TDOT
Department of Transportation

Concrete Mix Design Technician Course

Division of Materials and Tests

2024

Concrete Mix Design Technician Course

Tennessee Department of Transportation

2024 Manual

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WELCOME!

Concrete Mix Design Technician Course

Purpose of Certification

- To ensure proper performance of tests
- To improve reliability of results
- For quality control
- To comply with federal requirements

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Course Highlights

- Slide presentations
- Written Exam (No Phones Allowed)
  - Closed-book
  - Must get 70% overall
- Results
- Recertification – Every 5 years

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Resources

- Course materials
  - Course manual
  - Presentation slides and videos
- TDOT
  - 2021 Standard Specifications
  - Special Provisions
  - HQMT website: https://www.tn.gov/tdot/materials-and-tests.html

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ADA Notice of Requirements

- To be in compliance with TDOT's requirements listed on the website above, it is our goal to provide reasonable accommodations to those who identify themselves as having a disability and request such accommodations
- Please feel free to bring it to any of the course instructors and accommodations will be administered as discretely as possible
- Can be found at the following website:
  - https://www.tn.gov/tdot/government/g/ada-office0.html

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Tell Us About Yourself

- Who are you?
- Where do you work?
- What experience do you have?

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Questions

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Basic Concrete Ingredients

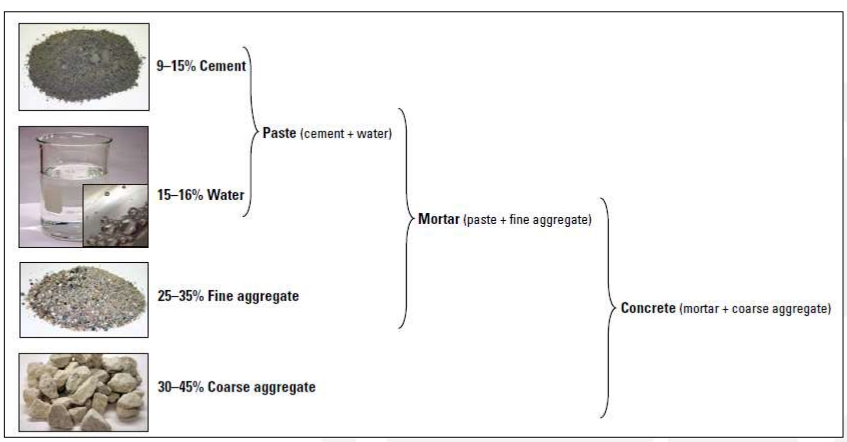
Basic Concrete Ingredients

References

NRMCA Publication No. 159

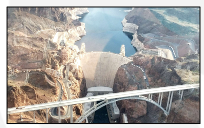
FHWA Publication No. HIF-07-004

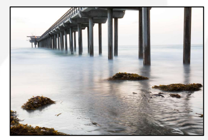
Basic Ingredients



Types of Cement

- **Type I/IL – Normal Use**
  - Used for common applications
  - Type IL is a blended hydraulic cement
- **Type II – Moderate Sulfate Resistance and Heat of Hydration**
  - Where concrete contacts with soil or water with modest sulfate concentrations.
  - Used when you have large volumes of concrete
- **Type III – High Early Strength**
  - Cement sets faster and produces higher early strength than Type I
- **Type IV - Low Heat of Hydration**
  - Produces less heat and generally used with massive structures
  - Very few sources still exist
- **Type V – Sulfate Resistant**
  - Only used where high concentrations of sulfate in the soil or groundwater





Supplementary Cementitious Materials

- Pozzolans have no cementing value alone
- React with lime from cement hydration to form additional cementing compounds
- Generally, reduce early strength of concrete
- Contribute to strength at later ages
- Examples: fly ash, silica fume, slag cement

Fly Ash

- Two types
  - C-ash
  - F-ash
- Reduction in water
- Increased workability
- Reduces bleeding and segregation
- Improved pumpability
- Reduced heat of hydration

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Alkali-Silica Reactivity Resistance

- ASR of most reactive aggregates can be controlled with certain SCMs
  - Reduces alkali content of the system
  - Reduces permeability
  - Slows ingress of water
- Class F fly ash
  - Low calcium
  - Reduced reactivity expansion
- Class C fly ash
  - High calcium
  - Can reduce reactivity at optimum proportioning
  - At low level may exacerbate ASR, aka pessimum effect

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Slag Cement (GGBFS)

- Has minimal pozzolanic properties
- Slightly less water
- Setting time delayed
- Early strengths depressed
- Later strengths increased

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Silica Fume

- Used in addition to relatively high cement contents
  - Produce extremely dense, strong, concrete mixtures
- Has extremely fine particles
  - Increase in water demand
  - Normally used with high range water reducers
- Increases long-term strength
- Reduces permeability
- High risk of shrinkage cracking due to reduction in bleeding

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Effects of SCMs on Fresh Concrete Properties

	Fly ash		GGBF slag	Silica fume
	Class F	Class C		
Water requirements	↓↓	↓↓	↓	↑↑
Workability	↑	↑	↑	↓↓
Bleeding and segregation	↓	↓	↕	↓↓
Air content	↓↓*	↓*	↓	↓↓
Heat of hydration	↓	↕	↓	↔
Setting time	↑	↕	↑	↔
Finishability	↑	↑	↑	↕
Pumpability	↑	↑	↑	↑
Plastic shrinkage cracking	↔	↔	↔	↑

↑↑ Significant increase
↓↓ Significant decrease
↔ No change
↕ Unpredictable
↑ Increase
↓ Decrease

* Effect depends on properties of fly ash, including carbon content, alkali content, fineness, and other chemical properties

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Chemical Admixtures

- Type A - Water Reducers
  - Reduce mixing water 5%-30%
  - Increase ultimate strength
  - Improve workability
- Type B - Retarders
  - Longer set time
  - Improve hot weather workability
- Type C - Accelerators
  - Shorter set time
  - Increase early strength
- Type D = Type A + Type B
- Type E = Type A + Type C
- Type F – High Range Water Reducer
  - Minimum 12% reduction in mixing water
  - Increase ultimate strength
  - Improve workability
- Type G = Type F + Type B
- Type S – Specific Performance
  - Viscosity modifying
  - Shrinkage reducing
  - Corrosion inhibitor

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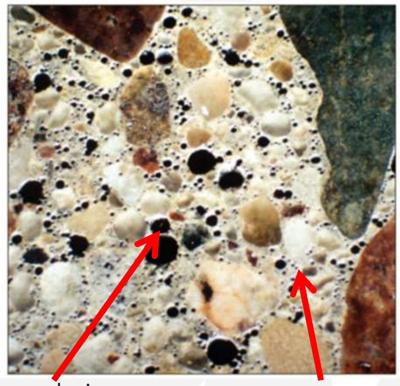
Air Entrainment

- Improves durability
- Improves workability
- Reduces water demand
- Generally, for every 1% air, concrete loses about 5% strength



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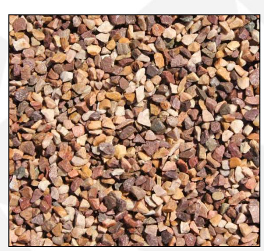
Coarse Aggregate (903.03)

- Crushed Limestone, Gravel, Granite, Sandstone, and Slag available in Tennessee
- Retained on No. 4 sieve
- Desire well graded aggregates
  - Less water to produce workable mix
  - Increased compressive strengths with comparable cement



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Coarse Aggregate Sizes

- Concrete Pavement requires a No. 467 aggregate blend
- Must submit a written request to Regional Materials & Tests with justification for use of a stone size other than in Table 903.03-1

Table 903.03-1: Coarse Aggregate Sizes

Application	Coarse Aggregate Size [1]
Structural concrete	No. 57
Self-Consolidating concrete	Maximum-No. 67
Prestressed concrete	No. 57 or 67
Precast concrete	Any size fraction
Concrete for Bridge Repair [2]	No. 57 or 67
Concrete curbing placed by machine-extrusion methods	No. 7, 57, 67, or 78
Cement treated permeable base	No. 57

(1) Gradation shall conform to **903.22**.
(2) If proposing to use a coarse aggregate size not specified submit a written request to Regional Materials and Tests explaining the necessity for the change.

