### Concrete Mix Design Technician Course
#### Tennessee Department of Transportation
#### Volume 17.1

<table>
<thead>
<tr>
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<th>3</th>
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<tbody>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cement</td>
</tr>
<tr>
<td></td>
<td>Coarse Aggregate</td>
</tr>
<tr>
<td></td>
<td>Fine Aggregate</td>
</tr>
<tr>
<td></td>
<td>Water</td>
</tr>
</tbody>
</table>
Concrete Mix Design Technician Course

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Concrete Mix Design Technician Course

Tennessee Department of Transportation Volume 17.1

Class Schedule

1. Registration
2. Introduction
3. Basic Concrete Ingredients
4. Making and Curing Concrete Test Specimens in the Laboratory (ASTM C 192)
5. Compressive Strength of Cylindrical Concrete Specimens (AASHTO T-22)
6. Break
7. Concrete Mix Design Submittal (TDOT Standard Specifications)
8. Concrete Mix Design Template & Checklist
9. Concrete Mix Design
10. Lunch
11. Appendix
12. Written Exam
Concrete Mix Design Technician Course
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  Sample Design 1: Class A straight cement
  Sample Design 2: Class D w/ash
  Sample Design 3: Ternary mix design

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  SOP 4-4: Procedures for Submittal and Approval of Concrete Mix Designs
Welcome!

Concrete Mix Design Technician Certification

Introduction

• Technician Certification Program
• Purpose
• Who’s Who
• Course Highlights
• Written Examination
• Results/Certification
• Resources/Contacts
• Summary/Questions
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Technician Certification Program

• Asphalt Roadway Inspector
• Asphalt Plant Inspector
• Asphalt Mix Design
• Concrete Field Testing
• Concrete Plant Quality Control
• Concrete Mix Design
• Soils and Aggregate
• Nuclear Gauge Safety (TDOT Employees Only)
Introduction

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
    - ASTM/AASHTO Test Methods
    - Mix Design Submittals
    - Mix Design Calculations
  - Written exam
  - Results
  - Certification
- Recertification
  - every 5 years
Written Examination

• Consists of:
  • 30 questions
  • Open-book

• To Pass:
  • Must get 70% overall

Results

• Available within one week of completion

• Contact the Headquarters Materials & Tests Training Coordinator, Kim Whitby

  • kimberly.whitby@tn.gov
  • 615-350-4158
Resources

- Course materials
  - Course textbook
  - Presentation slides
  - Handouts
- TDOT
  - Standard Specifications, January 1, 2015
  - Special Provisions
- Contacts
  - Regional Materials Supervisors

Resources

- Tennessee Department of Transportation
  - http://www.tdot.state.tn.us/
- American Road & Transportation Builders Association
  - http://www.artba.org/
- Tennessee Road Builders Association
  - http://www.trba.org/
- Tennessee Ready Mixed Concrete Association
  - http://www.trmca.org/
- American Association of State Highway Transportation Officials
  - http://www.aashto.org/
- American Society of Testing Materials
  - http://www.astm.org/
- American Concrete Institute
  - http://www.aci-int.org/
- Construction Materials Engineering Council
  - http://www.cmecc.org/
- Portland Cement Association
  - http://www.portcement.org/
ADA Notice of Requirements

- Can be found at the following website:

- 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.
1

Basic Concrete Ingredients
Concrete is a mixture of paste and aggregates.

- 6% Air
- 11% Portland Cement
- 41% Gravel or Crushed Stone (Coarse Aggregate)
- 26% Sand (Fine Aggregate)
- 16% Water
Basic Ingredients

Types of Cement

**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 & produces higher early strength than Type I

**Type IV – Low Heat of Hydration**
- Produces less heat & generally used with massive structures

**Type V – Sulfate Resistant**
- Only used where high concentrations of sulfate in the soil or groundwater

http://www2.cement.org/basics/images/flashtour.html
Basic Ingredients

Pozzolans

*Often called Supplementary Cementing Materials*

- No cementing value alone but, in concrete, 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, ground granulated blast furnace slag

Fly Ash

- Two types
  - C-ash
  - F-ash

- Reduction in water

- Increased workability

- Reduces bleeding & segregation

- Improved pumpability

- Reduced heat of hydration
Silica Fume

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

Metakaolin (Calcined Kaolin)

- Particle size is smaller than cement but not as fine as silica fume
- More durable than straight cement mixes
- Reduces permeability, absorption, and chloride permeability
- Potential to produce high strength and high performance concretes
- Research projects underway
Basic Ingredients

Ground Granulated Blast Furnace Slag

- Slag is a cementitious material
- Has minimal pozzolanic properties
- Slightly less water
- Setting time delayed
- Early strengths depressed
- Later strengths increased

Effects of SCMs on Fresh Concrete Properties

<table>
<thead>
<tr>
<th>Fly ash</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>
Basic Ingredients

Effects of SCMs on Hardened Concrete Properties

<table>
<thead>
<tr>
<th>Fly ash</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>
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</tr>
</tbody>
</table>

Aggregates

**Coarse Aggregates**
- Gravel or crushed stone
- Size greater than ¼”
- Desire well graded aggregates
  - Less water to produce workable mix

**Fine Aggregates**
- Natural or Manufactured sand
- Max of ¼” down past No. 100
- Limits to amount of fines due to deleterious material
Air Entrainment

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

Chemical Admixtures

- Type A - Water Reducer
  - Reduces the amount of water needed to maintain adequate workability.

