Weight (y)		
For D =	**147.2**	pcf
A =	**3.2**	% Air

or

To calculate Unit Weight from % Air:

Solve: A = [(T - D)/T] x 100 for D

A/100 = (T - D)/T

AT/100 = T - D

D = T - AT/100

Calculate Unit Weight (y) from % Air (x)		
For A =	**7.6**	% Air
D =	**140.4**	pcf

7. Mix Design Compressive Strength & Unit Weight Data - 6.0 sk Trial 1

Mix Design Compressive Strength & Unit Weight Data - 6sk Trial 1, No Air, f'c = 5000 psi

Note: Blue Font = Data Entry, Red Font = Calculation   1.00 psi = 6.894761 kPa

Date & Age Data			Cylinder Compressive Strength Data					Compressive Strength	
Cast	Tested	Age (Days)	Cyl ID	Diameter 1 (Inches)	Diameter 2 (Inches)	XC Area (Sq Inch)	Peak Load (Pounds)	f'c (psi)	f'c (kPa)
5/3/2013	5/6/2013	3	181	4.00	4.00	12.57	34,085	2710	18700
5/3/2013	5/6/2013	3	182	4.00	4.01	12.60	34,040	2700	18600
5/3/2013	5/6/2013	3	183	3.99	4.00	12.53	34,020	2710	18700
5/3/2013	5/6/2013	3	184	4.00	3.99	12.53	33,765	2690	18500
5/3/2013	5/10/2013	7	185	4.000	4.000	12.57	58,015	4620	31900
5/3/2013	5/10/2013	7	186	4.020	3.990	12.60	58,565	4650	32100
5/3/2013	5/10/2013	7	187	4.020	4.010	12.66	57,115	4510	31100
5/3/2013	5/10/2013	7	188	4.020	4.010	12.66	58,175	4590	31600
5/3/2013	5/17/2013	14	189	4.000	4.010	12.60	71,855	5700	39300
5/3/2013	5/17/2013	14	190	3.990	4.010	12.57	71,350	5680	39200
5/3/2013	5/17/2013	14	191	3.990	4.000	12.53	69,875	5570	38400
5/3/2013	5/17/2013	14	192	4.010	4.000	12.60	70,755	5620	38700
5/3/2013	5/31/2013	28	193	3.990	4.000	12.53	78,255	6240	43000
5/3/2013	5/31/2013	28	194	4.000	3.980	12.50	75,930	6070	41900
5/3/2013	5/31/2013	28	195	3.980	3.980	12.44	76,835	6180	42600
5/3/2013	5/31/2013	28	196	3.980	3.980	12.44	75,110	6040	41600