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Fine Aggregate (903.01)

- Natural sand
  - Dredged river sand
  - Pit sand
  - Processed sandstone
- Manufactured Sand
- Passing No. 4 sieve

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Surface Aggregates (903.24)

- Resistant to polishing
- Maintains high frictional properties
- Natural sand required for any concrete riding surface
  - TDOT Specifications 501.02 and 604.03
- Coarse surface aggregate must be used in:
  - Concrete pavement travel lanes including mainline pavements and ramps
  - Bridge decks and approach slabs on interstates and 4 or more lane highways

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Let's Review

- Fly ash has what effect on workability?
- Set time is decreased with the addition of which type admixture?
- Paste is the accumulation of ___________________
- Which type of cement will produce less heat?

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Questions

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TDOT Concrete Classes

TDOT Concrete Classes

References

TDOT Standard Specifications

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Classes of Concrete

- Class CP – Concrete Pavement
- Class A – Structural, General Use
- Class A Paving
- Class D, DS – Bridge Decks
- Class L – Lightweight
- Class S – Seal
- Class X – Plans Specific/High Early
- Class SCC, SH-SCC – Self Consolidating Concrete
- Class P-SCC
- Class P – Prestressed/Precast Bridge Members
- Class PEM – Performance Engineered Mixture
- Precast Concrete
- Flow Fill
- Shotcrete
- Grout

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Class CP (501.03-1)

- Concrete Pavement

Table 501.03-1: Class CP – Paving Concrete

28 Day Compressive Strength, min (PSI)	Minimum Cementitious Content (pounds per cubic yard)	Maximum Water/Cement Ratio (pound/pound)	Air Content (%)	Slump (inch)
3000	526 [1] 545 [2]	0.45	5% design 3 – 8% production	0 – 2 [3] 3 ± 1 [4]

(1) 526 pounds required when the coarse aggregate is crushed stone
(2) 545 pounds required when the coarse aggregate is gravel
(3) Allowable slump for slipform paving
(4) Allowable slump for other than slipform paving

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Class A (604.03-1)

- General Use Structural Concrete
- Class A Slipform has different slump requirements
- Class A Paving requires surface aggregate

Table 604.03-1: Composition of Various Classes of Concrete

Class of Concrete	Min 28-Day Compressive Strength (psi)	Min Cement Content (pound per cubic yard)	Maximum Water/Cement Ratio (pound/pound)	Air Content % (Design ± production tolerance)	Slump (inches)
A	3,000	564	0.45	6 ± 2	3 ± 1 [(1)]

(1) For slip forming, the slump shall range from 0 to 3 inches.

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Class D, DS (604.03-1)

- Bridge Deck Concrete
- Class DS requires surface aggregate

Table 604.03-1: Composition of Various Classes of Concrete

Class of Concrete	Min 28-Day Compressive Strength (psi)	Min Cement Content (pound per cubic yard)	Maximum Water/Cement Ratio (pound/pound)	Air Content % (Design ± production tolerance)	Slump (inches)
D (2, 3)	4,000	620	0.40	7 (3)	8 max (4)

(2) Use Class D concrete in all bridge decks except box and slab type structures unless otherwise shown on the Plans.

(3) Design Class D and Class L concrete at 7% air content. Acceptance range for pumping and other methods of placement is 4.5-7.5%. Sampling will be at the truck chute.

(4) Water reducing admixtures are acceptable; however, do not exceed the maximum water/cement ratio in order to achieve the required slump.

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Class L (604.03-1)

- Lightweight Concrete

Table 604.03-1: Composition of Various Classes of Concrete

Class of Concrete	Min 28-Day Compressive Strength (psi)	Min Cement Content (pound per cubic yard)	Maximum Water/Cement Ratio (pound/pound)	Air Content % (Design ± production tolerance)	Slump (inches)
L (3, 5)	4,000	620	0.40	7 (3)	8 max (4)

(3) Design Class D and Class L concrete at 7% air content. Acceptance range for pumping and other methods of placement is 4.5-7.5%. Sampling will be at the truck chute.

(4) Water reducing admixtures are acceptable; however, do not exceed the maximum water/cement ratio in order to achieve the required slump.

(5) The unit weight of air dried Class L concrete (lightweight concrete) shall not exceed 115 pounds per cubic foot as determined according to ASTM C567.

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Class S (604.03-1)

- Seal Concrete
- Underwater foundation applications
- Used when washout of cement is a concern

Table 604.03-1: Composition of Various Classes of Concrete

Class of Concrete	Min 28-Day Compressive Strength (psi)	Min Cement Content (pound per cubic yard)	Maximum Water/Cement Ratio (pound/pound)	Air Content % (Design ± production tolerance)	Slump (inches)
S (Seal) [6]	3,000	682	0.47	6 ± 2	6 ± 2

[6] The use of fly ash as a cement replacement will be allowed in Class S (Seal) concrete.

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Class X/High Early

- Plans Specific Requirements
  - For local programs, mix design approved by Local Government/CEI
  - Entire page should be sent in with Class X requirements

HIGH EARLY STRENGTH CONCRETE:

FOR THE SIDEWALK REPAIR ON DWG. NOS. BR-128-29 AND BR-128-31, THE MIX IS TO MEET THE REQUIREMENTS OF THE STANDARD SPECIFICATIONS, CLASS "X", THE CEMENT CONTENT SHALL BE A MINIMUM OF 714 LBS., THE WATER CEMENT RATIO SHALL BE A MAXIMUM OF 0.40, DESIGN AIR CONTENT SHALL BE 6% WITH ±2% ACCEPTANCE RANGE IN THE FIELD. SLUMP SHALL BE 3±1. IF USING A TYPE A, F, OR G WATER REDUCER THE SLUMP SHALL BE MAXIMUM OF 8 INCHES. NO FLY ASH REPLACEMENT WILL BE PERMITTED, AND THE MINIMUM 28 DAY COMPRESSIVE STRENGTH SHALL BE 3,500 p.s.i..

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Class X/High Early (604.03.C)

- Concrete strength requirement prior to 28 days
- Concrete repair applications
- Minimum Cement Content:
  - Type I/IL – 714 lbs/yd^3
  - Type III – 620 lbs/yd^3
- Contractor can elect to use in place of Class A when approved in writing by the engineer

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Class SCC & SH-SCC (604.03-2)

- Self-consolidating concrete (SCC) can be used as a replacement for Class A
- Class SH-SCC is used in drilled shafts

Table 604.03-2: Composition of Self-Consolidating Concrete

Class of Concrete	Min 28-Day Compressive Strength (psi)	Min Cement Content (pound per cubic yard)	Maximum Water/Cement Ratio (pound/pound)	Air Content % (Design ± production tolerance)	Slump Flow (inches)
SCC (2,3,4,5)	3,000(1)	564	0.45	6 ± 2	26 ± 5
SH-SCC (2,3,4,5,6)	4,500	620	0.45	6 ± 2	26 ± 5

(1) Or as shown on the Plans or approved shop drawings.
(2) Acceptance range for the T50 test in accordance with ASTM C1611 shall be between 2-7 seconds.
(3) Passing ability in accordance with ASTM C1621 shall be equal to or less than 2 inches for acceptance.
(4) Visual Stability Index (VSI) shall not exceed 1 as per ASTM C1611 for acceptance.
(5) Static segregation as measured by ASTM C1610 shall not exceed 20%.
(6) Air Content may be reduced if placed under water or underground if approved by the Engineer.

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Class P-SCC (615.09-1)

- For prestressed members

Table 615.09-1: Class P Concrete

Class of Concrete	Min 28-Day Compressive Strength (psi)	Min Cement Content (pound per cubic yard)	Maximum Water/Cement Ratio (pound/pound)	Air Content % (Design ± production tolerance)	Slump or Slump Flow (inches)
P-SCC (4)	5,000(1)	658	0.45	0-6(2)	26 ± 5

(1) Or as shown on the Plans or approved shop drawings.

(2) Air entraining is optional with the Contractor, unless otherwise shown on the Plans or shop drawings.

(4) Maximum coarse aggregate size of a No. 67 stone.

