Designing a Concrete Mixture

HOW IS IT TAUGHT IN THE HTCP PCCTEC-II TRAINING PROGRAM?

ANDRÉA BREEN,
QC MANAGER ZINGEGO READY MIX, & HTCP INSTRUCTOR
HTCP Program
A BRIEF OVERVIEW
Highway Technician Certification Program

Program Resources

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The Highway Technician Certification Program (HTCP) certifies that you have demonstrated abilities to engage in quality control or quality assurance activities in highway work contracted by the Wisconsin Department of Transportation (WisDOT).

Through revisions in its specifications and contractual practices, WisDOT has developed quality management programs for the highway work. Through the improvement of quality control in the work of the contractor, WisDOT has noticed improvements in the quality of the work. The program focuses on training individuals to work in highway construction, maintenance, and repair projects. The program is designed to provide participants with the knowledge and skills necessary to perform quality control and assurance tasks on highway projects.

Visit the UW-Platteville website for more information on the Highway Technician Certification Program and other educational opportunities.
Highway Technician Certification Program Advisory Board

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WisDOT Northeast Region

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WisDOT, Bureau of Project Development

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UW-Platteville College of Engineering, Mathematics and Science

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Follow us!
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Type</th>
<th>Start Date</th>
<th>End Date</th>
<th>Location</th>
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<td>Class</td>
<td>5/26/2020</td>
<td>5/28/2020</td>
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<td>Transportation Materials Sampling Technician</td>
<td>Exam</td>
<td>2/28/2020</td>
<td>2/28/2020</td>
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PORTLAND CEMENT CONCRETE TECHNICIAN I (PCCTEC-I)

Course Prerequisites: None

This course requires 30 hours of classroom/laboratory attendance. This course will discuss fundamentals of concrete, concrete paving, random sampling, sampling and testing of freshly mixed concrete, air pressure meter calibration, casting and curing concrete cylinders, quality control charts, acceptable quality management program specifications for bridge decks and other structural members along with mainline pavements. Upon successful completion of this course you will earn 2.0 Continuing Education Units (CEUs).

Download the PCCTEC-I manual.

NOTE: If you are ACI Certified and attending the PCCTEC-I Class please contact the HTCP Office at 608-944-1545 or http://uwplatt.edu with your ACI Certification to receive a $100 discount on the registration, HTCP will then ask you to help assist the PCCTEC-I instructor during the lab portion of the class.

PORTLAND CEMENT CONCRETE TECHNICIAN II (PCCTEC-II)

Course Prerequisites: Portland Cement Concrete Technician I (PCCTEC-I)

This course requires 32 hours of classroom attendance. This course will cover aggregate correction factor, coarse and fine specific gravity and absorption, dry and oven weights, cementitious materials, admixtures, combined aggregate gradation, proportioning of concrete mixtures, hot and cool weather cementing, statistical analysis, record keeping, current quality management program specifications, curing/concrete, and depth probing. Upon successful completion of this course you will earn 3.2 Continuing Education Units (CEUs). The PCCTEC-II certification carries the PCCTEC-I certification.

Download the PCCTEC-II manual.

GRADING TECHNICIAN I (GRADINGTEC-I)

Course Prerequisites: None

This course requires 32 hours of classroom/laboratory attendance. The course content will cover random sampling methods, basic sort types, moisture-density relationship, the Atterberg Limits, VSODOT's grading quality management program, VSODOT standard specifications, and statistical quality control. Upon successful completion of this course you will earn 3.2 Continuing Education Units (CEUs).

Download the Grading Technician I manual.