Average 3 day f'c= 2700

Average 7 day f'c= 4590

Average 14 day f'c= 5640

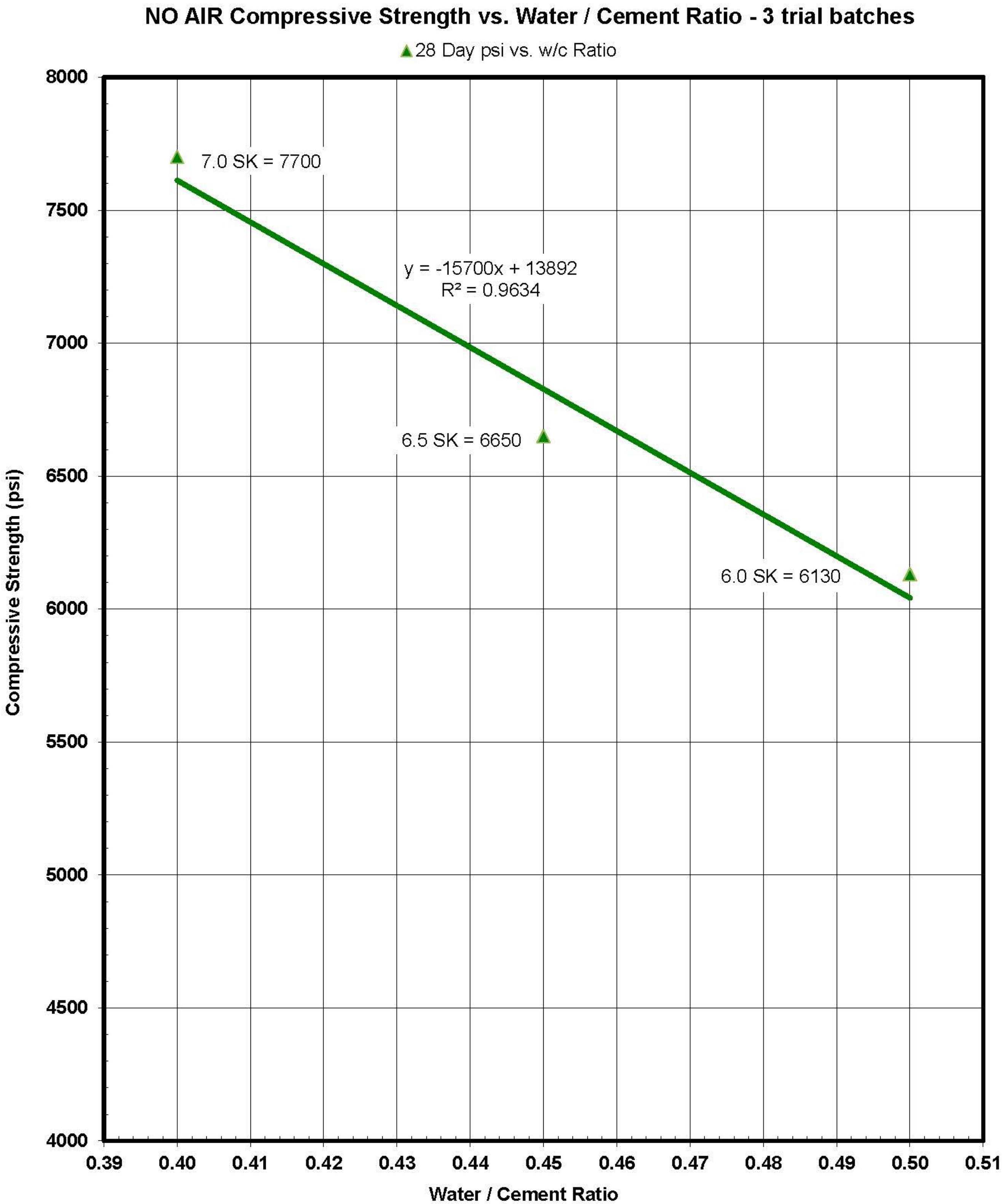
Average 28 day f'c= **6130**

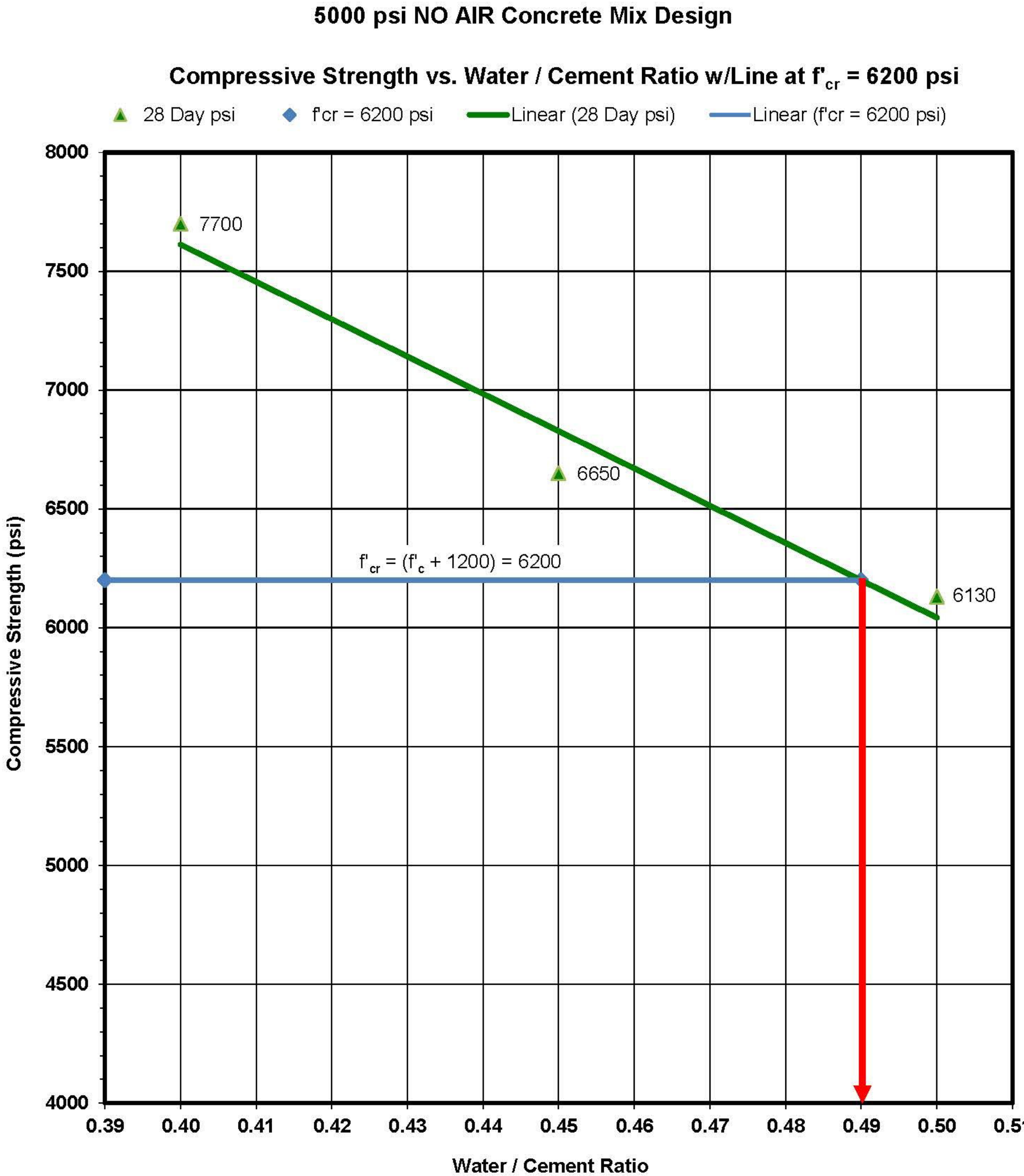
Note: Use cylinder unit weight to check wet unit weight and mix design value. Find root cause if D > 1.85 pcf

Cylinder Unit Weight Data							Unit Weight	
Cyl ID Number	Wt in Air (grams)	Wt in H_2O (grams)	H_2O Temp (^0C)	H_20 Density (g/cm^3)	Cyl Volume (cm^3)	Cyl Density (g/cm^3)	(lbs/ft^3)	(kg/m^3)
181	3944.5	2298.1	22.8	0.99759	1640.8	2.4039	150.0	2404
182	3960.2	2315.3	22.8	0.99759	1639.3	2.4158	150.7	2416
183	3926.3	2285.1	22.8	0.99759	1635.7	2.4004	149.8	2400
184	3938.1	2295.2	22.8	0.99759	1637.4	2.4052	150.1	2405
185	3948.9	2304.1	23.9	0.99732	1638.6	2.4099	150.4	2410
186	3973.4	2328.2	23.9	0.99732	1638.9	2.4244	151.3	2424
187	3975.1	2325.2	23.9	0.99732	1643.7	2.4185	150.9	2418
188	3949.9	2305.6	23.9	0.99732	1638.1	2.4113	150.5	2411
189	3981.8	2338.5	20.6	0.99808	1638.8	2.4297	151.6	2430
190	3971.2	2320.1	20.6	0.99808	1646.6	2.4117	150.5	2412
191	3990.2	2349.6	20.6	0.99808	1636.1	2.4389	152.2	2439
192	3989.5	2348.3	20.6	0.99808	1636.7	2.4376	152.1	2438
193	3970.1	2322.7	20.5	0.99810	1643.0	2.4164	150.8	2416
194	3956.0	2312.4	20.5	0.99810	1639.2	2.4134	150.6	2413
195	3967.5	2322.8	20.5	0.99810	1640.3	2.4188	150.9	2419
196	3977.4	2332.9	20.5	0.99810	1640.1	2.4252	151.3	2425

