“Manual of Instructions for Design of Concrete Mixtures”
PORTLAND CEMENT CONCRETE LEVEL III TECHNICIAN COURSE -
MANUAL OF INSTRUCTIONS FOR DESIGN OF CONCRETE MIXTURES

1. POLICY

It is the policy of the Department of Transportation to publish and maintain a manual which provides guidelines for designing concrete mixtures.

2. PURPOSE

The purpose of this Policy is to provide for the publication of a manual to serve as a guide and source of reference for the practices and procedures for those involved in the designing of concrete mixtures.

3. GUIDELINES FOR IMPLEMENTATION

A. The manual is prepared with emphasis on practices and procedures currently used by the department.

B. The manual is intended to train individuals in the design of concrete mixtures.

C. Department training classes shall utilize the current edition of the manual for all applicable procedures.

D. The manual contains design procedures that will provide uniformity of work performed by the contractor, the department or consultants retained by either.

4. RESPONSIBILITIES

The following outlines the individual and office responsibilities to ensure compliance with the provisions of this Policy and its accompanying manual.

A. The Bureau of Materials and Physical Research (BMPR) is responsible for the issuance of this Policy.
B. The Division of Highways' (DOH) regions/districts are responsible for ensuring compliance with this Policy.

C. The Engineer of Concrete and Soils of the DOH's BMPR Materials Testing Section shall be contacted when questions arise regarding the application of these procedures.

5. ACCESSIBILITY

A. LOCATION

Electronic versions of this Policy and its accompanying manual are located at the Policy & Research Center site on insideIDOT, the department's internal website. Electronic versions can also be found at http://www.dot.illinois.gov/materials/guides/manuals.html.

Questions regarding this manual may be directed to the Bureau of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766.

B. COPIES

Hard copies of this Policy may be obtained by contacting the Bureau of Business Services (BoBS), Quality and Document Management Services Section.

C. ARCHIVES & REVISION HISTORY

 Archived versions of this Policy and its revision history may be examined by contacting BMPR.

CLOSING NOTICE


Supersedes: Manual of Instructions for Design of Concrete Mixtures.
Effective: January 1, 1988

Approved:  
Director of Highways

Date
LAKE LAND COLLEGE
INSTRUCTOR AND COURSE EVALUATION

Course: PCC Level III Technician Course  Section: __________  Date: ________________

PURPOSE: The main emphasis at Lake Land College is teaching. In this regard, each instructor must be continuously informed of the quality of his/her teaching and the respects in which that teaching can be improved. As a student, you are in a position to judge the quality of teaching from direct experience, and in order to help maintain the quality of instruction at Lake Land, you are asked to complete this evaluation.

DIRECTIONS: DO NOT SIGN YOUR NAME. Your frankness and honesty are appreciated.

First, please record your general impressions and/or comments on the following:
Course __________________________________________________________________________________
________________________________________________________________________________________
Instructor ________________________________________________________________________________

For each remaining item, circle the number from the scale which seems most appropriate to you for the instructor and course that you are evaluating. You are strongly encouraged to make any comments that will clarify particular rating on the back of this form; please refer to each item you are discussing by its number.

WEAK SUPERIOR

OBJECTIVES AND APPROPRIATENESS OF THE COURSE:

1. Clarity of Objectives The objectives of the course were clearly identified. Objectives were adequately covered.
   1 2 3 4 5

2. Selection content Content was relevant and met the level of the class.
   1 2 3 4 5

ORGANIZATION AND CONTENT OF LESSONS:

3. Teacher preparation Instructor was organized and knowledgeable in subject matter and prepared for each class.
   1 2 3 4 5

4. Organization of classes Classroom activities were well organized and clearly related to each other.
   1 2 3 4 5

5. Selection of materials Instructional materials and resources used specific, current, and clearly related to the objectives of the course.
   1 2 3 4 5

6. Clarity of presentation Content of lessons was presented so that it was understandable to the students.
   1 2 3 4 5

7. Clarity of presentation Different point of view and/or methods with specific illustrations were used when appropriate.
   1 2 3 4 5

OVER
LAKE LAND COLLEGE
INSTRUCTOR AND COURSE EVALUATION
(PAGE 2)

PERSONAL CHARACTERISTICS AND STUDENT RAPPORT:

8. Vocabulary  Instructor's vocabulary level was appropriate 1 2 3 4 5 for the class.

9. Pupil participation and interest  Instructor encouraged students to ask questions and actively participate in class.

10. Personal attributes  Instructor indicated an interest and enthusiasm for teaching the subject matter.

11. Personal attributes  Instructor was familiar with current industry practices.

12. Personal attributes  Instructor's mannerisms were pleasing.

13. Instructor-student rapport  Instructor indicated a willingness to help you in times of difficulty.

14. Instructor-student rapport  Instructor was fair and impartial in dealings with you.

EXAMINATION:

15. Exam material  The exam correlated to the materials being covered in class.

SUMMARY:

16. Considering everything, how would you rate this instructor? 1 2 3 4 5

17. Considering everything, how would you rate this course? 1 2 3 4 5

LAPTOP COMPUTER:

18. If you brought a laptop computer, was the class training adequate for learning the PCC Mix Design software? 1 2 3 4 5

COMMENTS: (Please use the area below to add any additional comments regarding the class and exam.)

