Concrete Mix Design Technician Course
Tennessee Department of Transportation
2020 Manual
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Tennessee Department of Transportation

2020 Manual

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Classroom Rules

• Be Respectful
• Facility Information
• Keep It Clean
• Phone Etiquette
Who Are YOU?

- Name
- Company
- Experience
- Why are you here?

Purpose of Certification

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

- Course schedule
  - Slide presentations
  - Written exam
  - Results
- Examination
  - Written Exam (No Phones Allowed)
    - Open-book
    - Must get 75% overall to pass
- Recertification
  - Every 5 years

Resources

- Course materials
  - Course textbook
  - Presentation slides and videos
- TDOT
  - Standard Specifications, January 1, 2015
  - Special Provisions
ADA Notice of Requirements

• Can be found at the following website:

• To be in compliance with TDOTs 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.

Questions
1

Basic Concrete Ingredients
Basic Concrete Ingredients

References
NRMCA Publication No. 159
FHWA Publication No. HIF-07-004

Concrete is a mixture of paste and aggregates
Basic Ingredients

- Type I – Normal Use
  - Used for common applications

- 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

Types of Cement
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
Slag Cement (GBFS)

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

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
### Effects of SCMs on Fresh Concrete Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Class F</th>
<th>Class C</th>
<th>GGBF slag</th>
<th>Silica fume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water requirements</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Workability</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Bleeding and segregation</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Air content</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Heat of hydration</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Setting time</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Finishability</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Pumpability</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Plastic shrinkage cracking</td>
<td>←</td>
<td>→</td>
<td>←</td>
<td>→</td>
</tr>
</tbody>
</table>

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

### Effects of SCMs on Hardened Concrete Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Class F</th>
<th>Class C</th>
<th>GGBF slag</th>
<th>Silica fume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early strength</td>
<td>↓</td>
<td>←</td>
<td>←</td>
<td>↑</td>
</tr>
<tr>
<td>Long-term strength</td>
<td>↑</td>
<td>↑</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>Permeability</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Chloride ingress</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>ASR</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Sulfate resistance</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Freezing and thawing</td>
<td>←</td>
<td>→</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>Drying shrinkage</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
</tr>
</tbody>
</table>
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

Air Entrainment

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

Entrapped air

Entrained air
Coarse Aggregate

- 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
- Must meet TDOT specifications

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

<table>
<thead>
<tr>
<th>Application</th>
<th>Coarse Aggregate Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural concrete</td>
<td>No. 57</td>
</tr>
<tr>
<td>Self-Consolidating Concrete</td>
<td>Maximum No. 67</td>
</tr>
<tr>
<td>Prestressed concrete</td>
<td>No. 57 or 67</td>
</tr>
<tr>
<td>Prestressed concrete</td>
<td>Any size fraction</td>
</tr>
<tr>
<td>Concrete for Bridge Repair</td>
<td>No. 5, 57, 67, or 78</td>
</tr>
<tr>
<td>Concrete curbing placed by machine-</td>
<td>No. 5, 57, 67, or 78</td>
</tr>
<tr>
<td>extrusion methods</td>
<td></td>
</tr>
<tr>
<td>Cement treated permeable base (3)</td>
<td>No. 57</td>
</tr>
</tbody>
</table>

(3) Gradation shall conform to 903.22.
(3) Aggregate shall meet the quality requirements specified below.
**Fine Aggregate**

- Natural sand
  - Dredged river sand
  - Pit sand
  - Processed sandstone
- Manufactured Sand
  - Processed limestone
- Passing No. 4 sieve
- Must meet TDOT specifications

**Surface Aggregates**

*(TDOT Specification 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
Questions
TDOT Concrete Classes
TDOT Concrete Classes

References
TDOT Standard Specifications

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
- Class SCC, SH-SCC – Self Consolidating Concrete
- Class P-SCC
- Class P – Prestressed/Precast Bridge Members
- HE – High Early Strength
- Precast Concrete
Class CP
(TDOT Specifications Table 501.03-1)

- Concrete Pavement

<table>
<thead>
<tr>
<th>28 Day Compressive Strength, min (PSI)</th>
<th>Minimum Cementitious Content (pounds per cubic yard)</th>
<th>Maximum Water/Cement Ratio (pound/pound)</th>
<th>Air Content (%)</th>
<th>Slump (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000</td>
<td>526 (1)</td>
<td>0.49</td>
<td>5% design</td>
<td>0 - 2 (2)</td>
</tr>
<tr>
<td></td>
<td>545 (3)</td>
<td></td>
<td>3 - 8% production</td>
<td>3 ± 1 (4)</td>
</tr>
</tbody>
</table>

(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

Class A
(TDOT Specifications Table 604.03-1)