Average Unit Weight = **150.9**

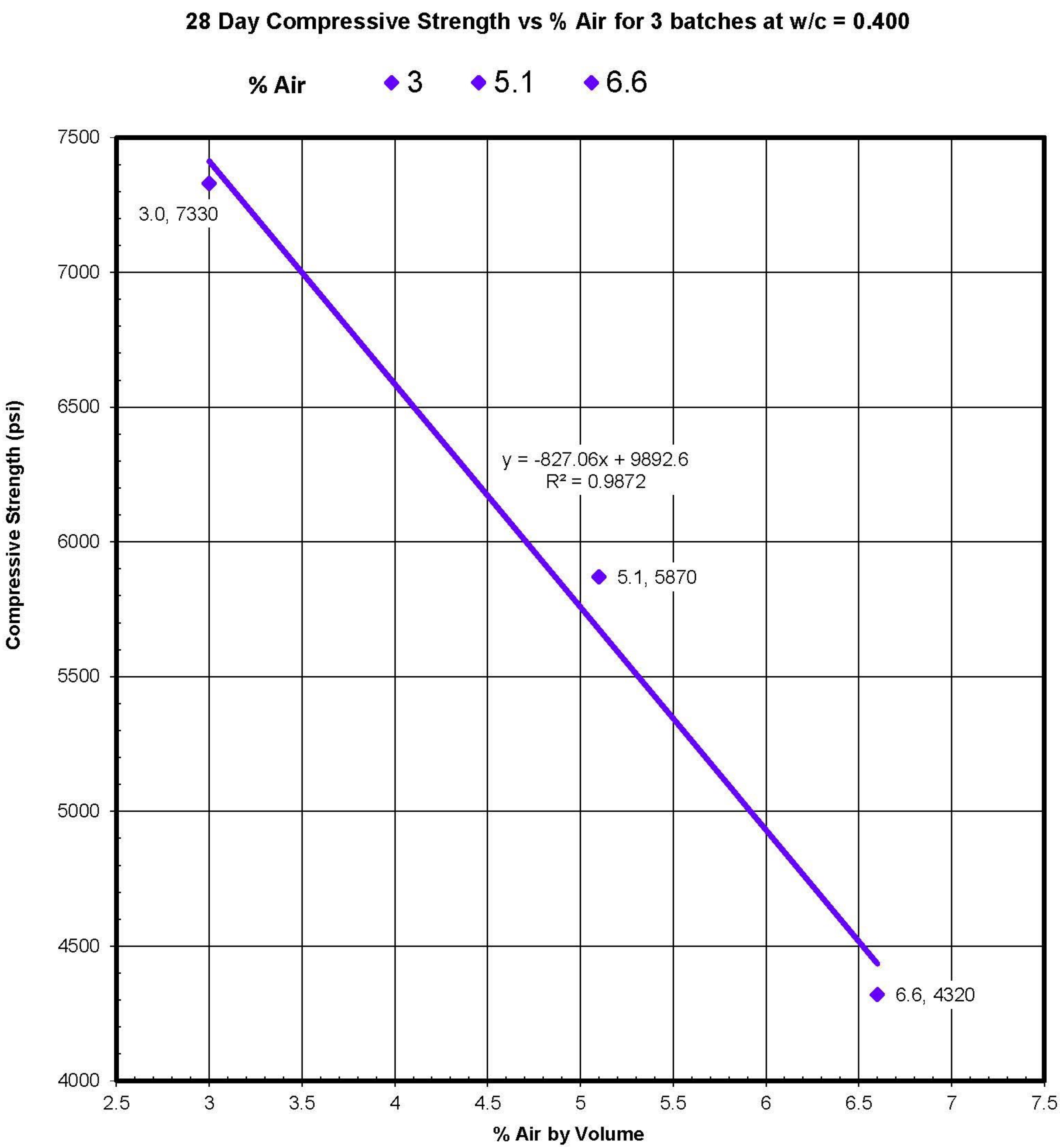
5000 psi NO AIR Concrete Mix Design



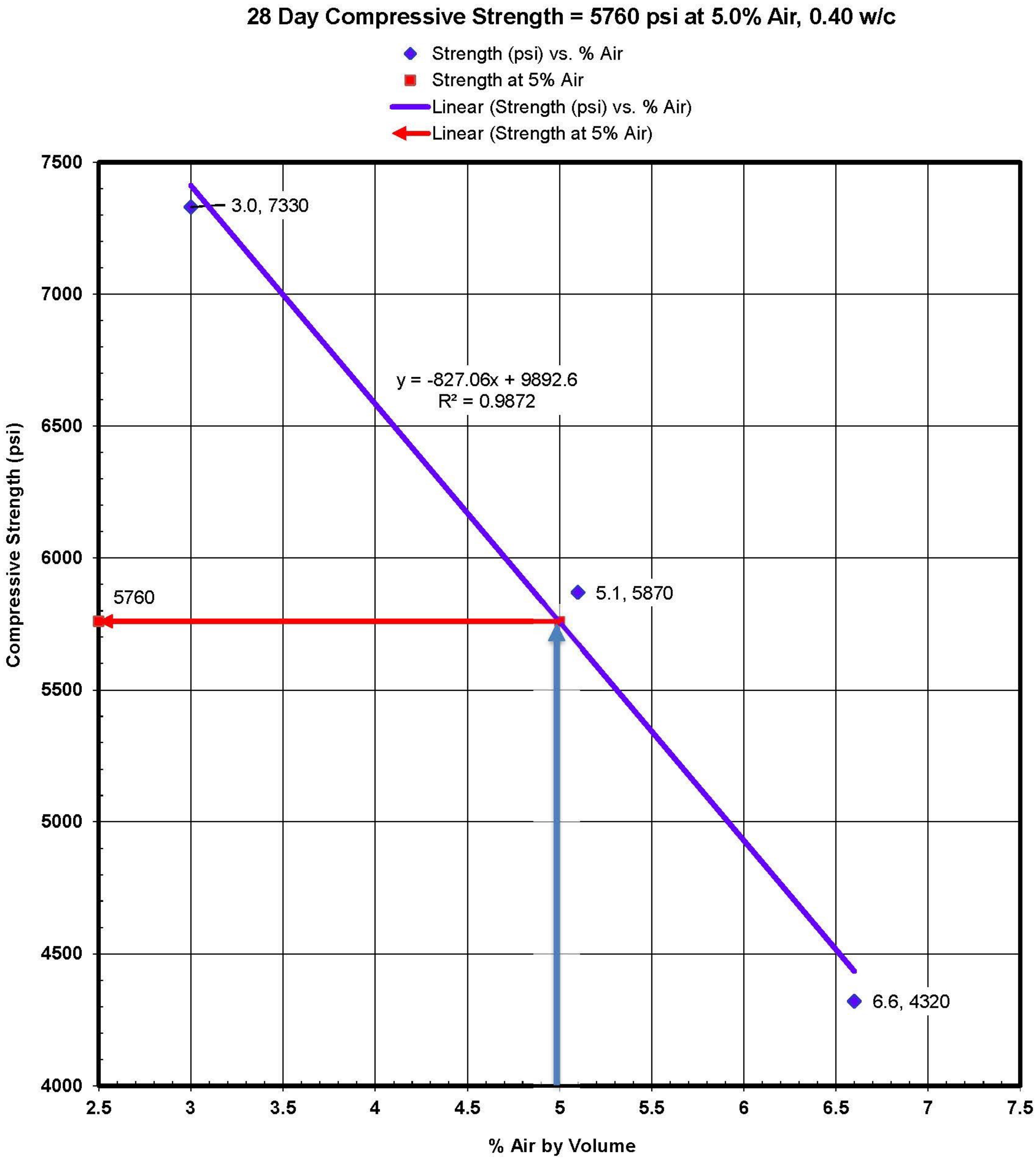


For 5000 psi No Air concrete final proportions: Maximum w/c = 0.49

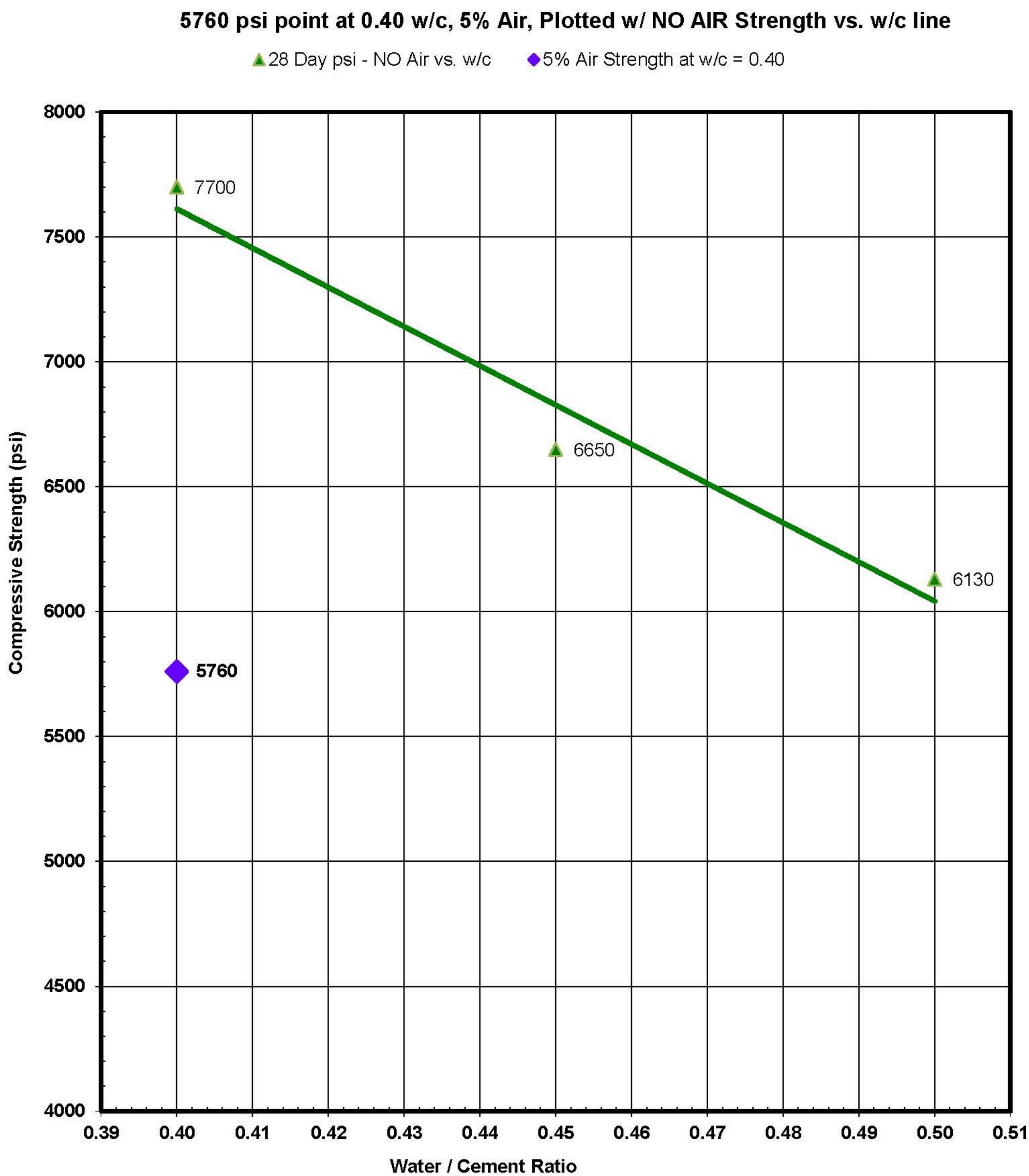
4000 psi, 5% Air Concrete Mix Design