- Type B - Retarder
  - Slows down the initial set.

- Type C - Accelerator
  - Increases the early strength development, shortens the time of set, or both.

- Type D - Water Reducer & Retarder
Chemical Admixtures

• Type E - Water Reducer & Accelerator

• Type F - High Range Water Reducer
  • Reduces the amount of mixing water of a given consistency by greater than 12%.

• Type G - High Range Water Reducer & Retarder

• Type S - Specific Performance
  • Provides a desired performance characteristic other than reducing water content, changing setting time, or both without adverse affects on the concrete properties or durability.

Chemical Admixtures

**Water Reducers**

• Reduce mixing water 5%-30%
• Increase ultimate strength
• Improve workability

**Retarders**

• Longer set time
• Improve hot weather workability

**Accelerators**

• Shorter set time
• Increase early strength
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 C 192

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**Apparatus**

- Cylinder molds
- Beam and prism molds
- Tamping rods
- Mallets
- Vibrators
- Small Tools - shovels, pails, trowels, wood float, straightedge, scoops, etc.

- Slump apparatus
- Sampling and mixing pan
- Wet-sieving equipment
- Air content apparatus
- Scales
- Concrete mixer - power-driven revolving drum, tilting mixer, or revolving paddle mixer
Cylindrical Specimens

- May be of various sizes.

- 4 x 8 in. or 6 x 12 in. cylinders shall be used for correlation or comparison with cylinders made in the field.

- 4 x 8 cylinders for precast/prestress

Prismatic Specimens

Long axis horizontal for:

- beams for flexural strength
- cubes for compressive strength
- prisms for freezing and thawing, bond, length change, volume change
Specimen Size vs. Aggregate Size

The diameter of a cylindrical specimen must be at least 3 times the nominal maximum size of the coarse aggregate.

Occasionally, large-sized particles must be removed by hand.

Concrete with aggregate larger than appropriate for the mold used must be wet-sieved.
Making & Curing

Number of Specimens

TDOT Specifications dictate
- the number of specimens
- the frequency of testing
- the number of test batches
- who prepares the samples
- who tests the samples

Number of Specimens

- Compressive Strength Tests
  - Two samples for 14-day strength
  - Two samples for 28-day strength

- Flexural Strength Tests
  - Two samples for 14-day strength
  - Two samples for 28-day strength

- Concrete with Type III Cement
  - Samples for 1, 3, 7, and 28 days

- Later Tests
  - 3, 6, and 12 months
Preparation of Materials

Temperature

All materials in the mix should be at room temperature in the range of 68 to 86°F (20 to 30 °C).

Preparation of Materials

Cement

• Should be stored:
  • In a dry place
  • In moisture-proof containers, preferably made of metal
  • Shall be mixed thoroughly for uniformity.
  • Shall be passed through a No. 20 sieve to remove all lumps, remixed on a tarp or plastic sheet, and returned to containers.
Preparation of Materials

Aggregates

• Separate into size fractions then recombine for test batches for proper gradation.
• Maintain aggregate in damp condition.
• Determine the specific gravity.
• Ensure a definite and uniform moisture condition before use.

Preparation of Materials

Chemical Admixtures

• Mix powdered admixture with a small amount of cement before introducing it to the concrete mix.
• Pozzolans should be handled in the same manner as cement.
• Insoluble powdered admixtures should be mixed with sand before use.
Preparation of Materials
Chemical Admixtures

- Water-soluble and liquid admixtures should be added in solution to the mixing water before use.
- Incompatible admixtures should not be combined before adding to the mixer.
- Time, sequence, and method of adding the admixtures should remain constant from batch to batch.

Procedure
Hand-Mixing

- Mix in clean, damp, watertight, metal container.
- Mix so there is 10% excess.
- Only hand-mix batches of 1/4 ft$^3$ or less.
- Sequence
  1) Cement, powdered admixtures, fine aggregate until blended
  2) Coarse aggregate
  3) Mixing water and solution of admixture to desired consistency
Procedure
Machine-Mixing

- Mix so 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

Procedure
Slump, Air, Yield, & Temperature

- Measure slump of each batch after mixing except for no-slump concrete.
- Determine the air content with appropriate method.
- Determine the yield of every batch.
- Determine the temperature.
Procedure
Making Specimens

• Mold specimens near storage area.
• Store specimens immediately after striking off.
• Storage area should be free of vibration.
• Do not agitate the sample.
• Ensure that concrete in molds is representative of the concrete batch.
• Prevent segregation during molding.

TABLE 1 Number of Layers Required for Specimens

<table>
<thead>
<tr>
<th>Specimen Type and Size</th>
<th>Mode of Consolidation</th>
<th>Numbers of Layers of Approximate Equal Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter, mm [in.]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75 to 100 [3 or 4]</td>
<td>rodding</td>
<td>2</td>
</tr>
<tr>
<td>150 [6]</td>
<td>rodding</td>
<td>3</td>
</tr>
<tr>
<td>225 [9]</td>
<td>rodding</td>
<td>4</td>
</tr>
<tr>
<td>up to 225 [9]</td>
<td>vibration</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prisms and horizontal creep Cylinders: Depth, mm [in.]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>up to 200 [8]</td>
<td>rodding</td>
<td>2</td>
</tr>
<tr>
<td>over 200 [6]</td>
<td>rodding</td>
<td>3 or more</td>
</tr>
<tr>
<td>up to 200 [8]</td>
<td>vibration</td>
<td>1</td>
</tr>
<tr>
<td>over 200 [8]</td>
<td>vibration</td>
<td>2 or more</td>
</tr>
</tbody>
</table>
### Procedure