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

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Min 28-Day Compressive Strength (psi)</th>
<th>Min Cement Content (pound per cubic yard)</th>
<th>Maximum Water/Cement Ratio (pound/pound)</th>
<th>Air Content % (Design ± production tolerance)</th>
<th>Slump (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3,000</td>
<td>564</td>
<td>0.45</td>
<td>6 ± 2</td>
<td>3 ± 1 (3)</td>
</tr>
</tbody>
</table>

(3) For slip forming, the slump shall range from 0 to 3 inches.
Class D, DS
(TDOT Specifications Table 604.03-1)

- Bridge Deck Concrete
- Class DS requires surface aggregate

**Table 604.03-1: Composition of Various Classes of Concrete**

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Min 28-Day Compressive Strength (psi)</th>
<th>Min Cement Content (pound per cubic yard)</th>
<th>Maximum Water/Cement Ratio (pound/pound)</th>
<th>Air Content % (Design ± production tolerance)</th>
<th>Slump (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (1, 2)</td>
<td>4,000</td>
<td>620</td>
<td>0.40</td>
<td>7 (5), 8 max (6)</td>
<td></td>
</tr>
</tbody>
</table>

(1) Use Class D concrete in all bridge decks except box and slab type structures unless otherwise shown on the Plans.
(2) 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.
(3) Water reducing admixtures are acceptable; however, do not exceed the maximum water/cement ratio in order to achieve the required slump.

Class L
(TDOT Specifications Table 604.03-1)

- Lightweight Concrete

**Table 604.03-1: Composition of Various Classes of Concrete**

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Min 28-Day Compressive Strength (psi)</th>
<th>Min Cement Content (pound per cubic yard)</th>
<th>Maximum Water/Cement Ratio (pound/pound)</th>
<th>Air Content % (Design ± production tolerance)</th>
<th>Slump (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L (3, 4)</td>
<td>4,000</td>
<td>620</td>
<td>0.40</td>
<td>7 (5), 8 max (6)</td>
<td></td>
</tr>
</tbody>
</table>

(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.
Class S
(TDOT Specifications Table 604.03-1)

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

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Min 28-Day Compressive Strength (psi)</th>
<th>Min Cement Content (pound per cubic yard)</th>
<th>Maximum Water/Cement Ratio (pound/pound)</th>
<th>Air Content % (Design ± production tolerance)</th>
<th>Slump (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S (Seal) (6)</td>
<td>3,000</td>
<td>682</td>
<td>0.47</td>
<td>6 ± 2</td>
<td>6 ± 2</td>
</tr>
</tbody>
</table>

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

Class X

- Plans Specific Requirements
  - For local programs, mix design approved by Local Government/CEI

HIGH EARLY STRENGTH CONCRETE:
Class SCC & SH-SCC
(TDOT Specifications Table 604.03-4)

- Class SCC can be used as a replacement for Class A
- Class SH-SCC is used in drilled shafts

<table>
<thead>
<tr>
<th>Table 604.03-4: Composition of Self-Consolidating Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of Concrete</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>SCC</td>
</tr>
<tr>
<td>SH-SCC (Class A)</td>
</tr>
</tbody>
</table>

(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 C3321 shall be less than 2 inches for acceptance.
(4) Visual Stability Index (VSI) shall not exceed 1.8 as per ASTM C661 for acceptance.
(5) Static segregation as measured by ASTM C1601 shall not exceed 20%.
(6) Air Content may be reduced if placed under water or underground if approved by the Engineer

Class P-SCC
(TDOT Specifications Table 615.09-1)

- For prestressed members

<table>
<thead>
<tr>
<th>Table 615.09-1: Class P Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of Concrete</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>P-SCC</td>
</tr>
</tbody>
</table>

(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.
**Class P**  
(TDOT Specifications Table 615.09-1)  
- Prestressed Concrete Bridge Members  
- Strengths will be dictated by approved plans or shop drawings

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Min. 28-Day Compressive Strength (psi)</th>
<th>Min. Cement Content (pound per cubic yard)</th>
<th>Maximum Water/Cement Ratio (pound/pound)</th>
<th>Air Content % (design ± production tolerance)</th>
<th>Slump or Slump Flow (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>5,000 (^{(1)})</td>
<td>658</td>
<td>0.45</td>
<td>0.8 (^{(2)})</td>
<td>2 ± 1 (^{(3)})</td>
</tr>
</tbody>
</table>

---

\(^{(1)}\) 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.

\(^{(3)}\) Not to exceed 5 inches before the addition of high range admixtures, and not to exceed 10 inches after the addition of high range admixtures. If water-cement ratio is equal to or less than 0.35 then the maximum slump is 10 inches. If the water-cement ratio is 0.36 - 0.45, the maximum slump is 8 inches.