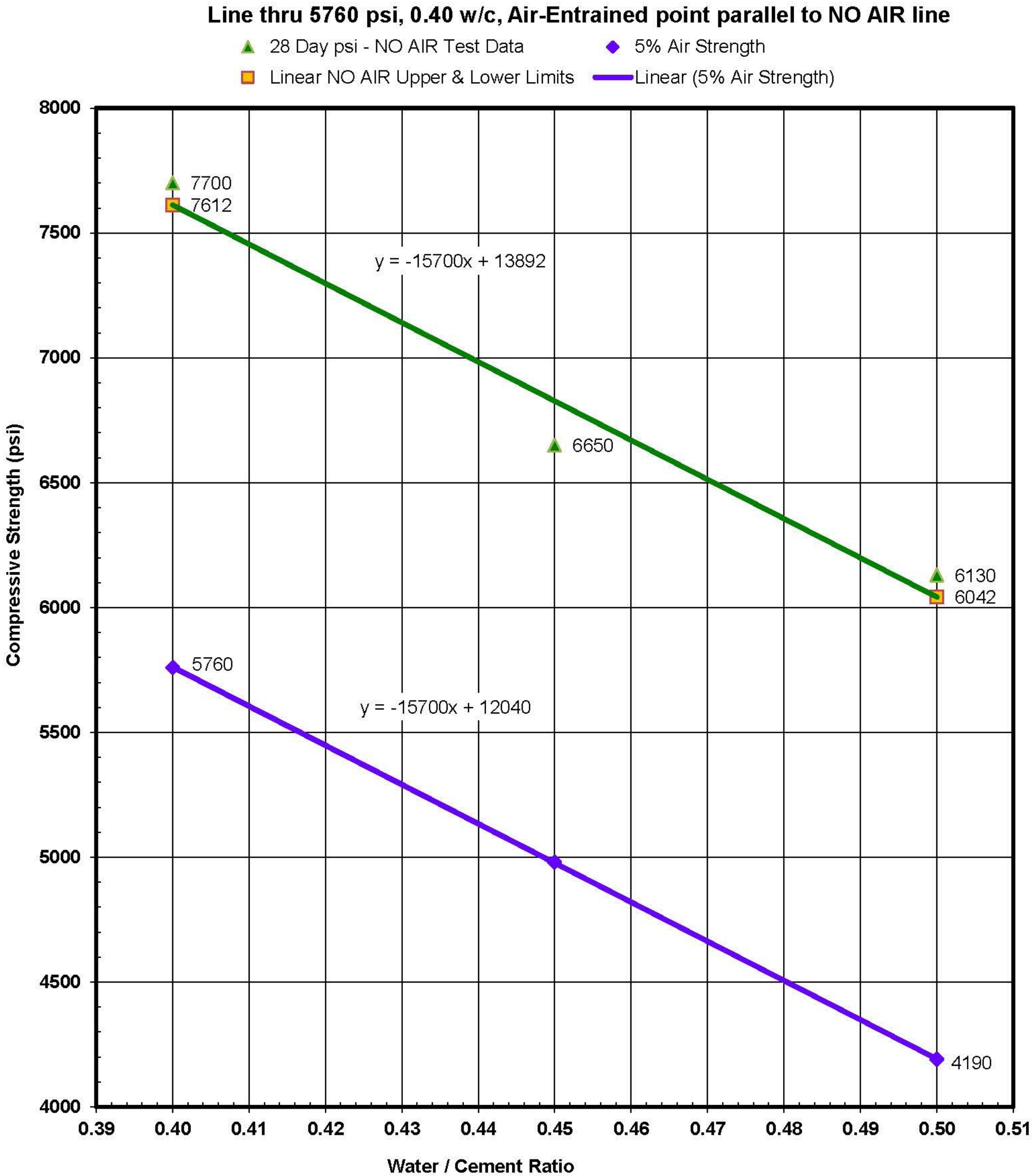
4000 psi, 5% Air Concrete Mix Design



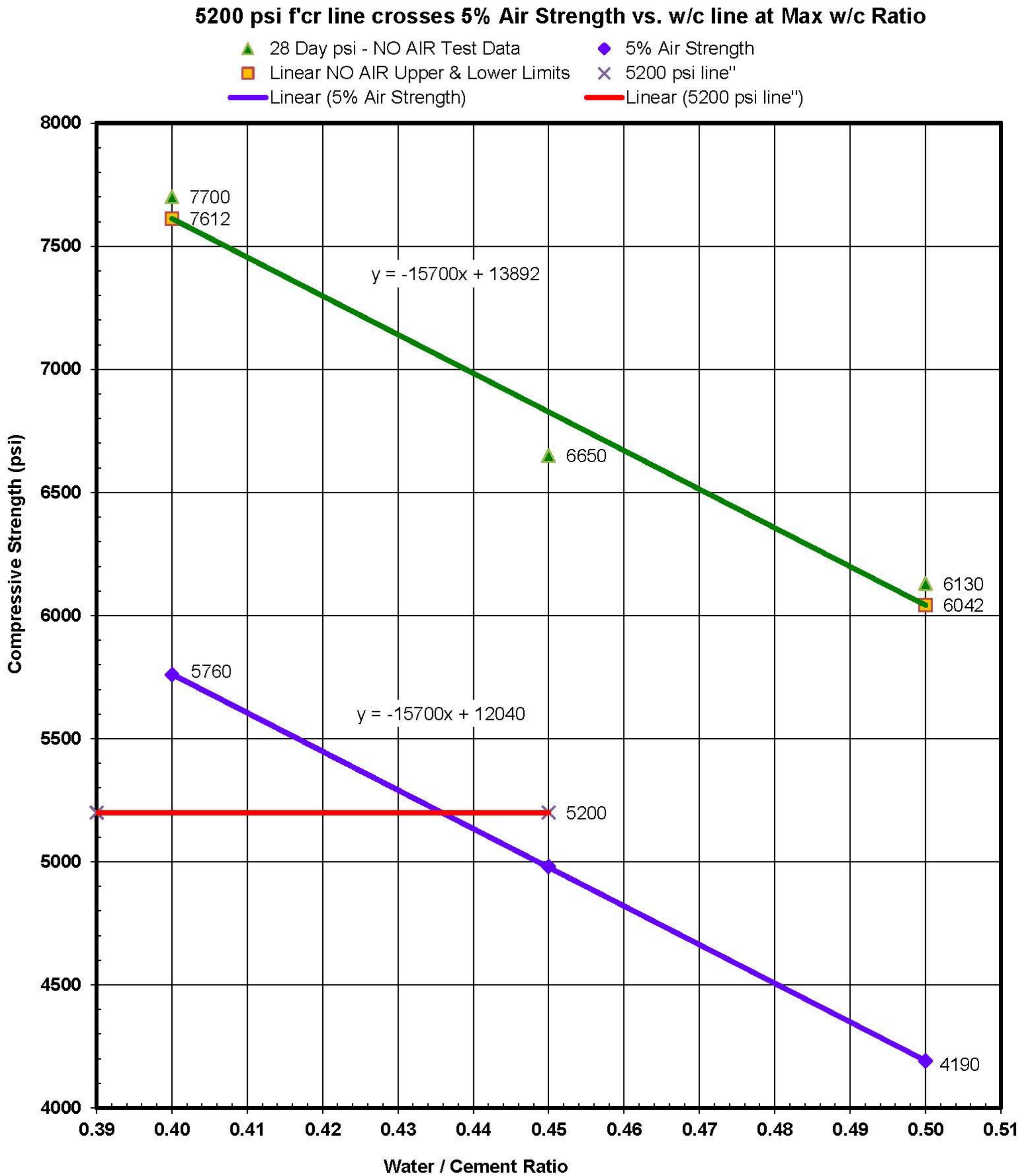
4000 psi, 5% Air Concrete Mix Design



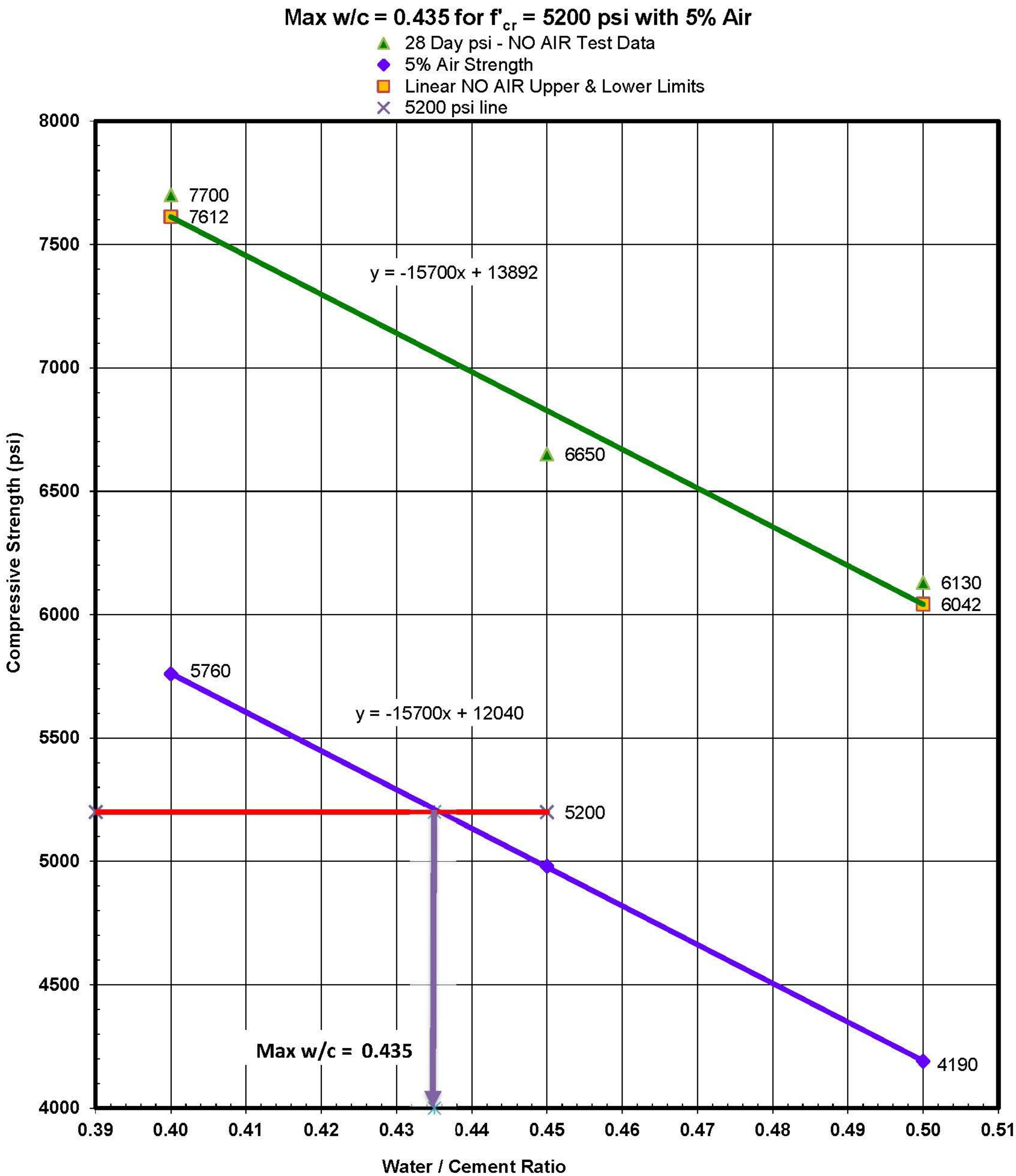
4000 psi, 5% Air Concrete Mix Design



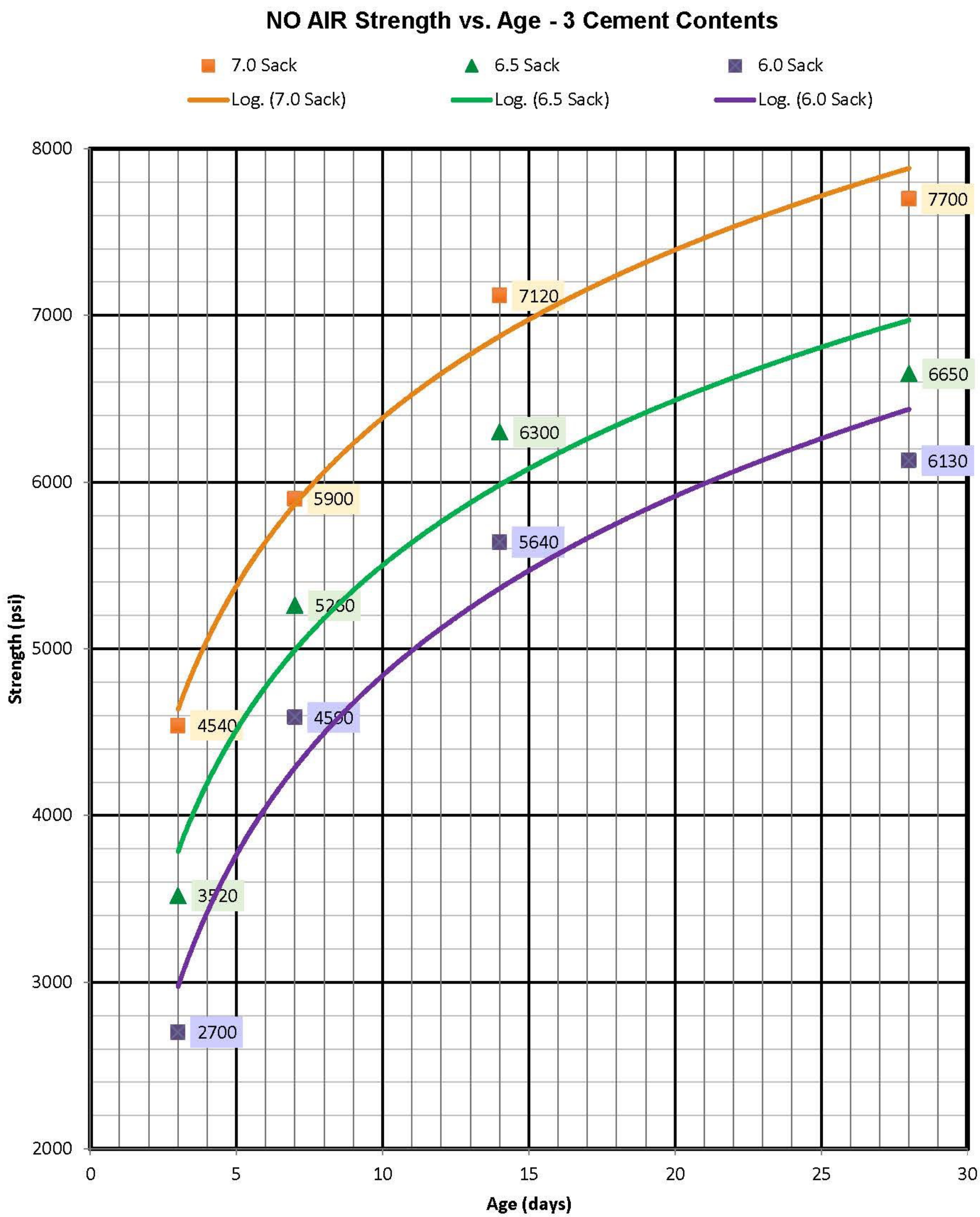