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Class PEM (604.03)*

- Performance Engineered Mixture
- Any design submitted must have a trial batch performed in the presence of HQMT
  - Regional Materials and Tests (M&T) shall be notified such that they may observe the trial batch in-person
- Proper documentation must be submitted for data collection purposes
  - Super Air Meter (SAM) number
  - Resistance of Concrete to Rapid Freezing and Thawing
  - Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration
  - Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction
  - Optimized Aggregate Gradations

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Precast Concrete (SOP 5-3)

- Different precast products have different design requirements
  - Precast deck panels, junction boxes, spring boxes: Class D
  - Mix designs for all other products are in accordance with:
    - Applicable AASHTO/ASTM Standards
    - Approved Shop Drawings
    - Contract Plans
    - TDOT Standard Drawings and Specifications
    - All mix design submittals shall include acceptance tolerances

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Let's Review

- Which classes of concrete require surface aggregate?
- When can high early strength concrete be used?
- What **additional** data must be submitted for a Class PEM mix?

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Questions

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Making and Curing Concrete Test Specimens in the Laboratory

TDOT Standard Method of Test for

Making and Curing Concrete Test Specimens in the Laboratory

References

TDOT Standard Specifications

ASTM C192

ASTM C497

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Equipment

- Cylinder molds
- Beam and prism molds
- Tamping rods
- Mallets
- Vibrators
- Scoops
- Testing equipment
- Sampling and mixing pan
- Scales
- Concrete mixer

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Preparation of Materials (Cementitious Material)

- Storage
  - A dry place
  - Moisture-proof containers
- Pass through a No. 20 sieve to remove all lumps, remixed on a tarp or plastic sheet, and returned to containers
- Mix thoroughly for uniformity

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Preparation of Materials (Aggregates)

- Maintain aggregate in SSD or Saturated condition
- Obtain the specific gravity and absorption from the aggregate facility
- Determine moisture content of aggregates
- Determine moisture corrections for aggregates and batching water

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Preparation of Materials (Chemical Admixtures)

- Consult with manufacturer to determine if powdered admixtures should be mixed with cement or sand before incorporating in the mix

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Machine-Mixing

- Batch so that there is 10% excess
- Sequence:
  1. Coarse aggregate
  2. Small amount of mixing water and solution of admixture
  3. Start mixer
  4. Fine aggregate, cement, and water
  5. 3 minutes mixing
  6. 3 minutes rest (covered, to avoid evaporation)
  7. 2 minutes final mixing
  8. Deposit in clean, damp mixing pan, and remix to uniformity

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Freshly Mixed Concrete Testing

- Look for signs of segregation
- Determine :
  - Air Content
  - Slump
  - Temperature
  - Unit Weight
  - Yield

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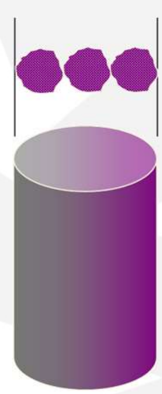
Concrete Cylinders

- Cylinder diameter must be at least **3 times** the nominal maximum size of the aggregate
- Concrete pavement cylinders shall be 6"x12"
- Make all other cylinders 4"x8"



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Concrete Prisms/Beams

- Beams for flexural strength
  - Typically, 6"x6" cross-section with 18" span
- Prisms are also used for freezing and thawing, length change, and volume change

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Number of Cylinders

- TDOT Specifications require test results for compressive strength at 28 days
  - 2 cylinders per test
  - For high early mixes, need results at specified early age (e.g., 18 hours)
  - Temporary approval may be issued provided the concrete meets or exceeds the 28-day strength requirement
    - 28-day result must be provided within one month of the submission or the design will be expired

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Making Cylinders and Beams

TABLE 1 Number of Layers Required for Specimens

Specimen Type and Size	Mode of Consolidation	Numbers of Layers of Approximate Equal Depth
Cylinders: Diameter, mm [in.]		
75 to 100 [3 or 4]	rodding	2
150 [6]	rodding	3
225 [9]	rodding	4
up to 225 [9]	vibration	2
Prisms and horizontal creep Cylinders: Depth, mm [in.]		
up to 200 [8]	rodding	2
over 200 [8]	rodding	3 or more
up to 200 [8]	vibration	1
over 200 [8]	vibration	2 or more

Making Cylinders and Beams

TABLE 2 Diameter of Rod and Number of Roddings to be Used in Molding Test Specimens

	Cylinders	
Diameter of Cylinder, mm [in.]	Diameter of Rod mm [in.]	Number of Strokes/Layer
75 [3] to < 150 [6]	10 ± 2 [3/8 ± 1/16]	25
150 [6]	16 ± 2 [5/8 ± 1/16]	25
200 [8]	16 ± 2 [5/8 ± 1/16]	50
250 [10]	16 ± 2 [5/8 ± 1/16]	75
	Beams and Prisms	
Top Surface Area of Specimen, cm^2 [$in.^2$]	Diameter of Rod mm [in.]	Number of Roddings/Layer
160 [25] or less	10 ± 2 [3/8 ± 1/16]	25
165 to 310 [26 to 49]	10 ± 2 [3/8 ± 1/16]	one for each 7 cm^2 [1 $in.^2$] of surface
320 [50] or more	16 ± 2 [5/8 ± 1/16]	one for each 14 cm^2 [2 $in.^2$] of surface
	Horizontal Creep Cylinders	
Diameter of Cylinder mm [in.]	Diameter of Rod mm [in.]	Number of Roddings/Layer
150 [6]	16 ± 2 [5/8 ± 1/16]	50 total, 25 along both sides of axis

Making Drycast Cylinders

- When concrete is too stiff to be consolidated via rodding or internal vibration, use the method in ASTM C497
  - Vibrating table
  - 3 layers
  - Vibrate with cylindrical hammer on surface of each lift until cement paste oozes around hammer

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Finishing

- Strike-off the surface
- No depressions or projections larger than 1/8"
- Cover immediately to prevent evaporation
  - Nonabsorptive, nonreactive cover
  - Plastic sheeting
  - Wet burlap
- Mold cylinders near storage area
- Store cylinders immediately after striking off
- Storage area should be free of vibration

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Curing (722.09)

- Remove from molds within 24 ± 8 hours after casting
- Moist cure at 73.5 ± 3.5°F until tested
- Free water on entire surface at all times
  - Immersion in saturated-lime water
  - Moist room or cabinet
  - No dripping or running water
- Vibration-free area for first 48 hours
- Curing conditions shall be monitored in compliance with AASHTO M 201

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Let's Review

- Beams are fabricated to measure

  ____

- For cylinders with a diameter of 6 inches, how many strokes per layer are required?
- Cylinder diameter must be ___ times the nominal maximum size of the aggregate.

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Questions

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Compressive Strength of Cylindrical Concrete Specimens

AASHTO T 22
ASTM C 39

TDOT Standard Method of Test for

Compressive Strength of Cylindrical Concrete Specimens

References

TDOT Standard Specifications

AASHTO T 22

ASTM C39

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Significance & Use

- This test method is used to determine the compressive strength of cylinders
- The compressive strength is used as a basis for performance of a mix
- The results are also used to determine compliance with TDOT Specifications

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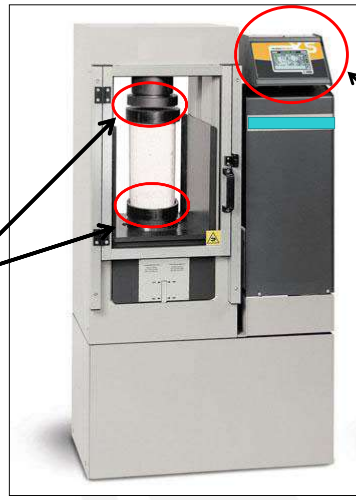
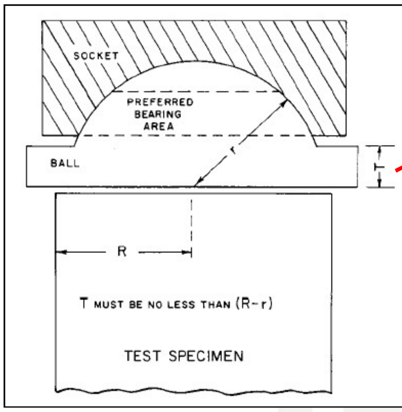
Compressive Strength Testing Machine