____________________________________________________________________
____________________________________________________________________
COURSE REQUIREMENTS FOR SUCCESSFUL COMPLETION

Student must attend all class sessions.

- PREREQUISITE COURSES — Either the Mixture Aggregate Technician Course (3-day) or the Aggregate Technician Course (5-day), and the Portland Cement Concrete Level I & II Technician Courses are required.

- WRITTEN TEST — The test is open book. The time limit is 2.5 hours. A minimum grade of 70 is required.

  Note: The Department has no out-of-state reciprocity.

- WRITTEN RETEST — If the student fails the written test, a retest can be performed. The retest is open book. The time limit is 2.5 hours. A minimum grade of 70 is required. A retest will not be given on the same day as the initial test. A retest must be taken by the end of the academic year that the initial test was taken. The academic year runs from September 1st to August 31st. (For example, if the test was taken January 24, 2013, the last date to retest is August 31, 2013.) Failure of a written retest, or failure to comply with the academic year retest time limit, shall require the student to retake the class and the test. The student shall be required to pay the appropriate fee for the additional class.

- NOTIFICATION — The student will be notified by letter of their test score. A certificate of completion will be issued if the student passes the course, and 12 professional development hours earned will be indicated on the certificate. Once trained, the Department will not require the individual to take the class again for recertification purposes.
PREFACE

This manual has been prepared to train the student to become a Level III Portland Cement Concrete (PCC) Technician. The main focus of the manual is to provide a procedure to design concrete mixes for Illinois Department of Transportation (herein referred to as “IDOT” or the “Department”) Quality Control/Quality Assurance (QC/QA) projects. The manual summarizes various specifications, but project contract specifications shall govern in all cases. The manual provides basic information and is intended to be a useful reference tool. This manual is applicable for the January 1, 2012, Standard Specifications for Road and Bridge Construction, the Portland Cement Concrete (BDE) Special Provision, Revised: January 1, 2013 and the Placing and Consolidating Concrete (BDE) Special Provision, Effective: January 1, 2013. It shall be noted that Section 1020 in the Portland Cement Concrete (BDE) Special Provision completely replaces Section 1020 in the Standard Specifications. Therefore, any reference to an Article in Section 1020 in this manual is referring to the Portland Cement Concrete (BDE) Special Provision.

The American Concrete Institute (ACI), statistical average/standard deviation, workability and other information in this manual were obtained from a course sponsored by the Federal Highway Administration (FHWA) and the Iowa Department of Transportation (DOT). The course “Introduction to Designing and Proportioning Portland Cement Concrete Mixtures” explained the American Concrete Institute’s method for concrete mix design. Portions from that manual have been reproduced herein as permitted by the FHWA and Iowa DOT.
Revision History and Document Control

The Portland Cement Concrete Level III Technician Course Manual will be reviewed by the Engineer of Concrete and Soils for adequacy annually and updated as necessary to reflect the current policies and technology changes. Updates are made to the electronic file as needed and hard copies are uncontrolled. Archive versions are available to examine in the Bureau of Material and Physical Research.