PROFILER TECHNICIAN I (PROFILER)

Course Prerequisites: None
PCCTEC-II
GOING THROUGH THE COURSE
4 day course

- Day 1 & 2 – Lecture
- Day 3, 4-station lab day, including aggregate testing and concrete mixing
- Day 4, Exam
- 3.2 CEUs available
- 3 year certification
  - Recert exam available
  - PCCTEC-I pre-requisite
  - PCCTEC-II carries the PCCTEC-I cert
Introduction to Materials

- Overview of all components
  - Cement; Fly Ash; Slag Cement; Silica Fume, Calcined Clay, Metakaolin
  - Chemical Admixtures, Air Entrainment for F/T Protection
  - Concrete aggregate quality, moisture conditions, specific gravity and absorption, gradation
Wisconsin’s geologic past

Changing landscapes
- Fossils and rocks are known at different times in the past 2.8 billion years...
- Mountains and volcanoes once stood tall in central Wisconsin.
- A shallow sea covered nearly the entire state.
- Glaciers flowed across Wisconsin, leaving behind broad, rolling hills.

How old are the rocks?
This map shows the age of the uppermost rock layer you would find if you dug down to solid rock.

What's under Milwaukee?
- A cold past
  - Many times during the past 2 million years, glaciers covered much of the state. Woolly mammoths migrated north as the glaciers melted.
- Dinosaurs in Wisconsin?
  - About 360 million years of the rock record are missing here. Dinosaurs likely roamed this area, but any rock that contained their bones has eroded away.
- Wisconsin underwater
  - For much of 140 million years, Wisconsin was covered by a shallow sea. The rocks from these time periods are all rocks you could find forming on the sea floor today.
- Shifting sands
  - Just 14 million years ago, the beaches and riverbeds today, these sandy layers were laid down in these kinds of places in the past.
- Missing rock layers
  - About 1 billion years of the rock record is missing between these layers. Lassen was down and destroyed the rocks.
- Wisconsin's oldest rocks
  - Our oldest rocks are about 2.8 billion years old and are exposed in the central and northern parts of the state.

Slice of earth
If you made a slice through the ground from La Crosse to Milwaukee, this is what the rock layers would look like.
Standard Specifications
Section 106: Control of Materials

106.3.4.2.2 Department-Approved Aggregate Sources
Durability and quality testing for aggregates

- AASHTO T96 – LA Wear, strength and aggregate hardness
- AASHTO T104 – Sodium Sulfate Soundness, resistance to weathering
- AASHTO T103 – Freeze Thaw Soundness, continuity and size of pores and presence of shale (clay or mud stone)
- Deleterious Substances, affecting water demand, bond, and strength/durability concerns
- Flat and Elongated Particles, affecting workability
- Chemical Reactivity, ASR
Other Aggregate Factors Affecting Mix Design

- Texture and Shape
- Surface Area
- Moisture Conditions

MOISTURE CONDITION OF AGGREGATES

- Ovendry: None
- Air dry: Less than potential absorption
- Saturated, surface dry: Equal to potential absorption
- Damp or wet: Greater than absorption

Total moisture
Aggregate Performance for Mixture Proportioning

- Specific Gravity
- Absorption
- Gradation
- Fineness Modulus
  - Higher FM, 3.1 max, is coarse
  - Lower FM, 2.3 min, finer gradation
  - $\text{SUM RET}(1.5'', \ 3/4'' \ 3/8'', \ #4, \ #8, \ #16, \ #30, \ #50, \ #100)/100$
Coarseness and Workability Factors

- **Coarseness Factor (CF):** describing a gap-graded or well-graded combined aggregate
  
  \[ CF = \frac{\text{Combined } \% \text{ Retained 3/8” sieve and above}}{\text{Combined } \% \text{ retained #8 and Above}} \times 100 \]

- **WF:** Combined % passing #8
Shilstone Method: Coarsness and Workability Factors

- IV: Sandy
- III: Well graded, small agg L.T. ½"
- II: Well graded, gap ¾'' - 1 ½"
- I: Coarse
- V: Coarseness Factor (%)

- Workability Factor (%)
Tarantula Curve Method

- Hides in hole in the ground during the day
- Large size and fangs
- Sharp bristles called urticating hairs
Excessive amount that decreases workability and promotes segregation and edge slumping.