**Making Specimens**

<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>200 [8]</td>
<td>16 ± 2 [% ± ⅛ in]</td>
<td>50</td>
</tr>
<tr>
<td>250 [10]</td>
<td>16 ± 2 [% ± ⅛ in]</td>
<td>75</td>
</tr>
</tbody>
</table>

**Beams and Prisms**

<table>
<thead>
<tr>
<th>Top Surface Area of Specimen, cm² [in.²]</th>
<th>Diameter of Rod mm [in.]</th>
<th>Number of Roddings/Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 [25] or less</td>
<td>10 ± 2 [% ± ⅛ in]</td>
<td>25</td>
</tr>
<tr>
<td>165 to 310 [26 to 49]</td>
<td>10 ± 2 [% ± ⅛ in]</td>
<td>one for each 7 cm² [1 in.²] of surface</td>
</tr>
<tr>
<td>320 [50] or more</td>
<td>16 ± 2 [% ± ⅛ in]</td>
<td>one for each 14 cm² [2 in.²] of surface</td>
</tr>
</tbody>
</table>

**Horizontal Creep Cylinders**

<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>16 ± 2 [% ± ⅛ in]</td>
<td>50 total, 25 along both sides of axis</td>
</tr>
</tbody>
</table>
Making & Curing

Procedure
Consolidation

Methods of Consolidation
- Rod or vibrate
  - Slump ≥ 1”
- Vibration
  - Slump < 1”
- Internal vibration
  - Not for cylinders with diameter less than 4”
- External vibration

Procedure
Finishing

- Strike-off the surface
- Float or trowel the surface
- Cap cylinders
Covering After Finishing

- Cover immediately after finishing.
  - Nonabsorptive, nonreactive cover
  - Plate or plastic sheeting
  - Wet burlap
- Prevent evaporation.
- Ensure cardboard molds do not get wet.

Removal from Molds

Remove from molds within 24 ± 8 hours after casting.
Curing Environment

• Remove from molds within 24 ± 8 hours after casting.
• Moist cure at 73.5± 3.5°F (23 ± 2.0°C) until tested.
  • Free water on entire surface area at all times
    • Immersion in saturated-lime water
    • Moist room or cabinet
    • No dripping or running water
• Vibration-free area for first 48 hours
• 20 hours in saturated lime solution for *flexural strength test specimens*
3

Compressive Strength of Cylindrical Concrete Specimens

AASHTO T 22
ASTM C 39
Summary of Method

• A compressive axial load is applied to concrete cylinders or cores at a prescribed rate until failure occurs.

• The maximum load divided by the cross-sectional area of the cylinder is considered to be the compressive strength.
Significance and Use

• This test method is used to determine the compressive strength of cylinders that have been properly prepared and cured.

• The compressive strength is used as a basis for quality control.

• The results are also used to determine compliance with TDOT Specifications.

Apparatus

Compressive strength testing machine
Apparatus

Bearing blocks

Apparatus

Load indication
**Testing Machine Requirements**

- Sufficient capacity and proper rate of loading
- Calibration
  - Upon installation or relocation
  - At least annually not to exceed 13 months
  - After repair of weighing system
  - When accuracy is in question

**Testing Machine Requirements**

- Design
  - Power operated
  - Continuous loading
  - Calibration device must fit into the test specimen area

- Accuracy
  - % Error ± 1.0% of indicated load
  - Properly verified (see paragraphs 5.1.3.2 through 5.1.3.6 of AASHTO T22)
Bearing Block Requirements

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

Load Indication Requirements
Load Indication Requirements

- Digital indicators must have numerical increments less than or equal to 0.10% of full scale load.
- Dial must have a zero adjustment
- 1% accuracy of maximum load

Specimens

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

3000.0 lbs.
The ends must not depart from perpendicularity to the axis by more than 0.5°

6 x12 inch cylinder
0.12 inch in 12 inch

4 x8 inch cylinder
0.08 inch in 8 inch

Cap, saw, or grind the ends

The ends of cylinders to be tested for compressive strength must be plane to within 0.050 mm (0.002 in.)
**Specimens**

- Measure length to the nearest 0.05 in. at three locations around circumference.

- Record average length to nearest 0.05 in.

**Procedure**

- Compression tests of moist-cured specimens shall be made as soon as possible after removal from moist storage.

- Cylinders shall be tested in the moist condition.
Compressive Strength

Time Tolerances
Test specimens shall be broken within the permissible time tolerance for a given test age.

<table>
<thead>
<tr>
<th>Test Age</th>
<th>Permissible Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hours</td>
<td>± 0.5 hours or 2.1%</td>
</tr>
<tr>
<td>3 days</td>
<td>2 hours or 2.8%</td>
</tr>
<tr>
<td>7 days</td>
<td>6 hours or 3.6%</td>
</tr>
<tr>
<td>28 days</td>
<td>20 hours or 3.0%</td>
</tr>
<tr>
<td>56 days</td>
<td>40 hours or 3.0%</td>
</tr>
<tr>
<td>90 days</td>
<td>2 days or 2.2%</td>
</tr>
</tbody>
</table>

Procedure
• Wipe clean the faces of the upper and lower bearing blocks.
• Wipe both ends of the cylinder.
Procedure

• Place the cylinder on the lower bearing block.

• Align the axis of the cylinder with the center of the upper bearing block.