Testing Machine Requirements

- Sufficient capacity
- Capable of controlling the rate of loading
- Calibration
  - Upon installation, repair, or relocation
  - Within 13 months of the last calibration
  - When accuracy is in question

Bearing Block Requirements



Typical Spherical Bearing Block

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Load Indication Requirements

- Digital indicators must have numerical increments ≤ 0.1% of full scale load
- Analog indicators must have a graduated scale readable to the nearest 0.1% of full scale load
- Dial must have a zero adjustment
- 1% accuracy of maximum load

3000.0 lbs

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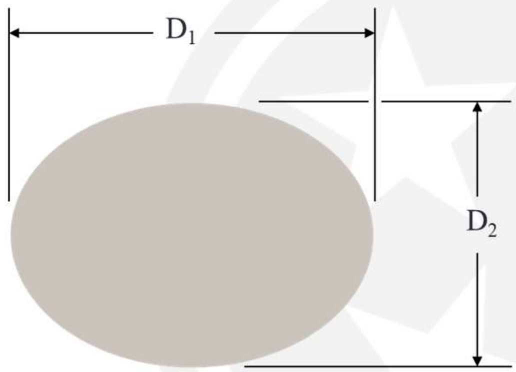
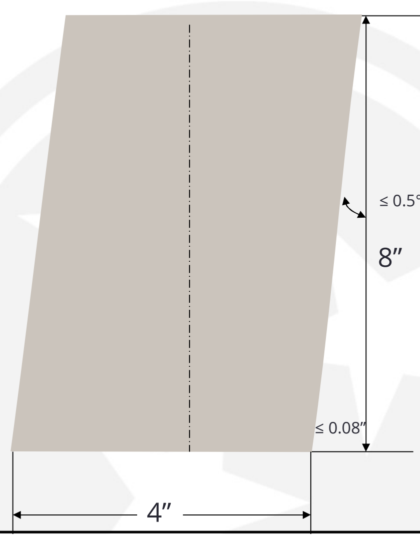
Cylinder Diameters

- Cylinders are not tested if any diameter of the cylinders differs from any other diameter of the same cylinder by more than 2%



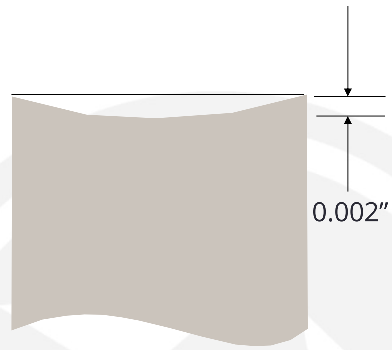
Cylinder Requirements

- The ends must not depart from perpendicularity to the axis by more than 0.5°
- 6″x12″ cylinder
  - 0.12″ for 12″
- 4″x8″ cylinder
  - 0.08″ for 8″
- Cap, saw, or grind the ends



Cylinder Requirements

- Depressions under a straight edge measured with a round wire gage across any diameter shall not exceed 0.20”
- The ends of cylinders to be tested for compressive strength must be plane to within 0.002” when making direct contact with steel



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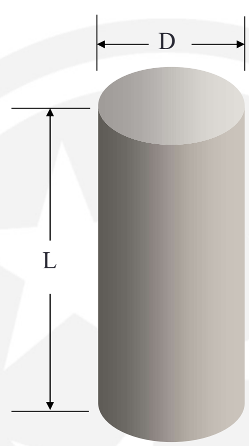
Cylinder Requirements

- Measure length to the nearest 0.05” at three locations around circumference
- Record average length to nearest 0.05”



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Time Tolerances

- Test cylinders shall be broken within the permissible time tolerance for a given test age
- 2% tolerance for any age not specified

Test Age	Permissible Tolerance
24 hour	± 0.5 hours
3 days	± 2 hours
7 days	± 6 hours
28 days	± 20 hours
90 days	± 2 days

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Procedure

- Compression tests shall be performed as soon as possible after removal from moist storage
- Cylinders shall be kept in a moist condition until they are tested

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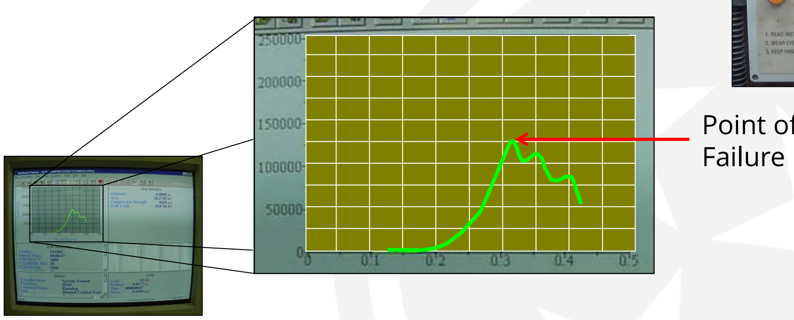
Procedure

- Wipe clean the faces of the upper and lower plates
- Wipe both ends of the cylinder
- If using compression pads, keep record of use and replace when required

Procedure

- Apply a continuous load without shock
- Apply the load until the cylinder fails



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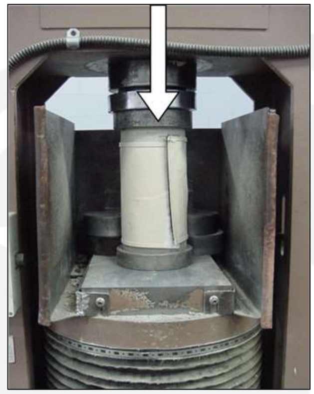
Rate of Loading

- Hydraulic machines
  - 35 ± 7 psi/sec
- Screw-type machines
  - Preliminary testing necessary to establish required rate of movement



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Measured Strength

- If cylinder breaks lower than expected, examine the fracture for:
  - Large air voids
  - Segregation
  - Verify end preparation
    - Capping Compound
    - Neoprene pad
  - Cracking of aggregate

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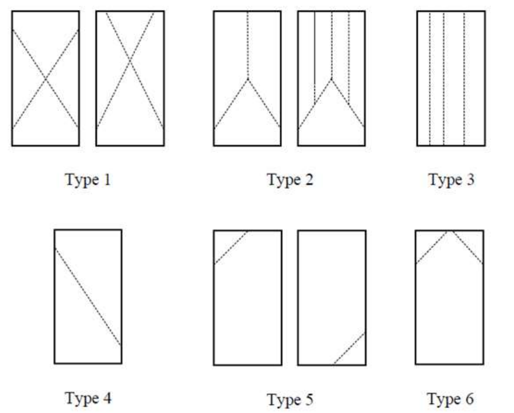
Cylinder Fractures



Type 1—Reasonably well-formed cones on both ends, less than 25mm (1 in.) of cracking through caps.

Type 2—Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end.

Type 3—Columnar vertical cracking through both ends, no well-formed cones.

Type 4—Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type 1

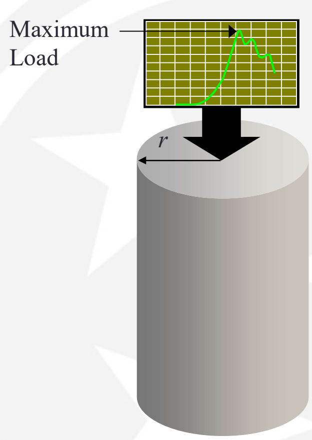
Type 5—Side fractures at top or bottom; commonly occurs with unbonded caps.

Type 6—Similar to Type 5 but end of cylinder is pointed.