Not in Scope of work

Excessive amount creates workability issues.

Creates surface finishability problems normally associated with manufactured sands.

24-34% of fine sand (#30-200)

<table>
<thead>
<tr>
<th>% Retained</th>
<th>#200</th>
<th>#100</th>
<th>#50</th>
<th>#30</th>
<th>#16</th>
<th>#8</th>
<th>#4</th>
<th>0.375</th>
<th>0.5</th>
<th>0.75</th>
<th>1</th>
<th>1.5</th>
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<tr>
<td>30%</td>
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<td></td>
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<td>25%</td>
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<td>20%</td>
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<tr>
<td>15%</td>
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<td>10%</td>
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<td>12%</td>
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<td></td>
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<tr>
<td>20%</td>
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</table>
Factors for Mix Design

- Field performance basis
  - Existing project data
  - Statistical analysis
- Trial batching
  - w/cm curve with 3 values
- Volumetric “Absolute Volume” Method
  - Known specific gravities of all materials
  - Converts to batch weights
Material data needed to start Volumetric Design

- Sieve analysis for each aggregate to be used
- Unit Weight of aggregate (dry rodded density)
- Bulk Specific Gravity, absorption and moisture content
- Mixing water content, historical basis
- Specific Gravity, all cementitious materials
- Choice of maximum coarse aggregate size
  - 1/5 the narrowest dimension between forms
  - 1/3 the depth of a slab
  - ¾ the minimum clear space between reinforcing bars or strands
- Air Content, per specification 501.3.2.4.2 Air Entrainment
Establishing the Mix Design

- 1. Section 715 or 716 of the standard spec will define w/cm and minimum cement content
- 2. w/cm ratio will be used to calculate water content.
- 3. FM and Maximum Coarse Aggregate size of coarse aggregate will be used to estimate % from chart5
- 4. (Unit weight of coarse agg, lb/cf) x (27 cf) x (%CA)
- 5. When water, cement and coarse aggregate are known, and air content, the remaining volume is fine aggregate
### DETERMINATION OF FIELD BATCH WEIGHTS FOR CONCRETE

**Wisconsin Department of Transportation**

**DT2220**

#### PROJECT DESCRIPTION

<table>
<thead>
<tr>
<th>Project</th>
<th>Contract</th>
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<td>Name of Road</td>
<td>Concrete Grade</td>
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#### CONCRETE DESCRIPTION

<table>
<thead>
<tr>
<th>bags</th>
<th>Lbs. of Cement</th>
<th>Lbs. of Fly Ash/Slag</th>
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</thead>
<tbody>
<tr>
<td>Per Cubic Yard</td>
<td>Per Cubic Yard</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Highway</th>
<th>County</th>
<th>Lbs. of Total Dry</th>
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<tbody>
<tr>
<td>Aggregate per Cubic Yard</td>
<td></td>
<td></td>
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</table>

<table>
<thead>
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<th>Contractor</th>
<th>Max. Total Mix Water in</th>
</tr>
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<tbody>
<tr>
<td>Gal. per Cubic Yard</td>
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#### AGGREGATE DATA

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<tr>
<th>Aggregate</th>
<th>Source</th>
<th>Test No.</th>
<th>Specific Gravity</th>
<th>% Absorp.</th>
<th>% Total Moisture</th>
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<tbody>
<tr>
<td>Fine Agg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 1 C.A.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2 C.A.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>No. 3 C.A.</td>
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#### BATCH SIZE DATA

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<th>Maximum Allowable Mixer Batch Volume</th>
<th>C.F.</th>
<th>C.Y.</th>
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<tr>
<td>Design Batch Volume:</td>
<td>C.F.</td>
<td>C.Y.</td>
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**PROPORTIONS (%):**

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<th>F.A.</th>
<th>C.A.</th>
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<tr>
<td>NO. 1</td>
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<tr>
<td>NO. 2</td>
<td>100</td>
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<tr>
<td>NO. 3</td>
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### Figure H-1A: Absolute Volume Calculations – SECTION 1