---

**High Early Strength Concrete**  
(TDOT Specifications 604.03.C)  
- Concrete strength requirement prior to 28 days  
- Concrete repair applications  
- Minimum Cement Content:  
  - Type I – 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
Different precast products have different design requirements

- Noise walls panels: Class A
- Retaining wall panels, junction boxes, and 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

Questions
Making and Curing Concrete Test Specimens in the Laboratory

ASTM C 192
TDOT Standard Method of Test for 
Making and Curing Concrete Test 
Specimens in the Laboratory

References
TDOT Standard Specifications
ASTM C192

Apparatus

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

Preparation of Materials
(Aggregates)

- Maintain aggregate in SSD condition
- Obtain the specific gravity and absorption from the aggregate facility
- Determine moisture content of aggregates
- Determine moisture corrections for aggregates and batching water
Preparation of Materials
(Chemical Admixtures)

• Consult with admixture manufacturer to determine if powered admixtures should be mixed with cement or sand before incorporating in the mix.

• Water-soluble and liquid admixtures should be added in solution to the mixing water before use.

• Incompatible admixtures (i.e. in concentrated form) should not be combined before adding to the mixer.

• Time, sequence, and method of adding the admixtures should remain constant from batch to batch.
Machine-Mixing

- Mix 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

Freshly Mixed Concrete Testing

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

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
Number of Cylinders

- TDOT Specifications require test results for compressive strength at 7, 14, and 28 days
  - 2 cylinders per test
  - For high early mixes, need results at specified early age (e.g. 18 hours)

Making Cylinders and Beams

<table>
<thead>
<tr>
<th>TABLE 1 Number of Layers Required for Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen Type and Size</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Cylinders:</td>
</tr>
<tr>
<td>Diameter, mm [in.]</td>
</tr>
<tr>
<td>75 to 100 [3 or 4]</td>
</tr>
<tr>
<td>150 [6]</td>
</tr>
<tr>
<td>225 [9]</td>
</tr>
<tr>
<td>up to 225 [9]</td>
</tr>
<tr>
<td>Prisms and horizontal creep Cylinders:</td>
</tr>
<tr>
<td>Depth, mm [in.]</td>
</tr>
<tr>
<td>up to 200 [8]</td>
</tr>
<tr>
<td>over 200 [8]</td>
</tr>
<tr>
<td>up to 200 [8]</td>
</tr>
<tr>
<td>over 200 [8]</td>
</tr>
</tbody>
</table>
## Making Cylinders and Beams

<table>
<thead>
<tr>
<th>Diameter of Cylinder, mm (in)</th>
<th>Diameter of Rod mm (in)</th>
<th>Number of Strokes/Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 (3) to &lt; 150 (6)</td>
<td>10 ± 2 (4/1 x 1/4)</td>
<td>25</td>
</tr>
<tr>
<td>150 (6)</td>
<td>10 ± 2 (4/1 x 1/4)</td>
<td>50</td>
</tr>
<tr>
<td>200 (8)</td>
<td>10 ± 2 (4/1 x 1/4)</td>
<td>75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top Surface Area of Specimen, cm² (in²)</th>
<th>Diameter of Rod mm (in)</th>
<th>Beams and Prisms</th>
<th>Number of Roddings/Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 (25) or less</td>
<td>10 ± 2 (4/1 x 1/4)</td>
<td>one for each 7 cm² (1 in²) of surface</td>
<td></td>
</tr>
<tr>
<td>165 to 210 (65 to 66)</td>
<td>10 ± 2 (4/1 x 1/4)</td>
<td>one for each 14 cm² (2 in²) of surface</td>
<td></td>
</tr>
<tr>
<td>220 (89) or more</td>
<td>15 ± 2 (4/1 x 1/4)</td>
<td>one for each 14 cm² (2 in²) of surface</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diameter of Cylinder mm (in)</th>
<th>Diameter of Rod mm (in)</th>
<th>Number of Roddings/Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 (6)</td>
<td>18 ± 2 (4/1 x 1/4)</td>
<td>60 total, 20 along both sides of axis</td>
</tr>
</tbody>
</table>

## Methods of Consolidation

- Rod or vibrate: Slump ≥ 1”
- Vibration: Slump < 1”
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

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
Curing

- 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
- *Flexural strength test prisms* shall be saturated in lime solution at least 20 hours prior to testing
4

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

**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
Compressive Strength Testing Machine

- Bearing blocks
- Load indicator

Testing Machine Requirements

- Sufficient capacity
- Capable of controlling the rate of loading
- Calibration
  - Upon installation, repair, or relocation
  - Annually
  - When accuracy is in question
Bearing Block Requirements

Typical Spherical Bearing Block

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

Compressive Strength

3000.0 lbs
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

- The ends of cylinders to be tested for compressive strength must be plane to within 0.002”