Procedure

Rotate the spherically seated block to ensure freedom of movement.
**Procedure**

Apply a continuous load without shock.

**Rate of Loading**

- **For hydraulic machines**
  - 0.25 to 0.05 Mpa/s
  - 35 ± 7 psi/s

- **For screw-type machines**
  - Preliminary testing necessary to establish required rate of movement.
Compressive Strength

**Procedure**

Apply the load until the cylinder fails.

**Types of Fracture**

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

Measured Strength
If cylinder breaks are lower than expected, examine the fracture for:
- Large air voids
- Segregation
- Verify end preparation
- Did fracture pass around or through coarse aggregate?

Sample Fractures
Compressive Strength

Calculation

\[
\text{compressive strength} = \frac{\text{maximum load}}{\text{cross-sectional area}} \times (\text{correction factor})
\]

or

\[
f' c = \frac{F_{\text{max}}}{A} \times C
\]

L/D Correction Factor

<table>
<thead>
<tr>
<th>L/D</th>
<th>1.00</th>
<th>0.98</th>
<th>0.96</th>
<th>0.93</th>
<th>0.87</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>
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</table>
L/D Correction Factor

Report

- Identification number
- Diameter
- Cross-sectional area
- Maximum load
- Compressive strength
- Type of fracture
- Defects in specimen or caps
- Age of specimen
Questions
Example 1

Given:
- A standard 6”x12” cylinder of Class D concrete.
- No preparation of the cylinder is required.
- The cylinder fails at a maximum force of 112,967 pounds.
Example 1

Given:

- A standard 6”x12” cylinder of Class D concrete.
- No preparation of the cylinder is required.
- The cylinder fails at a maximum force of 112,967 pounds.

\[
A = \pi r^2 =
\]

\[
\frac{L}{D} =
\]

\[
f'_c = \frac{F_{\text{max}}}{A} \cdot C
\]
Example 2

Given:
• A standard 6”x12” cylinder of Class A HE concrete (3,000psi in 18 hours).
• The ends were prepared so that the length of the cylinder is 9 inches.
• The cylinder fails at a maximum force of 123,681 pounds.
Example 2

Given:
- A standard 6”x12” cylinder of Class A HE concrete (3,000psi in 18 hours).
- The ends were prepared so that the length of the cylinder is 9 inches.
- The cylinder fails at a maximum force of 123,681 pounds.

\[
A = \pi r^2 = \frac{L}{D} = C = f_c' = \frac{F_{\text{max}}}{A} \cdot C
\]
Example 3

Given:
• A core was obtained from a bridge deck of Class D concrete.
• The ends were prepared so that the length of the cylinder is 6.4 inches.
• The cylinder fails at a maximum force of 53,000 pounds.
Example 3

Given:
• A core was obtained from a bridge deck of Class D concrete.
• The ends were prepared so that the length of the cylinder is 6.4 inches.
• The cylinder fails at a maximum force of 53,000 pounds.

\[ A = \pi r^2 \]

\[ \frac{L}{D} = \therefore C = \]

\[ f_c' = \frac{F_{\text{max}}}{A} \cdot C \]
Concrete Mix Design
Submittal

TDOT Standard Specifications
TDOT Process for
Concrete Mix Design Submittal

References
TDOT Standard Specifications
TDOT Supplemental Specifications
SOP 4-4
http://www.tdot.state.tn.us/materials/fieldops/sop/

Design Submittals

• Email to concrete.mixdesign@tn.gov

• Subject line
  • New or Same as
  • Contract, Pin, or Bridge Grant Number
New Design

• Contract, Pin, or Bridge Grant Number
• Producer Location
• Class of Concrete
• Strength Requirements & Time Period
  • Example: 3,000 psi in 18 hours or 4000 psi in 28 days
• Mix Design Template
  • Proportions
  • Company / Location of Each
• Trial Batch Data

Temporary Design

• Same Information as New Mix Design
• Need 7 or 14 day breaks, 2 cylinders
• Needs to Meet or Exceed 28 day requirements
• Expires the Day that 28 day cylinders are due
## CONCRETE MIXTURE DESIGN SUBMITTAL

**Contract Number:**

**Pin Number:**

**Project Ref. No.:**

**Plant Producer/ Location:**

**Contractor:**

**Plant Number:**

**Remarks:**

**Technician Name:**

### P/S Code | Cementitious Materials (cm) | Type/Grade | Source | G₂ (SSD) | Weight, lbs. | Volume, ft³
--- | --- | --- | --- | --- | --- | ---
0 | Cement | Domestic (Type I) | | | | |
89901382 | Flyash | Pozzolana (Fly Ash Class C) | Headwaters Resources - Newark, AR | | | |
0 | GGBFS | Bag Grade 106 | | | | |

### Aggregates

| P/S Code | Aggregates Type/Size | Source | G₂ (SSD) | Weight, lbs. | Volume, ft³
--- | --- | --- | --- | --- | ---
0 | Coarse Aggregate 1 (CA1) | Coarse Agg Concrete Crush Stone #57 | | | |
0 | Coarse Aggregate 2 (CA2) | | | | |
0 | Coarse Aggregate 3 (CA3) | | | | |
0 | Fine Aggregate 1 (FA1) | Natural Sand (Ready Mix Plants) | | | |
0 | Fine Aggregate 2 (FA2) | | | | |
0 | 918.09.011 Air-Entraining Admixture | Brand Name | 0 | Dosage Rate (oz/cwt) | % Air | Weight, lbs. | Volume, ft³
--- | --- | --- | --- | --- | --- | --- | ---
918.01.001 Water | w/cm = | #VALUE! | Well Water | 6.0 | --- | 1,620 |