<table>
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<tr>
<th>Component</th>
<th>OD Weight</th>
<th>OD Specific Gravity</th>
<th>Absolute Volume</th>
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</thead>
<tbody>
<tr>
<td>Cement</td>
<td>395</td>
<td>3.150</td>
<td>2.01</td>
</tr>
<tr>
<td>Ash</td>
<td>170</td>
<td>2.650</td>
<td>1.03</td>
</tr>
<tr>
<td>Slag</td>
<td>0</td>
<td>2.900</td>
<td>0.00</td>
</tr>
<tr>
<td>Sand</td>
<td>???</td>
<td>2.751</td>
<td>???</td>
</tr>
<tr>
<td>3/4&quot; CA (#1)</td>
<td>1246</td>
<td>2.730</td>
<td>3.13</td>
</tr>
<tr>
<td>1 1/2&quot; CA (#2)</td>
<td>671</td>
<td>2.674</td>
<td>4.03</td>
</tr>
<tr>
<td>Water</td>
<td>237</td>
<td>1.000</td>
<td>3.80</td>
</tr>
<tr>
<td>Air</td>
<td>7.0%</td>
<td>1.89</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2719</strong></td>
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<td><strong>20.09</strong></td>
</tr>
</tbody>
</table>

- **Total Volume of Known Ingredients = 20.09 CF**
- The calculated absolute volume of fine aggregate is: 27.90 - 20.09 = 6.91 CF

**EQUATION 1B:**  OD Weight FA = (Absolute Volume FA) x (OD Sp Gr) x 62.3 LB/CF

- The weight of dry Fine Aggregate is: 6.91 CF x 2.751 x 62.3 LB/CF = 1184 LB

### Figure H-1B: Summary of Oven Dried (OD) Proportions – SECTION 1

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<thead>
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<th>OD Weight</th>
<th>OD Specific Gravity</th>
<th>Absolute Volume</th>
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<td>Sand</td>
<td>1184</td>
<td>2.751</td>
<td>6.91</td>
</tr>
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<td>1246</td>
<td>2.730</td>
<td>3.13</td>
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<tr>
<td>1 1/2&quot; CA (#2)</td>
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<tr>
<td>Air</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>3903</strong></td>
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<td><strong>27.00</strong></td>
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From above calculation
Where to go from here

- CMM Chapter 8 – Concrete
  - 8-70.2.2 Concrete Mix Design
- WisDOT form DT2220
  - Excel spreadsheet
- Lab trial batching and testing
  - Type B air meter
  - SAM values
  - Box Test
Box Test for use with Tarantula Curve mix design
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
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<tbody>
<tr>
<td>Step 1</td>
<td>Gather the different components of the Box Test.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Construct box and place clamps tightly around box. Hand scoop mixture into box until the concrete height is 9.5” (241.3 mm).</td>
</tr>
<tr>
<td>Step 3</td>
<td>Insert vibrator downward for 3 seconds and upward for 3 seconds. Remove vibrator.</td>
</tr>
<tr>
<td>Step 4</td>
<td>After removing clamps and the forms, inspect the sides for surface voids and edge slumping.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td><strong>3</strong></td>
</tr>
<tr>
<td>Over 50% overall surface voids.</td>
<td>30-50% overall surface voids.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>10-30% overall surface voids.</td>
<td>Less than 10% overall surface voids.</td>
</tr>
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Summary of Concrete Mix Design

- Familiarity with aggregates, cementitious and admixtures
- Testing for field performance and long term durability
- Continual monitoring of materials in production
- Conformance to acceptance testing criteria outlined in the specification
Thank you for your time!

Special thanks to the HTCP Program, the HTCP Board of Directors, and WCPA for all of their diligent effort to continuous improvement of the PCCTEC-II certification, and to the dedicated instructors and lab instructors for their efforts.