Cylinder Requirements

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

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

<table>
<thead>
<tr>
<th>Test Age</th>
<th>Permissible Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hour</td>
<td>± 0.5 hours</td>
</tr>
<tr>
<td>3 days</td>
<td>± 2 hours</td>
</tr>
<tr>
<td>7 days</td>
<td>± 6 hours</td>
</tr>
<tr>
<td>28 days</td>
<td>± 20 hours</td>
</tr>
<tr>
<td>90 days</td>
<td>± 2 days</td>
</tr>
</tbody>
</table>

**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
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

• Place the cylinder on the lower plate
• Align the axis of the cylinder with the center of the upper plate
• Rotate the bearing block to ensure freedom of movement
**Procedure**

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

**Rate of Loading**

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

---

**Cylinder Fractures**

- Cone
- Cone and Split
- Cone and Shear
- Shear
- Columnar
Calculating Compressive Strength

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

\[
\text{Cross - sectional Area} = \pi r^2
\]

Length/Diameter (L/D) Correction Factor

<table>
<thead>
<tr>
<th>L/D:</th>
<th>&gt;1.75</th>
<th>1.75</th>
<th>1.50</th>
<th>1.25</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td>1.00</td>
<td>0.98</td>
<td>0.96</td>
<td>0.93</td>
<td>0.87</td>
</tr>
</tbody>
</table>
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
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
Report

- Identification number
- Diameter
- Cross-sectional area
- Maximum load
- Compressive strength to nearest 10 psi
- Type of fracture
- Defects in cylinders or caps
- Age of cylinder

Questions
Concrete Mix Design
Submittal & Approval
TDOT Process for
Concrete Mix Design Submittal & Approval

References
TDOT Standard Specifications
TDOT Supplemental Specifications
SOP 4-4

Trial Batch
(SOP 4-4)

• Prepare trial batches for design, including admixtures in the proper proportions, no more than 90 days before the design submittal
• 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
• Any trial batch mixed for Class SCC, P-SCC, SH-SCC shall be verified in the presence of Regional Materials & Tests
  • 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
Trial Batch
(SOP 4-4)

• Any trial batch mixed for Class SCC, P-SCC, SH-SCC shall be verified in the presence of Regional Materials & Tests
  • 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)

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
Types of Designs
(SOP 4-4)

• New
  • Submit mix design template including all data from trial batch

• Temporary
  • Submit like a new design
  • 7 or 14 day breaks must exceed 28-day requirement
  • Design expires if 28-day breaks are not submitted

• 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
  • Not permitted for Class X, SCC, P-SCC, and SH-SCC designs

Design Submittals
(SOP 4-4)

• Submit to HQMT at least 14 days prior to mix production via email
• Ready Mix or Prestressed: TDOT.Concrete.Email@tn.gov
• Precast: TDOT.PrecastMTR@tn.gov
  • 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
    • PE licensed in TN
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 if the following are not satisfied:
  - Design strength
  - Field requirements/performance

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 7, 14, and 28 days
    - High early designs need breaks for specified early strength time
  - All material sources must be TDOT approved
    - Producer List
    - Qualified Products List (QPL)
  - Batch weights of all materials
- If Class X, also send a copy of the plans sheet
Cementitious Materials
(Mix Design Template)

- Cement, Fly Ash, Slag
  - Type, class, grade
  - Specific Gravity \( (G_s) \) from producer, typically 3.15
- 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

Cement
(TDOT Specification 901.01)

- The maximum allowable equivalent alkalis is 0.6% for all cements and blended cements used in concrete riding surfaces that include surface aggregates
- Equivalent alkalis are found on the Mill Test Report

<table>
<thead>
<tr>
<th>ASTM STANDARD REQUIREMENTS</th>
<th>CHEMICAL DATA C159</th>
<th>MILL CERTIFICATION VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_s + 4.75(C_{2A}) - % )</td>
<td>( C_s + 4.75(C_{2A}) - % )</td>
<td>99.9</td>
</tr>
<tr>
<td>( \text{N}_2O \text{O Equivalent} - % )</td>
<td>( \text{N}_2O \text{O Equivalent} - % )</td>
<td>0.63</td>
</tr>
<tr>
<td>Free CaO - %</td>
<td>Free CaO - %</td>
<td>0.88</td>
</tr>
</tbody>
</table>
Cement Replacement

Table 604.03-3: Type I or Type II. Cement Modified by Fly Ash or Ground Granulated Blast Furnace Slag (GGBFS)

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Maximum Cement Replacement Rate % (by weight)</th>
<th>Minimum Modifier Cement Substitution Rates (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGBFS (grade 100 or 120)</td>
<td>35.0</td>
<td>1:1</td>
</tr>
<tr>
<td>Class &quot;F&quot; Fly Ash</td>
<td>25.0</td>
<td>1:1</td>
</tr>
<tr>
<td>Class &quot;C&quot; Fly Ash</td>
<td>25.0</td>
<td>1:1</td>
</tr>
</tbody>
</table>

The Contractor may use ternary cementitious mixtures (mixtures with Portland cement, ground granulated blast furnace slag, and fly ash) for Class A and Class D 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 as a partial replacement for the hydraulic cement.