### Chemical and Other Admixtures

| P/S Code | Admixtures Type/Size | Brand Name | Source | Dosage Rate (oz/cwt) |
--- | --- | --- | --- | ---
0 | 918.09.012 Water Reducer | | 0 |
0 | 918.09.013 Retarder | | 0 |
0 | 918.09.014 Accelerator | | 0 |
0 | 918.09.015 Water Reducer/Retarder | | 0 |
0 | 918.09.016 Water Reducer/Accelerator | | 0 |
0 | 918.09.017 High-Range Water Reducer | | 0 |
0 | 918.09.018 High-Range Water Reducer/Retarder | | 0 |
0 | 918.09.024 Misc Admixtures for Concrete 1 | | 0 |
0 | 918.09.024 Misc Admixtures for Concrete 2 | | 0 |
0 | 918.09.022 Type S Admixtures | | 0 |
0 | 918.09.023 Picast | | 0 |

### 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 | | | | | | | | | | | | | | | | | | | | | |
FA2 | | | | | | | | | | | | | | | | | | | | | |

### COMPRRESSIVE STRENGTH DATA

| Sample No. | Date Made | Date Tested | Age, days | Length, in. | Diam., in. | L/D | C | Area, in² | Load, lbs. | Strength, psi | Average, psi |
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
0 | | | | | | | | | | | #DIV/0! |
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**Remarks:**

**Mix ID:**

**Certification Number:**

**Version:** 3.6.17
### CONCRETE MIXTURE DESIGN SUBMITTAL

**Version:** 3.6.17

<table>
<thead>
<tr>
<th>Contract Number</th>
<th>CNQ 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin Number</td>
<td>CNQ 000</td>
</tr>
<tr>
<td>Project Ref. No.</td>
<td>19005-3161-44</td>
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<tr>
<td>Plant Number</td>
<td>32200003</td>
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</tbody>
</table>

**Plant Producer/Location:** Kiewit Infrastructure

**Contractor:** Kiewit Infrastructure

**Class of Concrete:**
- Class A Type I Cement

**Reqd Strength:** 3000 psi @ 28 DAYS

**Early Strength:** 3000 psi @ 18 HOURS

<table>
<thead>
<tr>
<th>P/S Code</th>
<th>Cementitious Materials (cm)</th>
<th>Type/Grade</th>
<th>Source</th>
<th>G2 (SSD)</th>
<th>Weight, lbs.</th>
<th>Volume, ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>89900106</td>
<td>Cement</td>
<td>Domestic (Type I)</td>
<td>Carne - Knoxville, TN</td>
<td>3.15</td>
<td>714.0</td>
<td>3.632</td>
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<tr>
<td>0</td>
<td>Flyash</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>GGBFS</td>
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<td></td>
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<table>
<thead>
<tr>
<th>P/S Code</th>
<th>Aggregates</th>
<th>Type/Size</th>
<th>Source</th>
<th>G2 (SSD)</th>
<th>Weight, lbs.</th>
<th>Volume, ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>42000005</td>
<td>Coarse Aggregate 1 (CA1)</td>
<td>Coarse Ap/Concrete Crush Stone S57</td>
<td>Vulcan Materials - Perrysville</td>
<td>2.68</td>
<td>1775.0</td>
<td>10.614</td>
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<td>Coarse Aggregate 2 (CA2)</td>
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<tr>
<td>0</td>
<td>Coarse Aggregate 3 (CA3)</td>
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<td>34300001</td>
<td>Fine Aggregate 1 (FA1)</td>
<td>Natural Sand (Ready Mix Plants)</td>
<td>San Graul - New Johnsonville</td>
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<td>Fine Aggregate 2 (FA2)</td>
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**918.09.011 Air-Entraining Admixture**

<table>
<thead>
<tr>
<th>P/S Code</th>
<th>Chemical and Other Admixtures</th>
<th>Brand Name</th>
<th>Source</th>
<th>Dosage Rate (oz/cwt)</th>
<th>% Air</th>
<th>Weight, lbs.</th>
<th>Volume, ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>918.09.012 Water Reducer</td>
<td>MasterAir AE 200 (Micro-Air)</td>
<td>BASF - Cleveland, OH</td>
<td>0.5</td>
<td>6.0</td>
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<tr>
<td>0</td>
<td>918.09.013 Retarder</td>
<td>MasterSet DelVu or Delvo Stabilizer</td>
<td>BASF - Cleveland, OH</td>
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<td>0</td>
<td>918.09.014 Accelerator</td>
<td>MasterSet AC 534 or Pozzolith MC 5</td>
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<tr>
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<td>MasterGrun 760 or Grun 79</td>
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<td>5</td>
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<td>918.09.024 Misc Admixtures for Concrete 1</td>
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**AGGREGATE DATA**

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<thead>
<tr>
<th>CA/FA</th>
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<th>3-1/2”</th>
<th>3”</th>
<th>2-1/2”</th>
<th>2”</th>
<th>1-1/2”</th>
<th>1”</th>
<th>3/4”</th>
<th>1/2”</th>
<th>3/8”</th>
<th>No. 4</th>
<th>No. 8</th>
<th>No. 16</th>
<th>No. 30</th>
<th>No. 100</th>
<th>No. 200</th>
<th>FM</th>
<th>Absorption</th>
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<td>100</td>
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<td>CA2</td>
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<td>2.63</td>
<td>1.3</td>
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</tbody>
</table>