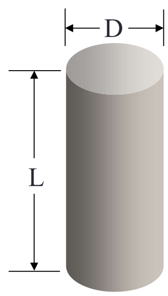
Calculating Compressive Strength

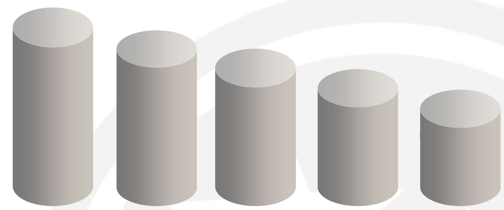
$$Compressive\ Strength = \frac{Maximum\ Load}{Cross - sectional\ Area} \times Correction\ Factor$$

$$Cross - sectional\ Area = \pi r^2$$



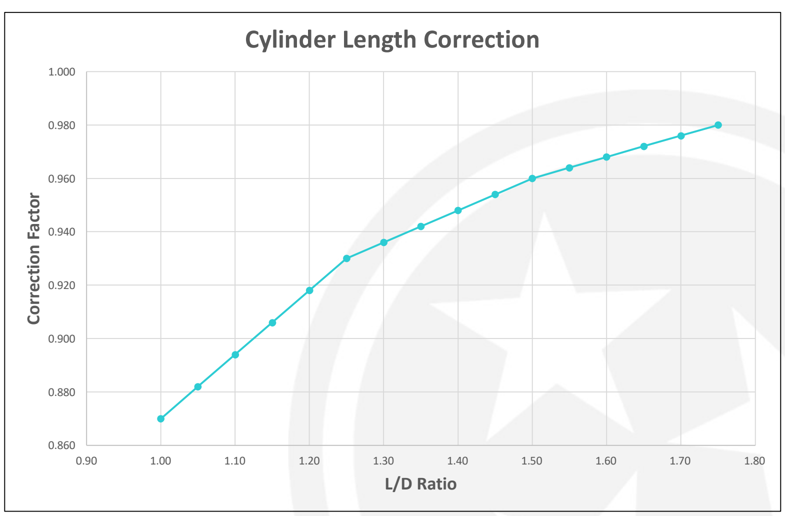
Length/Diameter (L/D) Correction Factor





L/D:	>1.75	1.75	1.50	1.25	1.00
Factor:	1.00	0.98	0.96	0.93	0.87

L/D Correction Factor Graph



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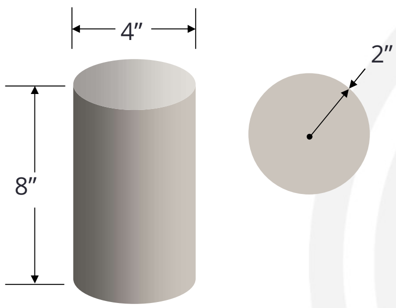
Example #1

Given:

- A standard 4”x8” cylinder of Class D concrete
- No preparation of the cylinder is required
- The cylinder fails at a maximum force of 53,259 pounds



$$\frac{L}{D} = \frac{8"}{4"} = 2 \quad \rightarrow \quad C = 1$$

$$f_c' = \frac{F_{max}}{A} \cdot C$$

$$f_c' = \frac{53259}{12.57} \times 1 = 4237 \text{ psi}$$

Reported to nearest 10 psi = 4240 psi

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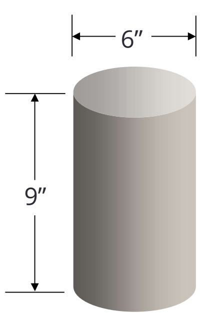
Example #2

Given:

- A standard 6”x12” cylinder of Class CP
- The ends were prepared so that the length of the cylinder is 9”
- The cylinder fails at a maximum force of 92,075 pounds



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Report

- Identification number
- Diameter
- Cross-sectional area
- Maximum load
- Compressive strength to nearest 10 psi
- Average compressive strength to nearest 10 psi
- if 2+ companion cylinders are tested
- Type of fracture
- Defects in cylinders or caps
- Age of cylinder

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Let's Review

- Cylinders are not tested if any diameter of the cylinders differs from any other diameter of the same cylinder by more than _____
- The ends must not depart from perpendicularity to the axis by more than _____.
- The rate of loading for hydraulic machines is _____________.

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Questions

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5

Concrete Mix Design Submittal & Approval

TDOT Process for

Concrete Mix Design Submittal & Approval

References

TDOT Standard Specifications

TDOT Supplemental Specifications

SOP 4-4

TN TDOT Department of Transportation

Trial Batch (SOP 4-4)

- Prepare trial batches for design, including admixtures in the proper proportions, within 90 days of design submission
- Gradations and specific gravity for coarse and fine aggregates used in trial batch shall reflect the characteristics of stockpiles to be used in the mix

TN TDOT Department of Transportation

Trial Batch (SOP 4-4)

- Any trial batch mixed for Class SCC, P-SCC, SH-SCC is no longer mandatory to be verified in the presence of Regional Materials & Tests
  - HQMT shall be notified prior to lab trials
  - The field trial must simulate expected field conditions including expected transport time
  - Static Segregation Test (ASTM C 1610) shall be performed in addition to acceptance tests for verification of the mix design
- Preconstruction panels shall be made during the trial batch of shotcrete (622.04)

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Trial Batch Testing (SOP 4-4)

- Tests shall be conducted to determine:
  - Slump (Slump Flow for SCC)
  - Temperature
  - Air Content
  - Unit Weight and Yield
  - Passing Ability (SCC)
  - Static Segregation (SCC)
  - T-50 (SCC)
- The hardened cylinders shall then be tested for compressive strength
- See Appendix D of SOP 4-4

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Types of Designs (SOP 4-4)

- New
  - Submit mix design template including all data from trial batch
- Temporary
  - Submit like a new design
  - Breaks must exceed 28-day requirement
  - Design expires if 28-day breaks are not submitted within one month of the original submission.
- Same As
  - A "same as" design is associated to multiple projects for a plant instead of submitting a new one each time
  - Must be an approved design from current year
  - Concrete Design Contract Association Request Form
  - Class X, SCC, P-SCC, and SH-SCC designs require additional information to associate to a new contract.

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Design Submittals (SOP 4-4)

- Submit to HQMT at least 14 days prior to mix production via email
- Ready Mix, Prestressed or Volumetric: TDOT.Concrete.Email@tn.gov
- Precast: TDOT.PrecastMTR@tn.gov

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Design Submittals (SOP 4-4)

- Subject line
  - New or Same as
  - Contract, Pin, or Bridge Grant Number
- Include:
  - If required, include "Surface Aggregates Required"
  - Attach design template/same-as form
  - Contact information
- Must be submitted by TDOT Concrete Mix Design Technician

TN TDOT Department of Transportation

Expiration of Mix Designs (SOP 4-4)

- Approved concrete mix designs will expire at the end of each calendar year (i.e. December 31st)
- Mix designs will be subject to expiration under the following conditions:
  - **Design** strength not met
  - Inadequate field performance
  - Failure of constituent materials

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Mix Design Template

- Use the newest version
- Mix designs are plant specific
- Include the following on each template:
  - Required compressive strength
  - All fresh concrete properties from trial batch
  - Compressive strength results from the trial batch at 28 days or earlier
    - High early designs need breaks for specified early strength time
  - All material sources must be TDOT approved
    - Producer List
    - Qualified Products List (QPL)
  - Design weights of all materials
- If Class X, also send a copy of the plans sheet or specification with requirements
- If Class PEM, submit all necessary documentation for data collection purposes only

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Cementitious Materials (Mix Design Template)

- Cement, Fly Ash, Slag
  - Type, class, grade
  - Specific Gravity (G_s) from producer mill certification
    - Ask the cement producer if not specified
- Fly ash outage
  - New trial batch required with the exception of an emergency (project may be delayed)
  - Only submit new designs as necessary for each project

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Cement (901.01)

- The maximum allowable equivalent alkalis is 0.60% for all cements and blended cements used in concrete riding surfaces that include surface aggregates
- Equivalent alkalis are found on the Mill Test Report

ASTM STANDARD REQUIREMENTS		CHEMICAL DATA C150	MILL CERTIFICATION VALUES	
$C_3S + 4.75(C_3A)$ - %	A		$C_3S + 4.75(C_3A)$ - %	99.9
Na_2O Equivalent - %	max .60%		Na_2O Equivalent - %	0.53
Free CaO - %	A		Free CaO - %	0.88

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Cement Replacement

Table 604.03-3: Type I or Type IL Cement Modified by Fly Ash or Slag Cement

Modifier	Maximum Cement Replacement Rate % (by weight)	Minimum Modifier Cement Substitution Rates (by weight)
Slag Cement (Grade 100 or 120)	35.0	1:1
Class "F" Fly Ash	25.0	1:1
Class "C" Fly Ash	25.0	1:1

The Contractor may use ternary cementitious mixtures (mixtures with Portland cement, slag cement, and fly ash) for Class A, Class D, and Class DS concrete provided that the minimum Portland cement content is 50%. The maximum amount of fly ash substitution in a ternary cementitious mixture shall be 20%. The Department will allow Type IS cement with ternary cementitious mixtures. When using a Type IS cement, do not use any additional slag cement as a partial replacement for the hydraulic cement. The Department will allow a maximum of 20% fly ash as a partial hydraulic cement replacement in Class A concrete using only Type IS cement.