Cement Replacement Examples

- **Example 1:**
  - 620 lbs cement
  - Maximum class C fly ash replacement
  
  \[620 \text{ lbs} \times 25\% = 155 \text{ lbs } "C" \text{ Fly Ash}\]

- **Example 2:**
  - 564 lbs cement
  - 20% class F fly ash replacement
  
  \[564 \text{ lbs} \times 20\% = 113 \text{ lbs } "F" \text{ Fly Ash}\]
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)

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
Water
(Mix Design Template)

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

<table>
<thead>
<tr>
<th>Maximum Concentration in Mixing Water</th>
<th>Limits</th>
<th>ASTM Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride Ioa Content, ppm</td>
<td>500</td>
<td>C114</td>
</tr>
<tr>
<td>Alkalies as (Na2O + 0.658 K2O), ppm</td>
<td>600</td>
<td>C114</td>
</tr>
<tr>
<td>Sulfates as SO4, ppm</td>
<td>3000</td>
<td>C114</td>
</tr>
<tr>
<td>Total Solids by mass, ppm</td>
<td>50000</td>
<td>C1603</td>
</tr>
<tr>
<td>pH</td>
<td>4.5-8.5</td>
<td>(2)</td>
</tr>
</tbody>
</table>

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

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
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

Volumetric Mobile Mixers
(TDOT Specification 604.04B)

- 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
Materials & Tests Website


Click on Field Operations

Materials & Tests Website (continued)

Approved surface aggregate list

Same as forms

Mix design template (ready mix & volumetric)

Mix design template (precast & prestressed)
Questions
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

Before Designing a Mix

Need the following:

- Class of concrete/Type of construction
  - Slump
  - Maximum w/c ratio
  - Minimum cement
  - 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
**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

**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

\[
\frac{w}{cm} = \frac{\text{weight of water}}{\text{weight of cementitious material}}
\]

\[
\text{weight of water} = \text{w/cm ratio} \times \text{weight of cementitious material}
\]
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$^3$)

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$^3$)
Step 5: Unit Weight of Mix

Calculate the unit weight of the mix

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

- \(U_{lbs/ft^3}\) = unit weight of mix, lbs/ft³
- \(W_{total, lbs}\) = total weight of all the materials, lbs
- \(V_{total, ft^3}\) = total volume of the mix, ft³ (should be 27 ft³)

Questions
Table 604.03-1: Composition of Various Classes of Concrete

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Min 28-Day Compressive Strength (psi)</th>
<th>Min Cement Content (pound per cubic yard)</th>
<th>Maximum Water/Cement Ratio (pound/pound)</th>
<th>Air Content % (Design + production tolerance)</th>
<th>Slump (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3,000</td>
<td>564</td>
<td>0.45</td>
<td>$6 \pm 2$</td>
<td>$3 \pm 1$</td>
</tr>
<tr>
<td>D, DS(2, 3)</td>
<td>4,000</td>
<td>620</td>
<td>0.40</td>
<td>$7$ (3)</td>
<td>$8 \text{ max}$</td>
</tr>
<tr>
<td>L (3, 5)</td>
<td>4,000</td>
<td>620</td>
<td>0.40</td>
<td>$7$ (3)</td>
<td>$8 \text{ max}$</td>
</tr>
<tr>
<td>S (Seal) (6)</td>
<td>3,000</td>
<td>682</td>
<td>0.47</td>
<td>$6 \pm 2$</td>
<td>$6 \pm 2$</td>
</tr>
<tr>
<td>X (7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

(2) Use Class DS concrete in riding surfaces as described in 903.03 and in accordance to Specification 903.24 requirements. Use Class D concrete in all other bridge decks except box and slab type structures unless otherwise shown on the Plans.

(3) Design Class D, Class DS, 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.

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

(7) Plan specific requirements.
### 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)

<table>
<thead>
<tr>
<th>Constituent Materials</th>
<th>Weight</th>
<th>Specific Gravity</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>(W_{cm})</td>
<td>(G_s,\text{Cement})</td>
<td>(V_{\text{Cement}} = \frac{W_{\text{Cement}}}{(G_s,\text{Cement} \times U)})</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>(W_{\text{Flyash}})</td>
<td>(given)</td>
<td>(V_{\text{Flyash}} = \frac{W_{\text{Flyash}}}{(G_s,\text{Flyash} \times U)})</td>
</tr>
<tr>
<td>Slag</td>
<td>(W_{\text{Slag}})</td>
<td>(given)</td>
<td>(V_{\text{Slag}} = \frac{W_{\text{Slag}}}{(G_s,\text{Slag} \times U)})</td>
</tr>
<tr>
<td>Water</td>
<td>(w/cm)</td>
<td>(given)</td>
<td>(V_{\text{Water}} = \frac{W_{\text{Water}}}{(G_s,\text{Water} \times U)})</td>
</tr>
<tr>
<td>Air</td>
<td>Design Air</td>
<td>(V_{\text{Air}} = \frac{(Design \text{ Air} \times 27)}{100})</td>
<td></td>
</tr>
</tbody>
</table>