<table>
<thead>
<tr>
<th>Revision Date</th>
<th>Description</th>
<th>Approval</th>
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<tbody>
<tr>
<td>December 1, 2012</td>
<td>Added a question to the Instructor and Course Evaluation regarding the adequacy of training using the PCC Mix Design software.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised information in Preface regarding the updated Portland Cement Concrete (BDE) Special Provision, and added a reference to the Placing and Consolidating Concrete (BDE) Special Provision.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Updated Table of Contents.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added definition for “Supplementary Cementitious Material” to Definitions.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added Class PC “Precast Concrete” and Class PS “Precast Prestressed” to Class of Concrete.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added DEF “Delayed Ettringite Formation” to Abbreviations.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised 1.1 “Volumetric Mix Design and Mix Design Submittal” to note the new Appendix A which is a special provision allowing the Districts to provide mix designs. Also noted that the Districts may provide coarse aggregate voids.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Section 2.2, “Cement Factor” to note the minimum portland cement content required.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised 2.2.1 “Cement Factor for Class or Type of Concrete” to reference Table 2.2.1 “Cement Factor for Class or Type of Concrete” which was previously unnumbered.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Numbered Table 2.2.1 “Cement Factor for Class or Type of Concrete” to reference it.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Revised Note 3 of Table 2.2.1 “Cement Factor for Class or Type of Concrete” to remove the restriction from using shrink-mixed concrete for Class PV concrete.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised 2.4.1.2 “Ground Granulated Blast Furnace Slag” to refer to Article 1020.04 for minimum cement content.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Revised Sections 2.4.2 “Use of Finely Divided Minerals in Ternary Concrete Mix Designs” and 2.4.4 “Use of Finely Divided Minerals in Mass Concrete” to refer to Appendix O “Special Provision for Portland Cement Concrete (BDE)”.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised 2.4.3 “Mitigation of Alkali-Silica Reaction with Finely Divided Minerals” to provide some explanation of alkali-silica reaction, and to refer to Appendix P for the alkali-silica reaction specification flow chart.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised 2.5.1.2 “Coarse Aggregate Basic Water Requirement” with updated Illinois Test Procedure designation.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Table 2.5.2 “Adjustment to Basic Water Requirement”.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised terminology for High Range Water-Reducing Admixture (Superplasticizer) in 2.5.3 “Required Use of Admixtures”.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added a reference to Article 1020.05(b)(10) for Corrosion Inhibitor in Section 2.5.3 “Required Use of Admixtures”.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Section 2.5.4 “Optional Use of Admixtures” to note bridge deck microsilica concrete overlay and bridge deck high-reactivity metakaolin concrete overlay under Water-Reducing Admixture.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added fourth paragraph in Section 2.6, “Adjusted Basic Water Requirement and Water/Cement Ratio” regarding water content in admixtures. Also simplified formatting for the example calculation.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Section 2.7 “Air Content Absolute Volume Calculation” to note that the target air content for slipform construction can be lower than the midpoint.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added Note 2 in Table 2.7.1 “Air Content” regarding minimum air content for slipform construction.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Section 2.8.1 “Voids in Coarse Aggregate” to note that the District may provide coarse aggregate void values.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Sections 2.8.2.1 “General Concept” and 2.8.2.2 &quot;Volume Fraction Concept&quot; to simplify discussion relating to the figures shown.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Section 2.8.2.2 “Volume Fraction Concept” to distinguish apart the different ways to calculate the Volume Fraction of Mortar Per Unit Volume of Concrete.</td>
<td>Doug Dirks</td>
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<td>December 1, 2012</td>
<td>Revised table 2.8.2.3 “Design Mortar Factor” to allow CA 7 and CA 11 for Class PP-5 Concrete, and to correct allowable Coarse Aggregate Gradation for Class SC concrete. Also, revised Note 7 to indicate a minimum 95 percent passing the 3/4 in. (19 mm) sieve.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Corrected Sections 2.9 “Example Problem”, 2.9.1 “Example Using English Units”, and 2.9.2 “Example Using Metric Units” to use a non-crushed gravel coarse aggregate, to reference Section 2.4.1.1 “Fly Ash”, to disregard water in admixtures, and to revise the target slump based on the new allowable range for slipform construction.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised variable designations in Section 2.10 “Summary of Mix Design Equations”, and added a note regarding apparent specific gravity for cement and finely divided minerals.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Section 3.2 “Other Mixtures”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added Section 3.3 “Synthetic Fibers”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Updated reference to Appendix O in Section 4.0 “Ternary Concrete Mix Designs”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added Section 5.0 “Mass Concrete Mix Designs”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added Section 6.1 “Slump” regarding batching at slumps near the maximum to account for slump loss due to temperature and haul time.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Revised Note 1 of Table 6.1 “Slump” to allow up to 2-1/2 in. (64 mm) slump for slipform construction.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added Section 6.2 “Strength”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Revised Table 6.2 “Strength” to reference Class BS concrete for Concrete Wearing Surface. Also, added Note 9 regarding Steel Bridge Rail used in conjunction with Concrete Wearing Surface.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Revised Section 6.3 “Procedure for Trial Mixture”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Revised Section 7.0 “Determining the Concrete Mix Design Target Strength”.</td>
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<td>December 1, 2012</td>
<td>Revised Section 9.2.1 “Procedure for Trial Batch”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added new Appendix A “Concrete Mix Design – Department Provided (BDE)”.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added reference to Section 2.10 “Summary of Mix Design Equations” to 32. Abs. Vol. CA,B and 33. Abs. Vol. FA,A in Appendix B. Also, added a note to 53. Remarks regarding to note how alkali-silica reaction is being mitigated for the mix design.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Replaced Appendix B-A with “PCC Mix Design Software Tutorial (Version 2.3.5.1)“.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added to Appendix E recommendation regarding fineness modulus for slipform construction, and added discussion to Section 1.2.2 “The 0.45 Power Curve” regarding coarser and finer gradations.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Appendix F regarding Contractor mix designs for Cement Aggregate Mixture (CAM) II. Also, clarified mix design calculations and revised example problems.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added reference to Article 1019.06 to Appendix G.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added note regarding fly ash content and the flow cone test to Appendix I. Also, revised Section 2.2.1 “Procedure for Trial Batch” to be similar to Section 9.2.1 “Procedure for Trial Batch” in the main body of the manual.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Expanded Appendix J to be similar to Appendix I.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Added Appendix K to include cellular concrete for insertion lining of pipe culverts.</td>
<td>Doug Dirks</td>
</tr>
<tr>
<td>December 1, 2012</td>
<td>Revised Appendix L Section 2.2.1 “Procedure for Trial Batch” to be similar to Section 9.2.1 “Procedure for Trial Batch” in the main body of the manual.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added Appendix O “Portland Cement Concrete (BDE)&quot;.</td>
<td>Doug Dirks</td>
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<tr>
<td>December 1, 2012</td>
<td>Added Appendix P “Alkali-Silica Reaction Mitigation Flow Chart”.</td>
<td>Doug Dirks</td>
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<td>December 1, 2012</td>
<td>Added Appendix Q “Quality Control/Quality Assurance of Concrete Mixtures (BDE)”.</td>
<td>Doug Dirks</td>
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</tbody>
</table>
# TABLE OF CONTENTS