**COMPRRESSIVE STRENGTH DATA**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Date Made</th>
<th>Date Tested</th>
<th>Age, days</th>
<th>Length, in.</th>
<th>Diam., in.</th>
<th>L/D</th>
<th>C</th>
<th>Area, in²</th>
<th>Load, lbs.</th>
<th>Strength, psi</th>
<th>Average, psi</th>
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</thead>
<tbody>
<tr>
<td>17-014</td>
<td>6/3/17 13:20</td>
<td>6/4/17 7:20</td>
<td>0.75</td>
<td>8.00</td>
<td>4.00</td>
<td>2.00</td>
<td>1.00</td>
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<td>40000</td>
<td>3183</td>
<td>3541</td>
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<tr>
<td>17-014</td>
<td>6/3/17 13:20</td>
<td>6/4/17 7:20</td>
<td>0.75</td>
<td>8.00</td>
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<td>12.57</td>
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<td>3899</td>
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<td>7/11/17 13:20</td>
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<td>8.00</td>
<td>4.00</td>
<td>2.00</td>
<td>1.00</td>
<td>12.57</td>
<td>60000</td>
<td>4775</td>
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<td>7/11/17 13:20</td>
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<td>4.00</td>
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</table>

**Remarks:**

**Mix ID:**

**Technician Name:** John Doe  **Certification Number:** 1001
Same As Design

Must be used on a project or approved in the past 6 months

• Concrete Design Contract Association Request Form
• Possibly Attach Copy of Original Design
CONTRACTOR REQUEST FOR DESIGN/CONTRACT ASSOCIATION

Date ___________________  Concrete Producer

Associate the following design(s):

<table>
<thead>
<tr>
<th>Mix Design #</th>
<th>Previous Contract #</th>
<th>Class</th>
<th>New Contract #</th>
<th>Location</th>
<th>Comments</th>
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<tbody>
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</tbody>
</table>

Requested By __________________________________________  Certification # _________________
Cementitious Materials

Cement & Pozzolans (Fly Ash, GGBFS (Slag), Silica Fume)

- Material must be on the QPL
- Material must come from an approved source
- or
- Must have complete lab test report
- Producer/Brand
- Location
- Type, Class, Grade
- Specific Gravity

Cementitious Materials

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 “F” Fly Ash</td>
<td>25.0</td>
<td>1:1</td>
</tr>
<tr>
<td>Class “C” 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.
Cementitious Materials

Replacement Ratio Example

- 620 lb. Cement
- Max. “C” Fly Ash Replacement
  - Substitution Ratio 1:1

\[
620 \text{ lb.} \times 25\% = 155 \text{ lb. } “C” \text{ Fly Ash} @ 1:1, 155 \text{ lb. } “C” \text{ Fly Ash}
\]

- Substitution Ratio 1.5:1

\[
155 \text{ lb.} \times \frac{1.5 \text{ lb. Fly Ash}}{1 \text{ lb. Cement}} = 232.5 \text{ lb. } “C” \text{ Fly Ash}
\]

Aggregate

- Coarse and Fine Aggregate
  - Must have Complete Lab Test Report
  - Producer Name
  - Location
  - Specific Gravity (SG)
  - Gradation
  - Fineness Modulus (2.3-3.1) Fine Aggregate Only
  - % of Fine Aggregate of Total Aggregate Volume

- Allow 1 change in coarse aggregate
  - If like material
  - If SG is within 0.15 of original
Admixtures

- Each must be on the QPL
  - Producer
  - Brand
  - Air-Entrainers
  - Water Reducers
  - Retarders
  - Accelerators
  - Water Reducer/Retarder
  - Water Reducer/Accelerator
  - HR Water Reducer
  - HR Water Reducer/Retarder
  - Latex Modifier
  - Specific Performance

Properties of Plastic Concrete

- Proportions of Each Component
- Design Includes
  - % Air
  - Slump
  - Unit Weight
  - Yield
  - Temperature
  - w/cm Ratio
  - % Fine Aggregate of Total Aggregate Volume
Hardened Concrete Tests

Lab report
• 7-day compressive strength, 2 cylinders
• 14-day compressive strength, 2 cylinders
• 28-day compressive strength, 2 cylinders

Mix Design

TDOT Certified Concrete Mix Design Technician

• Technician Certification Number
  Or
• Professional Engineer Stamp
## CONTRACT INFORMATION

<table>
<thead>
<tr>
<th>Contract</th>
<th>Letting Date</th>
<th>Region</th>
<th>Project No.</th>
<th>Ref. No.</th>
<th>County</th>
<th>Project Manager</th>
<th>Contractor</th>
<th>Same as design</th>
<th>Lbs. of cement correct</th>
<th>Certified Concrete Mix Design technician</th>
<th>Certification number</th>
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</thead>
</table>

## GENERAL CONCRETE INFORMATION

<table>
<thead>
<tr>
<th>Concrete</th>
<th>Contractor's mix design provided</th>
<th>Class of concrete</th>
<th>Class of flyash</th>
<th>Compressive strength requirements</th>
<th>Compressive strength test results provided</th>
<th>Water/cement ratio is acceptable</th>
<th>Proportion of fines is acceptable</th>
<th>Design air is correct</th>
</tr>
</thead>
</table>