**Total Weight and Volume of Paste**: \(W_{\text{Paste}} = W_{cm} + W_{\text{Water}}\)

**Total Volume of Aggregate Required**: \(V_{\text{Agg}} = 27 \times (V_{cm} + V_{\text{Water}} + V_{\text{Air}})\)

**Aggregate**

- **Coarse (CA)**: \(W_{CA} = V_{CA} \times G_s,\text{CA} \times U\), \(\%V_{CA} = \frac{W_{CA}}{W_{\text{Total}}}\times 100\)
- **Fine (FA)**: \(W_{FA} = V_{FA} \times G_s,\text{FA} \times U\), \(\%V_{FA} = \frac{W_{FA}}{W_{\text{Total}}}\times 100\)

**TOTAL**: \(W_{\text{Total}} = W_{\text{Paste}} + W_{CA} + W_{FA}\)

**UNIT WEIGHT**: \(U_{\text{Concrete}} = \frac{W_{\text{Total}}}{V_{\text{Total}}}\)
# TABULATION OF CONCRETE MIX DESIGN PROPORTIONS

**Class of Concrete:** D with max ash

Use the table in Section 604.03 of the Standard Specifications (Classification and Proportioning and Quality Assurance)

<table>
<thead>
<tr>
<th>Constituent Materials</th>
<th>Weight</th>
<th>Specific Gravity</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>$W_{cm}$</td>
<td>$(W_{cm} \times %W_{Cement})/100$</td>
<td>$V_{Cement} = W_{Cement}/(G_s,Cement \times U)$</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>$W_{Flyash}$</td>
<td>$(W_{cm} \times %W_{Flyash})/100$</td>
<td>$V_{Flyash} = W_{Flyash}/(G_s,Flyash \times U)$</td>
</tr>
<tr>
<td>Slag</td>
<td>$W_{Slag}$</td>
<td>$(W_{cm} \times %W_{Slag})/100$</td>
<td>$V_{Slag} = W_{Slag}/(G_s,Slag \times U)$</td>
</tr>
<tr>
<td>Water</td>
<td>$W_{Water} = W_{cm} \times w/cm$</td>
<td></td>
<td>$V_{Water} = W_{Water}/(G_s,Water \times U)$</td>
</tr>
<tr>
<td>Air</td>
<td>Design Air</td>
<td></td>
<td>$V_{Air} = (Design Air \times 27)/100$</td>
</tr>
</tbody>
</table>

## Total Weight and Volume of Paste

<table>
<thead>
<tr>
<th>Constituent Materials</th>
<th>Weight</th>
<th>Specific Gravity</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paste</td>
<td>$W_{Total} = W_{cm} + W_{Water}$</td>
<td></td>
<td>$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$</td>
</tr>
</tbody>
</table>

## Total Volume of Aggregate Required

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Weight</th>
<th>Specific Gravity</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse (CA)</td>
<td>$W_{CA} = V_{CA} \times G_s,CA \times U$</td>
<td>(given)</td>
<td>$V_{CA} = (%V_{CA} \times V_{Agg})/100$</td>
</tr>
<tr>
<td>Fine (FA)</td>
<td>$W_{FA} = V_{FA} \times G_s,FA \times U$</td>
<td>(given)</td>
<td>$V_{FA} = (%V_{FA} \times V_{Agg})/100$</td>
</tr>
</tbody>
</table>

## TOTAL

<table>
<thead>
<tr>
<th>Constituent Materials</th>
<th>Weight</th>
<th>Specific Gravity</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>$W_{Total} = W_{Paste} + W_{CA} + W_{FA}$</td>
<td></td>
<td>$V_{Total} = V_{Paste} + V_{CA} + V_{FA}$</td>
</tr>
</tbody>
</table>

## UNIT WEIGHT

<table>
<thead>
<tr>
<th>Constituent Materials</th>
<th>Weight</th>
<th>Specific Gravity</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$U_{Concrete} = W_{Total}/V_{Total}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABULATION OF CONCRETE MIX DESIGN PROPORTIONS

**A Ternary w/ max ash**

Use the table in Section 604.03 of the Standard Specifications (Classification and Proportioning and Quality Assurance)