4000 psi, 5% Air Concrete Mix Design



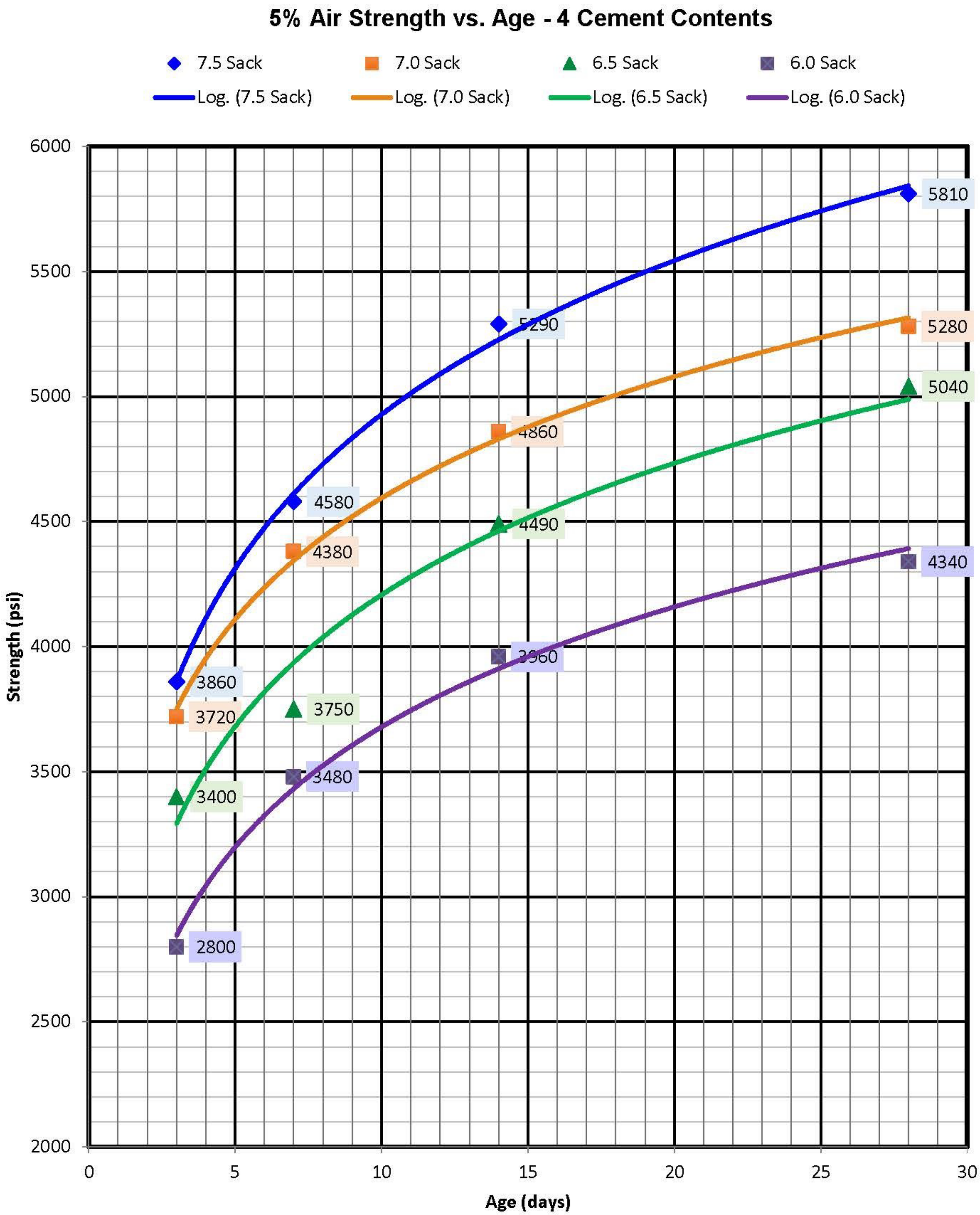
4000 psi, 5% Air Concrete Mix Design



5000 psi, NO AIR Concrete Mix Design



4000 psi, 5% Air Concrete Mix Design



Mix Design Unit Weight vs. % Air

(ASTM C138, Sec 7.6, Equation (7))
To calculate % Air from Unit Weight:
A = [(T - D)/T] x 100