## CEMENTITIOUS MATERIALS

<table>
<thead>
<tr>
<th>Cement</th>
<th>Fly Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source specified</td>
<td>Source specified</td>
</tr>
<tr>
<td>Product on QPL 15</td>
<td>Product on QPL 16</td>
</tr>
<tr>
<td>Certification from producer provided</td>
<td>Certification from producer provided</td>
</tr>
<tr>
<td>Certified mill test report provided specific gravity</td>
<td>Certified lab test results provided specific gravity</td>
</tr>
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## AGGREGATES

<table>
<thead>
<tr>
<th>Coarse Aggregates</th>
<th>Fine Aggregates</th>
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<tbody>
<tr>
<td>Source specified</td>
<td>Source specified</td>
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<tr>
<td>Source is approved</td>
<td>Source is approved</td>
</tr>
<tr>
<td>Lab test results provided</td>
<td>Lab test results provided</td>
</tr>
<tr>
<td>Gradation</td>
<td>Gradation</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>Specific gravity</td>
</tr>
<tr>
<td>Fineness Modulus</td>
<td>Fineness Modulus</td>
</tr>
</tbody>
</table>

## ADMIXTURES

| Sources and brands specified | Products on QPL 4 |

| TECHNICIAN NAME: | CERTIFICATION NUMBER: |
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**

- Concrete Class / Construction Type
  - 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

- Class CP – Concrete Pavement
- Class A – Structural, General Use
- Class D – Bridge Decks
- Class L – Lightweight
- Class S – Seal
- Class X – Plans Specific
- HE – High Early Strength
- Class P – Prestressed/Precast Bridge Members
- Class P-SCC – Self Consolidating Concrete

Step 2
Water Content

- Use the chart on the following slide to determine the minimum amount of cement required and the maximum w/cm ratio.
- Determine the maximum allowable water content using the equation below.

\[
\text{Water cement Ratio} = \frac{\text{weight of water}}{\text{weight of cement}}
\]

\[
\text{weight of water} = \text{water cement ratio} \times \text{cement}
\]
### TDOT Specification Table 604.03-01

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<th>Class of Concrete</th>
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<td>7 (3)</td>
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<td>3,000</td>
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1. For slip forming, the slump shall range from 0 to 3 inches.
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6. The use of fly ash as a cement replacement will be allowed in Class S (Seal) concrete.
7. Plan specific requirements

---

### Concrete Mix Design Technician Course, Grade 3

**Step 3**

**Absolute Volumes**

Calculate the absolute volume of any material

\[ V_{\text{ft}^3} = \frac{W_{\text{lbs}}}{G \times U} \]

- \( V_{\text{material}} \) = absolute volume of material, ft\(^3\)
- \( W_{\text{material}} \) = weight of material, lbs.
- \( G_{\text{material}} \) = 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

\[ W_{\text{lbs.}} = V_{\text{material}} \times G_{\text{material}} \times U \]

- \( W_{\text{material}} \) = weight of material, lbs.
- \( V_{\text{material}} \) = absolute volume of material, ft\(^3\)
- \( G_{\text{material}} \) = 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

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

- \( U_{\text{lbs./ft}^3} \) = unit weight of mix, lbs./ft\(^3\)
- \( W_{\text{total}} \) = total weight of all the materials, lbs.
- \( V_{\text{total}} \) = total volume of the mix, ft\(^3\) (should be 27 ft\(^3\))
Questions
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(7) Plan specific requirements
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<th>Volume (ft³)</th>
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<td>Cement</td>
<td>( W_{\text{Cm}} )</td>
<td>( %W_{\text{Cement}} )</td>
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<td>( w/cm )</td>
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</tr>
<tr>
<td>Air</td>
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<td></td>
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<td><strong>Total Weight and Volume of Paste</strong></td>
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</tr>
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<td><strong>Total Volume of Aggregate Required</strong></td>
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<td>( %V_{\text{CA}} )</td>
<td>( W_{\text{CA}} = V_{\text{CA}} \times G_{s,\text{CA}} \times U )</td>
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### Class of Concrete:

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\( U_{\text{Concrete}} = W_{\text{Total}}/V_{\text{Total}} \)
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</table>

#### 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

| $V_{Agg} = 27\cdot(\frac{W_{cm} + W_{Water} + V_{Air}}{U})$ |

#### Aggregate

| Coarse (CA) | $W_{CA} = V_{CA} \times G_{s,CA} \times U$ (given) | $\%V_{CA}$ (given) | $V_{CA} = \frac{(\%V_{CA} \times V_{Agg})}{100}$ |
| Fine (FA) | $W_{FA} = V_{FA} \times G_{s,FA} \times U$ (given) | $\%V_{FA}$ (given) | $V_{FA} = \frac{(\%V_{FA} \times V_{Agg})}{100}$ |

#### TOTAL

| $W_{Total} = W_{Paste} + W_{CA} + W_{FA}$ | $V_{Total} = V_{Paste} + V_{CA} + V_{FA}$ |

#### UNIT WEIGHT

<p>| $U_{Concrete} = \frac{W_{Total}}{V_{Total}}$ |</p>
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#### 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

<table>
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<tr>
<th></th>
<th>( W_{CA} )</th>
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**TOTAL**

\( W_{Total} = W_{Paste} + W_{CA} + W_{FA} \)