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Cement Replacement Examples

- Example 1:
  - 620 lbs cement
  - Maximum class C fly ash replacement

$$620 \text{ lbs } \times 25\% = 155 \text{ lbs "C" Fly Ash}$$

- Example 2:
  - 564 lbs cement
  - 20% class F fly ash replacement

$$564 \text{ lbs } \times 20\% = 113 \text{ lbs "F" Fly Ash}$$

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Coarse & Fine Aggregates (Mix Design Template)

- Type and size: crush stone, gravel, surface, lightweight
- Specific gravities and absorptions from producer(s)
- Allow 1 change in coarse aggregate:
  - If like material, and SG is within 0.15 of original
- Coarse and fine aggregate gradations
  - Fine aggregate Fineness Modulus (2.3-3.1)

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Fine Aggregate Proportioning

- For most classes of concrete, the fine aggregate shall not exceed 44% of the total aggregate by volume
- Exceptions
  - Class A Slipform: 46% max
  - Class SCC, SH-SCC, P-SCC: 50% max
  - Curb and gutter: 40 - 65%
  - Drycast used for precast products: 60% max

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Water (Mix Design Template)

- Municipal or non-municipal
- For non-municipal also submit most recent water results per TDOT Specification 921.01

Table 921.01-2 Quality Requirements for Mixing Water

Maximum Concentration in Mixing Water	Limits	ASTM Test Method (1)
Chloride Ion Content, ppm	500	C114
Alkalies as (NaO2 + 0.658 K2O), ppm	600	C114
Sulfates as SO4, ppm	3000	C114
Total Solids by mass, ppm	50000	C1603
pH	4.5-8.5	(2)

(1) Other methods (EPA or those used by water testing companies) are generally acceptable.
(2) No ASTM method available.

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Admixtures (Mix Design Template)

- Brand and type
- Dosage rates used in trial batch
- Concrete mixtures using multiple admixture manufacturers must prove compatibility
  - 3 months of field data from non TDOT projects
  - Trial and field batch witnessed by HQ Materials & Tests or designee

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Precast & Prestressed Mix Designs

- Submit designs for the following year by November 1st
- If resubmitting the previous year mix design, provide trial batch data or project break data from the past 90 days
- Precast mix design requirements are listed in SOP 5-3
- Prestressed mix design requirements are listed in SOP 5-4 and TDOT Specifications 615.09
  - Prestressed producers may use a mix design with a higher strength than that called for by contract plans, shop drawings, etc.
  - Approved prestressed designs will designate the maximum strength requirement it can be used for

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Volumetric Mobile Mixers (604.04C)

- Individual performing calibration must have BOTH of the following certifications:
  - VMMB Volumetric Mixer Operator
  - TDOT Concrete Mix Field Testing Technician
- Perform the calibration of gate settings according to the manufacturer's recommendations for the mix design to be used
- Inspections and calibrations shall be performed at a minimum of every 6 months or every 2500 cubic yards

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Questions

TN TDOT Department of Transportation

6

Abolute Volume Method for Concrete Mix Design

Absolute Volume Method for Concrete Mix Design

References

TDOT Standard Specifications
TDOT Supplemental Specifications
PCA, *Design and Control of Concrete Mixtures*, 13th Ed.
NRMCA, *Proportioning Concrete Mixtures*

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Before Designing a Mix

Need the following:

- Class of concrete/Type of construction
  - Slump
  - Maximum w/cm ratio
  - Minimum cementitious material
  - Air content
- Cement
  - Specific gravity
- Other cementitious materials
  - Pozzolans
  - GGBFS
  - Silica fume
- Fine aggregate
  - Specific gravity
  - Gradation
  - Fineness modulus
- Coarse aggregate
  - Specific gravity
  - Gradation
  - Nominal maximum size

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Step 1: Class of Concrete

- Determine the class of concrete
- Identify all applicable specifications
  - Minimum cementitious material content
  - Maximum w/cm ratio
  - Fresh properties
  - Strength requirement

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Step 2: Water Content

- Determine the minimum amount of cement required and the maximum w/cm ratio
- Water/Cementitious Materials ratio on design is the maximum
- Determine the maximum allowable water content using the equation below

$$\frac{w}{cm} = \frac{weight\ of\ water}{weight\ of\ cementitious\ material}$$

$$weight\ of\ water = w/cm\ ratio \times weight\ of\ cementitious\ material$$

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Step 3: Absolute Volumes

- Calculate the absolute volume of any material

$$V_{ft^3} = \frac{W_{lbs.}}{G \times U}$$

V_{ft^3} = absolute volume of material, ft^3
W_{lbs} = weight of material, lbs
G = specific gravity of material
U = unit weight of water (usually assumed 62.4 lbs/ft^3)

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Step 4: Weight of Material

- Calculate the weight of any material

$$W_{lbs} = V_{ft^3} \times G \times U$$

W_{lbs} = weight of material, lbs
V_{ft^3} = absolute volume of material, ft^3
G = specific gravity of material
U = unit weight of water (usually assumed 62.4 lbs/ft^3)

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Step 5: Unit Weight of Mix

- Calculate the unit weight of the mix

$$U_{lbs/ft^3} = \frac{W_{total, lbs.}}{V_{total, ft^3}}$$

$U_{lbs/ft3}$ = unit weight of mix, lbs/ft^3

$W_{total, lbs}$ = total weight of all the materials, lbs

$V_{total,ft3}$ = total volume of the mix, ft^3 (should be 27 ft^3)

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Questions

TN TDOT Department of Transportation

7.1

Example #1

Example #1

Given:

- Class A Concrete
- Air Content-6%
- Minimum amount of Cement
- No Fly Ash
- Maximum w/c ratio
- Maximum amount of Fine Aggregate
- Specific Gravities:
  - Cement-3.15
  - Coarse Aggregate-2.79
  - Fine Aggregate-2.63

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TABULATION OF CONCRETE MIX DESIGN PROPORTIONS

Class of Concrete: __________ **Use the table in Section 604.03 of the Standard Specifications (Classification and Proportioning and Quality Assurance)**

			Constituent Materials	Weight		Specific Gravity	Volume (ft³)	
Paste	Cementitious Materials	W_{cm} (from table)	Cement	$\%W_{Cement}$	$W_{Cement} = (W_{cm} \times \%W_{Cement})/100$			$V_{Cement} = W_{Cement}/(G_{s,Cement} \times U)$
			Fly Ash	$\%W_{Flyash}$	$W_{Flyash} = (W_{cm} \times \%W_{Flyash})/100$	(given)		$V_{Flyash} = W_{Flyash}/(G_{s,Flyash} \times U)$
			Slag	$\%W_{Slag}$	$W_{Slag} = (W_{cm} \times \%W_{Slag})/100$	(given)		$V_{Slag} = W_{Slag}/(G_{s,Slag} \times U)$
			Water	w/cm (from table)	$W_{Water} = W_{cm} \times w/cm$			$V_{Water} = W_{Water}/(G_{s,Water} \times U)$
			Air				Design Air	$V_{Air} = (\text{Design Air} \times 27)/100$
Total Weight and Volume of Paste					$W_{Paste} = W_{cm} + W_{Water}$			$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$
Total Volume of Aggregate Required								$V_{Agg} = 27-(V_{cm} + V_{Water} + Vair)$
Aggregate			Coarse (CA)		$W_{CA} = V_{CA} \times G_{s,CA} \times U$	(given)	$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
			Fine (FA)		$W_{FA} = V_{FA} \times G_{s,FA} \times U$	(given)	$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$
TOTAL					$W_{Total} = W_{Paste} + W_{CA} + W_{FA}$			$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$
UNIT WEIGHT						$U_{Concrete} = W_{Total}/V_{Total}$		

Paste Material Weights

Cementitious Material:

$W_{CEMENT} = W_{CM} * \%W_{CEMENT}$

Paste:

$W_{PASTE} = W_{CM} + W_{WATER}$

Water:

$W_{WATER} = W_{CM} * W/CM$

			Constituent Materials	Weight	
Paste	Cementitious Materials	W_{cm} (from table)	Cement	$\%W_{Cement}$	$W_{Cement} = (W_{cm} \times \%W_{Cement})/100$
			Fly Ash	$\%W_{Flyash}$	$W_{Flyash} = (W_{cm} \times \%W_{Flyash})/100$
			Slag	$\%W_{Slag}$	$W_{Slag} = (W_{cm} \times \%W_{Slag})/100$
			Water	w/cm (from table)	$W_{Water} = W_{cm} \times w/cm$
			Air		
Total Weight and Volume of Paste				$W_{Paste} = W_{cm} + W_{Water}$	

Paste Material Volume

Cementitious Material:

$V_{CEMENT} = W_{CEMENT} / (G_{CEMENT} * U)$

U= 62.4 lbs/ft ^{3}

Water:

$V_{WATER} = W_{WATER} / U$

Air:

$V_{AIR} = (\text{Design Air} * 27)/100$

Paste:

$V_{PASTE} = V_{CEMENT} + V_{WATER} + V_{AIR}$

Weight	Specific Gravity	Volume (ft^3)
$W_{Cement} = (W_{cm} \times \%W_{Cement})/100$		$V_{Cement} = W_{Cement}/(G_{s,Cement} \times U)$
$W_{Flyash} = (W_{cm} \times \%W_{Flyash})/100$	(given)	$V_{Flyash} = W_{Flyash}/(G_{s,Flyash} \times U)$
$W_{Slag} = (W_{cm} \times \%W_{Slag})/100$	(given)	$V_{Slag} = W_{Slag}/(G_{s,Slag} \times U)$
$W_{Water} = W_{cm} \times w/cm$		$V_{Water} = W_{Water}/(G_{s,Water} \times U)$
		Design Air; $V_{Air} = (\text{Design Air} \times 27)/100$
$W_{Paste} = W_{cm} + W_{Water}$		$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$

Aggregate Volume

Total Aggregate Volume:

$V_{AGG} = 27 - V_{PASTE}$

Coarse Aggregate Volume:

$V_{CA} = \%V_{CA} * V_{AGG} /100$

Fine Aggregate Volume:

$V_{FA} = \%V_{FA} * V_{AGG} /100$

$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$	
$V_{Agg} = 27-(V_{cm} + V_{Water} + Vair)$	
$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$
	$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$

Aggregate Weights

Coarse Aggregate Weight:

$W_{CA} = V_{CA} * G_{CA} * U$

Fine Aggregate Weight:

$W_{FA} = V_{FA} * G_{FA} * U$

$U = 62.4\ lbs/ft^3$

	Constituent Materials	Weight	Specific Gravity	Volume (ft^3)	
Aggregate	Coarse (CA)	$W_{CA} = V_{CA} \times G_{s,CA} \times U$	(given)	$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
	Fine (FA)	$W_{FA} = V_{FA} \times G_{s,FA} \times U$	(given)	$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$

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Total and Unit Weight

Total Weight:

$W_{TOTAL} = W_{CA} + W_{FA} + W_{PASTE}$

Unit Weight:

$U_{CONCRETE} = W_{TOTAL} / V_{TOTAL}$

	Constituent Materials	Weight	Specific Gravity	Volume (ft³)	
Total Weight and Volume of Paste		$W_{Paste} = W_{cm} + W_{Water}$		$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$	
Total Volume of Aggregate Required				$V_{Agg} = 27 - (V_{cm} + V_{Water} + V_{air})$	
Aggregate	Coarse (CA)	$W_{CA} = V_{CA} \times G_{s,CA} \times U$	(given)	$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
	Fine (FA)	$W_{FA} = V_{FA} \times G_{s,FA} \times U$	(given)	$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$
TOTAL		$W_{Total} = W_{Paste} + W_{CA} + W_{FA}$			$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$
UNIT WEIGHT			$U_{Concrete} = W_{Total}/V_{Total}$		

Questions

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7.2

Example #2

Example #2

Given:

- Class D Concrete
- Air Content – 7%
- Minimum amount of Cement
- Maximum Replacement of Fly Ash
- Maximum w/c ratio
- Maximum amount of Fine Aggregate
- Specific Gravities:
  - Type IL Cement – 3.11
  - Fly Ash – 2.55
  - Coarse Aggregate – 2.79
  - Fine Aggregate – 2.63

TABULATION OF CONCRETE MIX DESIGN PROPORTIONS

Class of Concrete: __________ **Use the table in Section 604.03 of the Standard Specifications (Classification and Proportioning and Quality Assurance)**

			Constituent Materials	Weight		Specific Gravity	Volume (ft^3)	
Paste	Cementitious Materials	W_{cm} (from table)	Cement	$\%W_{Cement}$	$W_{Cement} = (W_{cm} \times \%W_{Cement})/100$		$V_{Cement} = W_{Cement}/(G_{s,Cement} \times U)$	
			Fly Ash	$\%W_{Flyash}$	$W_{Flyash} = (W_{cm} \times \%W_{Flyash})/100$	(given)	$V_{Flyash} = W_{Flyash}/(G_{s,Flyash} \times U)$	
			Slag	$\%W_{Slag}$	$W_{Slag} = (W_{cm} \times \%W_{Slag})/100$	(given)	$V_{Slag} = W_{Slag}/(G_{s,Slag} \times U)$	
			Water	w/cm (from table)	$W_{Water} = W_{cm} \times w/cm$		$V_{Water} = W_{Water}/(G_{s,Water} \times U)$	
			Air				Design Air	$V_{Air} = (Design\ Air \times 27)/100$
Total Weight and Volume of Paste					$W_{Paste} = W_{cm} + W_{Water}$		$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$	
Total Volume of Aggregate Required							$V_{Agg} = 27-(V_{cm} + V_{Water} + Vair)$	
Aggregate			Coarse (CA)		$W_{CA} = V_{CA} \times G_{s,CA} \times U$	(given)	$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
			Fine (FA)		$W_{FA} = V_{FA} \times G_{s,FA} \times U$	(given)	$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$
TOTAL					$W_{Total} = W_{Paste} + W_{CA} + W_{FA}$			$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$
UNIT WEIGHT						$U_{Concrete} = W_{Total}/V_{Total}$		

Paste Material Weights

Cementitious Material:

$W_{CEMENT} = W_{CM} * \%W_{CEMENT}$

Water:

$W_{WATER} = W_{CM} * W/CM$

Paste:

$W_{PASTE} = W_{CM} + W_{WATER}$

			Constituent Materials	Weight	
Paste	Cementitious Materials	W_{cm} (from table)	Cement	$\%W_{Cement}$	$W_{Cement} = (W_{cm} \times \%W_{Cement})/100$
			Fly Ash	$\%W_{Flyash}$	$W_{Flyash} = (W_{cm} \times \%W_{Flyash})/100$
			Slag	$\%W_{Slag}$	$W_{Slag} = (W_{cm} \times \%W_{Slag})/100$
			Water	w/cm (from table)	$W_{Water} = W_{cm} \times w/cm$
			Air		
Total Weight and Volume of Paste				$W_{Paste} = W_{cm} + W_{Water}$	

Paste Material Volume

Cementitious Material:

$V_{CEMENT} = W_{CEMENT} / (G_{CEMENT} * U)$

U= 62.4 lbs/ft 3

Water:

$V_{WATER} = W_{WATER} / U$

Air:

$V_{AIR} = (\text{Design Air} * 27)/100$

Paste:

$V_{PASTE} = V_{CEMENT} + V_{WATER} + V_{AIR}$

Weight	Specific Gravity	Volume (ft³)	
$W_{Cement} = (W_{cm} \times \%W_{Cement})/100$		$V_{Cement} = W_{Cement}/(G_{s,Cement} \times U)$	
$W_{Flyash} = (W_{cm} \times \%W_{Flyash})/100$	(given)	$V_{Flyash} = W_{Flyash}/(G_{s,Flyash} \times U)$	
$W_{Slag} = (W_{cm} \times \%W_{Slag})/100$	(given)	$V_{Slag} = W_{Slag}/(G_{s,Slag} \times U)$	
$W_{Water} = W_{cm} \times w/cm$		$V_{Water} = W_{Water}/(G_{s,Water} \times U)$	
		Design Air	$V_{Air} = (\text{Design Air} \times 27)/100$
$W_{Paste} = W_{cm} + W_{Water}$		$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$	