<table>
<thead>
<tr>
<th>Constituent Materials</th>
<th>Weight</th>
<th>Specific Gravity</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>$W_{cm}$</td>
<td>$W_{Cement} = (W_{cm} \times %W_{Cement})/100$</td>
<td>$V_{Cement} = W_{Cement} / (G_{s,Cement} \times U)$</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>$W_{Flyash}$</td>
<td>$W_{Flyash} = (W_{cm} \times %W_{Flyash})/100$</td>
<td>$V_{Flyash} = W_{Flyash} / (G_{s,Flyash} \times U)$</td>
</tr>
<tr>
<td>Slag</td>
<td>$W_{Slag}$</td>
<td>$W_{Slag} = (W_{cm} \times %W_{Slag})/100$</td>
<td>$V_{Slag} = W_{Slag} / (G_{s,Slag} \times U)$</td>
</tr>
<tr>
<td>Water</td>
<td>$W_{Water}$</td>
<td>$W_{Water} = W_{cm} \times w/cm$</td>
<td>$V_{Water} = W_{Water} / (G_{s,Water} \times U)$</td>
</tr>
<tr>
<td>Total Weight and Volume of Paste</td>
<td></td>
<td></td>
<td>$V_{Paste} = V_{cm} + V_{Water} + V_{Air}$</td>
</tr>
<tr>
<td>Total Volume of Aggregate Required</td>
<td></td>
<td></td>
<td>$V_{Agg} = 27 - (V_{cm} + V_{Water} + V_{Air})$</td>
</tr>
<tr>
<td>Coarse (CA)</td>
<td>$W_{CA} = V_{CA} \times G_{s,CA} \times U$</td>
<td>2.79</td>
<td>56%</td>
</tr>
<tr>
<td>Fine (FA)</td>
<td>$W_{FA} = V_{FA} \times G_{s,FA} \times U$</td>
<td>2.63</td>
<td>44%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$W_{Total} = W_{Paste} + W_{CA} + W_{FA}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>UNIT WEIGHT</strong></td>
<td>$U_{Concrete} = W_{Total} / V_{Total}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7

Appendix
Appendix

Contacts

- Regional Contacts
  - Region 1: Brad Baskette - 865-594-4552
  - Region 2: Tony Renfro - 423-510-1190
  - Region 3: Kevin Isenberg - 615-350-4312
  - Region 4: Mitch Blankenship - 731-935-0215
- HQMT Training Coordinator
  - Kim Whitby – 615-350-4158;
    Kimberly.Whitby@tn.gov
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

Resources

- Tennessee Department of Transportation
  - https://www.tn.gov/tdot.html
- American Road & Transportation Builders Association
  - https://www.artba.org/
- Tennessee Road Builders Association
  - www.trba.org/
- Tennessee Ready Mixed Concrete Association
  - www.tnconcrete.org/
- American Association of State Highway Transportation Officials
  - https://www.transportation.org
- American Society for Testing and Materials
  - https://www.astm.org/
- American Concrete Institute
  - https://www.concrete.org/
- Construction Materials Engineering Council
  - https://www.cme.org/
- Portland Cement Association
  - www.cement.org/
SOP 4-4

- Submittal and approval process for concrete mixes
  - Ready mix
  - Volumetric mobile mixers
  - Prestressed
  - Precast
Tennessee Department of Transportation
Division of Materials and Tests

Submittal and Approval of
Concrete Mixture Designs (SOP 4-4)

Purpose: The purpose of this document is to establish a submittal and approval process for all concrete mixtures including ready-mixed, prestressed, precast and volumetric mixed concrete.

Discussion: Concrete designs submitted to TDOT for approval must exhibit certain physical performance properties indicated in TDOT Standard Specifications including but not limited to slump/slump flow, air content, temperature, unit weight, and yield; the hardened concrete must meet compressive strength.

Procedure: A concrete mix design shall be subject to the following procedures prior to being approved for use in TDOT work:

A Concrete Mix Design Technician (Level 3) or a registered Professional Engineer licensed by the State of Tennessee shall use volumetric mix design procedures. The proportions of all materials shall be in accordance with the appropriate TDOT Standard Specifications 501.03(A), 604.03(A), 615.09, and SOP 5-3 (Manufacture and Acceptance of Precast Drainage Structures, Noise Wall Panels, and Earth Retaining Wall Products) Section 5.0.

A trial batch shall be mixed according to those proportions, including appropriate admixtures. The tests for the freshly-mixed concrete shall be conducted to determine:

- Slump ASTM C 143/AASHTO T 119
- Slump Flow ASTM C 1611
- Temperature ASTM C 1064
- Air Content ASTM C 231/C 173/AASHTO T 152/T 196
- Unit Weight/Yield ASTM C 138/AASHTO T 121

Gradations and specific gravities for coarse and fine aggregates used in the trial batch shall reflect the characteristics of the stockpiles to be used in the mix. The hardened specimens, after proper curing, shall then be tested for compressive strength. Any trial batch mixed for Class SCC, P-SCC, and SH-SCC shall be verified in the presence of Regional Materials and Tests per TDOT Standard Specifications 604.03(A) and 615.09.