Where: A = % Air
D = Wet Unit Weight
T = Theoretical Maximum Unit Weight (pcf) = 152.0

To calculate Theroetical Max. Unit Weight (T) from Mix Design
Divide Gross Wt by Non-Air Volume:

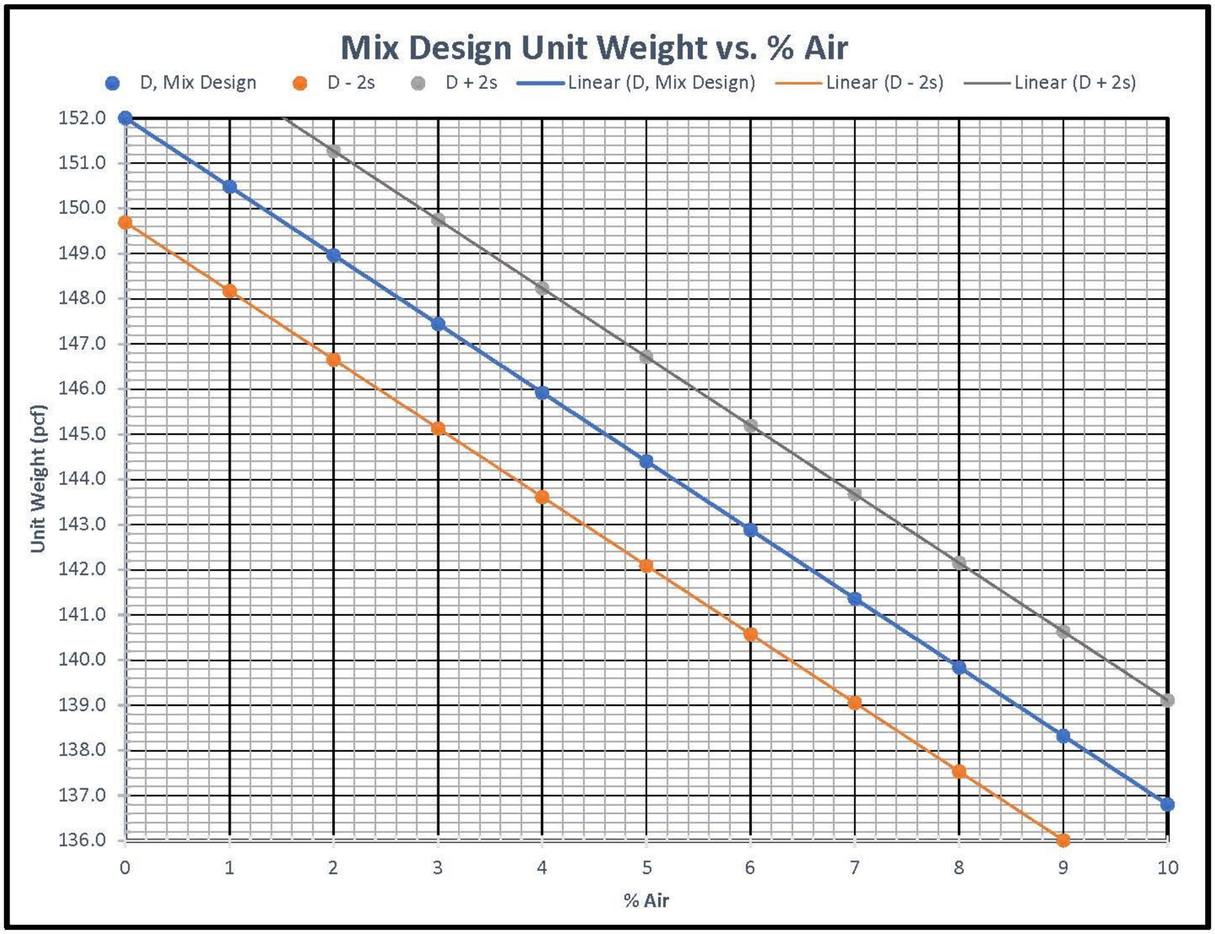
Gross Wt. (lb.)	Non-Air Volume (cu. ft.)	T, No Air (pcf)
3889.0	25.58	152.0

To calculate Unit Weight from % Air:
Solve for D: A = [(T - D)/T] x 100
A/100 = (T - D)/T
AT/100 = T - D
D = T - AT/100

ASTM C138 Unit Weight Precision (pcf):		
	1s	2s
Single Operator		
	0.65	1.85
Multi-Operator		
	0.82	2.31

Data for graphing Unit Weight vs. % Air

A	D	D - 2s	D + 2s
Air %	Unit Wt. (pcf)	Unit Wt.	Unit Wt.
10	136.8	134.5	139.1
9	138.3	136.0	140.6
8	139.8	137.5	142.2
7	141.4	139.1	143.7
6	142.9	140.6	145.2
5	144.4	142.1	146.7
4	145.9	143.6	148.2
3	147.4	145.1	149.8
2	149.0	146.7	151.3
1	150.5	148.2	152.8
0	152.0	149.7	154.3



Air-Entrained Concrete Strength vs. Gravimetric % Air