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Aggregate Volume

Total Aggregate Volume:

$V_{AGG} = 27 - V_{PASTE}$

Coarse Aggregate Volume:

$V_{CA} = \%V_{CA} * V_{AGG} / 100$

Fine Aggregate Volume:

$V_{FA} = \%V_{FA} * V_{AGG} / 100$

$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$	
$V_{Agg} = 27-(V_{cm} + V_{Water} + Vair)$	
$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$
	$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$

Aggregate Weights

Coarse Aggregate Weight:

$W_{CA} = V_{CA} * G_{CA} * U$

Fine Aggregate Weight:

$W_{FA} = V_{FA} * G_{FA} * U$

$U = 62.4\ lbs/ft^3$

	Constituent Materials	Weight	Specific Gravity	Volume (ft^3)	
Aggregate	Coarse (CA)	$W_{CA} = V_{CA} \times G_{s,CA} \times U$	(given)	$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
	Fine (FA)	$W_{FA} = V_{FA} \times G_{s,FA} \times U$	(given)	$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$

Total and Unit Weight

Total Weight:

$$W_{TOTAL} = W_{CA} + W_{FA} + W_{PASTE}$$

Unit Weight:

$$U_{CONCRETE} = W_{TOTAL} / V_{TOTAL}$$

	Constituent Materials	Weight	Specific Gravity	Volume (ft^3)	
Total Weight and Volume of Paste		$W_{Paste} = W_{cm} + W_{Water}$		$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$	
Total Volume of Aggregate Required				$V_{Agg} = 27-(V_{cm} + V_{Water} + Vair)$	
Aggregate	Coarse (CA)	$W_{CA} = V_{CA} \times G_{s,CA} \times U$	(given)	$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
	Fine (FA)	$W_{FA} = V_{FA} \times G_{s,FA} \times U$	(given)	$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$
TOTAL		$W_{Total} = W_{Paste} + W_{CA} + W_{FA}$			$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$
UNIT WEIGHT			$U_{Concrete} = W_{Total}/V_{Total}$		

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Questions

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7.3

Example #3

Example #3

Given:

- Class A Ternary
- Minimum amount of Cement
- Maximum Replacement of Fly Ash
- Maximum w/c ratio
- Maximum amount of Fine Aggregate
- Specific Gravities:
  - Cement – 3.15
  - Fly Ash – 2.55
  - Slag – 2.63
  - Coarse Aggregate – 2.79
  - Fine Aggregate – 2.63

TABULATION OF CONCRETE MIX DESIGN PROPORTIONS

Class of Concrete: ___________ **Use the table in Section 604.03 of the Standard Specifications (Classification and Proportioning and Quality Assurance)**

			Constituent Materials	Weight		Specific Gravity	Volume (ft³)	
Paste	Cementitious Materials	W_{cm} (from table)	Cement	$\%W_{Cement}$	$W_{Cement} = (W_{cm} \times \%W_{Cement})/100$		$V_{Cement} = W_{Cement}/(G_{s,Cement} \times U)$	
			Fly Ash	$\%W_{Flyash}$	$W_{Flyash} = (W_{cm} \times \%W_{Flyash})/100$	(given)	$V_{Flyash} = W_{Flyash}/(G_{s,Flyash} \times U)$	
			Slag	$\%W_{Slag}$	$W_{Slag} = (W_{cm} \times \%W_{Slag})/100$	(given)	$V_{Slag} = W_{Slag}/(G_{s,Slag} \times U)$	
			Water	w/cm (from table)	$W_{Water} = W_{cm} \times w/cm$		$V_{Water} = W_{Water}/(G_{s,Water} \times U)$	
			Air				Design Air	V_{Air} = (Design Air x 27)/100
Total Weight and Volume of Paste					$W_{Paste} = W_{cm} + W_{Water}$		$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$	
Total Volume of Aggregate Required							$V_{Agg} = 27-(V_{cm} + V_{Water} + Vair)$	
Aggregate			Coarse (CA)		$W_{CA} = V_{CA} \times G_{s,CA} \times U$	(given)	$\%V_{CA}$ (given)	$V_{CA} = (\%V_{CA} \times V_{Agg})/100$
			Fine (FA)		$W_{FA} = V_{FA} \times G_{s,FA} \times U$	(given)	$\%V_{FA}$ (given)	$V_{FA} = (\%V_{FA} \times V_{Agg})/100$
TOTAL					$W_{Total} = W_{Paste} + W_{CA} + W_{FA}$			$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$
UNIT WEIGHT						$U_{Concrete} = W_{Total}/V_{Total}$		

Questions

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Appendix

Appendix

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AASHTO/ASTM Resources

- Making and Curing Concrete Test Specimens in the Laboratory: ASTM C192
- Compressive Strength of Cylindrical Concrete Specimens: AASHTO T 22/ASTM C39

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SOP 4-4

- Submittal and approval process for concrete mixes
  - Ready mix
  - Volumetric mobile mixers
  - Prestressed
  - Precast

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CONCRETE MIXTURE DESIGN TEMPLATE

VERSION 11.22

Contract Number		**Pin Number**		**Project Ref. No.**	
Plant Producer/ Location				**Plant Number**	0
Contractor		**Class of Concrete**		**Strength (psi)** 3000 **at** 28 DAYS	**Early Str.** **at**

P/S Code	Cementitious Materials (cm)	Type/Class/Grade	Source	G_s (SSD)	Weight, lbs.	Volume, ft^3
0	Cement					
0	Flyash					
0	Slag Cement					
P/S Code	**Aggregates**	**Type/Size**	**Source**	**G_s (SSD)**	**Weight, lbs.**	**Volume, ft^3**
0	Coarse Aggregate 1 (CA1)					
0	Coarse Aggregate 2 (CA2)					
0	Coarse Aggregate 3 (CA3)					
0	Fine Aggregate 1 (FA1)					
0	Fine Aggregate 2 (FA2)					
0	**Air-Entraining Admixture**	**Brand Name - Product**	**Dosage (oz/cwt)**	**% Air**	**Weight, lbs.**	**Volume, ft^3**

	Water	w/cm =		1		

P/S Code	Chemical and Other Admixtures	Brand Name - Product	Dosage (units)
0	Type A - Water Reducer		
0	Type B - Retarder		
0	Type C - Accelerator		
0	Type D - Reducer/Retarder		
0	Type E - Reducer/Accelerator		
0	Type F - High-Range Water Reducer		
0	Type G - High-Range/Retarder		
0	Other (QPL Items)		
0	Other (QPL Items)		
0	Type S - Specific Performance		
0	Precast		

Design Parameters	
Total cm Weight, lbs.	
Total Aggregate Volume, ft^3	
%FA of Total Agg. Vol.	
Theoretical Unit Wt., pcf	
Freshly-Mixed Properties	
Air Content, %	
Temperature, °F	
Slump/Flow, in.	
Unit Weight, pcf	
Yield	

AGGREGATE DATA

CA/FA	4"	3-1/2"	3"	2-1/2"	2"	1-1/2"	1"	3/4"	1/2"	3/8"	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	FM	Absorption
CA1																		---	
CA2																		---	
CA3																		---	
FA1																		10.00	
FA2																		10.00	

COMPRESSIVE STRENGTH DATA

Sample No.	Date Made	Date Tested	Age, days	Length, in.	Dia., in.	L/D	C	Area, in^2	Load, lbs.	Strength, psi	Average, psi
			0			0.00		0.00		0	0
			0			0.00		0.00		0	
			0			0.00		0.00		0	0
			0			0.00		0.00		0	
			0			0.00		0.00		0	0
			0			0.00		0.00		0	
			0			0.00		0.00		0	0
			0			0.00		0.00		0	

Remarks: **Mix ID:**

Technician Name: **Certification Number:**

Questions

Materials & Tests Website

https://www.tn.gov/tdot/materials-and-tests.html

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THANK YOU!