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**UNIT WEIGHT**

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(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.
(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
<table>
<thead>
<tr>
<th>Constituent</th>
<th>Volume (ft³)</th>
<th>Weight</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>V Cement = W Cement ( \times ) ( \frac{G_s, Cement}{U} )</td>
<td>W Cement = (W cm ( \times ) %W Cement) ( \div ) 100</td>
<td>(given)</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>V Flyash = W Flyash ( \times ) ( \frac{G_s,Flyash}{U} )</td>
<td>W Flyash = (W cm ( \times ) %W Flyash) ( \div ) 100</td>
<td>(given)</td>
</tr>
<tr>
<td>Slag</td>
<td>V Slag = W Slag ( \times ) ( \frac{G_s, Slag}{U} )</td>
<td>W Slag = (W cm ( \times ) %W Slag) ( \div ) 100</td>
<td>(given)</td>
</tr>
<tr>
<td>Water</td>
<td>V Water = W Water ( \times ) ( \frac{G_s, Water}{U} )</td>
<td>W Water = (W cm ( \times ) %W Water) ( \div ) 100</td>
<td>(given)</td>
</tr>
</tbody>
</table>

**Design Air**

V Air = (Design Air \times 27) \( \div \) 100

**Total Volume of Aggregate Required**

V Agg = (27 - (V cm + V Water + V Air))

**Total Weight and Volume of Paste**

V Paste = V cm + V Water + V Air

**Total Weight and Volume of Paste**

W Paste = W cm + W Water

**Cementitious Materials**

- **Cement**
  - V Cement = W Cement \( \times \) \( \frac{G_s, Cement}{U} \)
  - W Cement = (W cm \( \times \) \%W Cement) \( \div \) 100

- **Fly Ash**
  - V Flyash = W Flyash \( \times \) \( \frac{G_s,Flyash}{U} \)
  - W Flyash = (W cm \( \times \) \%W Flyash) \( \div \) 100

- **Slag**
  - V Slag = W Slag \( \times \) \( \frac{G_s, Slag}{U} \)
  - W Slag = (W cm \( \times \) \%W Slag) \( \div \) 100

**Aggregate**

- **Coarse (CA)**
  - V CA = \( \frac{V_{CA}}{V_{Agg}} \) \( \times \) \( \frac{G_s, CA}{U} \)
  - W CA = \( \frac{V_{CA}}{V_{Agg}} \) \( \times \) \( \frac{W_{cm, CA}}{U} \)

- **Fine (FA)**
  - V FA = \( \frac{V_{FA}}{V_{Agg}} \) \( \times \) \( \frac{G_s, FA}{U} \)
  - W FA = \( \frac{V_{FA}}{V_{Agg}} \) \( \times \) \( \frac{W_{cm, FA}}{U} \)

**Total Weight and Volume of Paste**

V Total = V Paste + V CA + V FA

**Total Weight of Aggregate**

W Total = W Paste + W CA + W FA

**Total Weight and Volume of Aggregate**

V Total = W Total \( \times \) \( \frac{G_s, Aggregate}{U} \)
SOP 4-4

Procedures for Submittal and Approval of Concrete Mixtures
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 mix, prestressed, and precast concrete.

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

The contractor shall first determine from the Plans the class of concrete required along with the design criteria for the mix (i.e. a project-specific requirement of 3000 psi in 18 hours).

Procedure: A new 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 civil engineer licensed by the state of Tennessee shall determine, by using volumetric mix design procedures, the proportions of all materials in the mix in accordance with 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, and the tests for the freshly-mixed concrete shall be conducted to determine the actual slump, temperature, air content, unit weight, and yield. 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.

If all test results meet the required design criteria, the design must be submitted to Headquarters Materials and Tests no less than 14 working days prior to mix production. New design submittals must be listed on the Concrete Mix Design Template. Designs to be associated to another contract must be listed on the Concrete Design Contract Association Request Form, have been used on a TDOT funded project within the previous 6 months, and have passing test results. New or existing designs shall be emailed to concrete.mixdesign@tn.gov.

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 (Modified), should include “Surface Aggregates Required” in the body of the email.

**Materials:**

**Cement:** The source and location must be listed on the Qualified Products List (QPL 15) 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.

**Fly Ash:** The source and location must be listed on the Qualified Products List (QPL 16) 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 that participated in the Tennessee Concrete Association Fly Ash Round Robin Study. 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 Qualified Products List (QPL 16) 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 Qualified Products List (QPL 16). Any change of silica fume shall require a new submittal, including a new trial batch complete with test results.

**Water:** Must be from an approved source; 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. Gradation and specific gravity test results must be submitted reflecting the characteristics of the stockpile to be used in the mix.

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 and AASHTO M-6. Gradation, fineness modulus, and specific gravity test results must be submitted reflecting the characteristics of the stockpile to be used in the mix.

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 including Air-Entraining Admixtures**: All admixtures must be listed on the Qualified Products List (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 for all SCC and High Early Strength concrete designs. A change in admixture dosage rate may be allowed at the discretion of the project supervisor to adjust the physical characteristics of the concrete (workability, for example).

**Distribution**: Once the submittal is approved, the design will be distributed as follows:
- A copy is sent to HQ Materials and Tests Administrative Section. Administration sends an official copy to the project file.
- 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.

**Further Guidance**: Once approved, the mix design will be valid for any other State project provided that the test results, including compressive strength, are satisfactory and within allowable tolerances. Acceptance and quality control (QC) testing shall be conducted in accordance with SOP 1-1.

There is a maximum of 3 approved concrete designs of each class per project per producer unless authorized by the Materials Engineer. The approved mix design shall expire after 6 months if it is not used on a TDOT funded project or does not meet the minimum 28 day strength requirements.