1. If all test results meet the required mix design criteria and field performance tolerances, the producer shall submit a concrete mix design to Headquarters Materials & Test (HQMT) no less than fourteen (14) working days prior to mix production. Ready mixed submittals must be listed on the current...
version of the Concrete Mix Design Template. Precast or prestressed submittals must be listed on the Precast/Prestressed Mix Design Template. Ready mixed or prestressed designs shall be emailed to TDOT.Concrete.Email@tn.gov. Precast designs shall be emailed to TDOT.PrecastMTR@tn.gov. Once approved by HQMT, the new designs can be associated to another contract via the Concrete Design Contract Association Request Form.

2. **Approved concrete mix designs will expire at the end of each calendar year (i.e. December 31st).**

3. Mix designs will be subject to expiration upon review if design strength or field requirements are not met.

4. Design association requests shall not be allowed for Class X, SCC, P-SCC, and SH-SCC designs. Any Class X mix design shall be accompanied with a plans sheet detailing the item used and the mix design criteria.

5. Email subject lines must state whether the design is a new or existing design along with the contract number. Any submitted mix designs intended to be used for riding surfaces requiring the use of surface aggregate materials, e.g., Class CP, Class DS, and Class A Paving, should include “Surface Aggregates Required” in the body of the email.

6. **Class X mix designs for local programs projects shall be approved by the Local Government administering the project.**

**Materials:**

**Cement:** The source and location must be listed on the Producer List and meet the requirements outlined in Section 901.01 of the TDOT Standard Specifications. Any change of cement shall require a new submittal, including a new trial batch complete with test results unless otherwise directed by HQMT.

**Fly Ash:** The source and location must be listed on the Producer List and meet the requirements outlined in Section 921.15 of the TDOT Standard Specifications. Any change of fly ash shall require a new submittal, including a new trial batch complete with test results, with the exception of an emergency fly ash outage as specified below. Fly ash replacement shall be in accordance with TDOT Standard Specifications 501.03(A) or 604.03(A).

In the event that a project may be delayed due to a fly ash outage, the source of fly ash may be changed to another approved fly ash source listed on Producer List. A new mix design template worksheet shall be submitted to Headquarters Materials and Tests for review, but a new trial batch will not be required. In the body of the mix design submittal email, a detailed message of the substitution shall be provided. Upon review and approval, a new mix design number will be assigned to the new design with the substituted fly ash.

**Ground Granulated Blast Furnace Slag (GGBFS):** The source and location must be listed on the Producer List and meet the requirements outlined in Section 921.16 of the TDOT Standard Specifications. Any change of GGBFS shall require a new submittal, including a new trial batch complete with test results. GGBFS replacement shall be in accordance with TDOT Standard Specifications 501.03(A) or 604.03(A).
Silica Fume: The source and location must be listed on the Producer List. Any change of silica fume shall require a new submittal, including a new trial batch complete with test results.

Water: Refer to TDOT Standard Specification 921.01. Non-municipal water sources shall provide their most recent water results per Table 921.01-1 and 921.01-2 of the TDOT Standard Specification along with the mix design submittal package.

Coarse Aggregate: The source and location must be from an approved source meeting quality test requirements outlined in Section 903.03 of the TDOT Standard Specifications.

Where approved surface aggregates are required as per TDOT Standard Specifications 903.03, coarse aggregates must meet the specifications stated in 903.24. The TDOT Approved Surface Aggregates list outlines all of the approved sources.

In the event that a project may be delayed due to an insufficient supply of coarse aggregate, the source of aggregate may be changed to another approved source of like material (e.g. limestone for limestone, or granite for granite) provided the specific gravity of the new material is within 0.15 of the original material.

Fine Aggregate: The source and location must be from an approved source meeting quality test requirements outlined in Section 903.01 of the TDOT Standard Specifications.

Any change of fine aggregate shall require a new submittal, including a new trial batch complete with test results. Manufactured sand shall not be used in mixes designed as surface courses.

Chemical Admixtures: All admixtures must be listed on the QPL 4 and, in a given mix, must all be supplied by the same manufacturer. Admixture dosage rates (oz/cwt) used in the trial batch shall be submitted on the Concrete Mix Design Template.

Distribution:

Once the design submittal is approved, the design will be distributed as follows:

- A copy is kept on file at HQMT
- Regional Materials and Tests and the producer will receive an electronic copy.
  - Regional Materials and Tests will forward copies to the Project Supervisor; the Project Supervisor will ensure that the Project Inspector receives a copy

The Concrete Mix Design Submittal and Approval Process Flowchart illustrates the distribution of an approved concrete mix design.