**DEFINITIONS** (Page xii)

**APPLICABLE SPECIFICATIONS** (Page xv)

**CLASS OF CONCRETE** (Page xvi)

**UNITS OF MEASURE CONVERSION** (Page xvii)

**SIGNIFICANT DIGITS AND ROUNDING** (Page xviii)

**ABBREVIATIONS** (Page xix)

### 1.0 MIX DESIGN OVERVIEW (Page 1)

1.1 VOLUMETRIC MIX DESIGN AND MIX DESIGN SUBMITTAL

1.2 MIX DESIGN SOFTWARE
   - 1.2.1 Department Software
   - 1.2.2 Available Software Applications

### 2.0 CONCRETE MIX DESIGN DEVELOPMENT USING IDOT METHOD (Page 4)

2.1 INTRODUCTION – ABSOLUTE VOLUME

2.2 CEMENT FACTOR
   - 2.2.1 Cement Factor for Class or Type of Concrete
   - 2.2.2 Allowable Cement Factor Reduction – Admixture

2.3 CEMENT ABSOLUTE VOLUME CALCULATION

2.4 FINELY DIVIDED MINERALS ABSOLUTE VOLUME CALCULATION
   - 2.4.1 Cement Replacement with Finely Divided Minerals and The Optional Use of Microsilica and High Reactivity Metakaolin (HRM)
     - 2.4.1.1 Fly Ash
     - 2.4.1.2 Ground Granulated Blast-Furnace Slag
     - 2.4.1.3 Microsilica
     - 2.4.1.4 High-Reactivity Metakaolin (HRM)
   - 2.4.2 Use of Finely Divided Minerals in Ternary Concrete Mix Designs
   - 2.4.3 Mitigation of Alkali-Silica Reaction with Finely Divided Minerals
   - 2.4.4 Use of Finely Divided Minerals in Mass Concrete

2.5 WATER ABSOLUTE VOLUME CALCULATION
   - 2.5.1 Basic Water Requirement
     - 2.5.1.1 Fine Aggregate Basic Water Requirement
     - 2.5.1.2 Coarse Aggregate Basic Water Requirement
     - 2.5.1.3 Basic Water Requirement Total
   - 2.5.2 Adjustment to Basic Water Requirement
   - 2.5.3 Required Use of Admixtures
   - 2.5.4 Optional Use of Admixtures

2.6 ADJUSTED BASIC WATER REQUIREMENT AND WATER/CEMENT RATIO
   - 2.6.1 Water/Cement Ratio
2.7 AIR CONTENT ABSOLUTE VOLUME CALCULATION
   2.7.1 Air Content
   2.7.2 Minimum Air Content

2.8 FINE AND COARSE AGGREGATE ABSOLUTE VOLUMES CALCULATIONS
   2.8.1 Voids in Coarse Aggregate
   2.8.2 Mortar Factor
       2.8.2.1 General Concept
       2.8.2.2 Volume Fraction Concept
       2.8.2.3 Design Mortar Factor
   2.8. Coarse Aggregate Absolute Volume Calculation
   2.8.4 Fine Aggregate Absolute Volume Calculation
   2.8.5 Converting Aggregate Absolute Volume to Mass (Weight)

2.9 EXAMPLE PROBLEM
   2.9.1 Example Using Metric Units
   2.9.2 Example Using English Units

2.10 SUMMARY OF MIX DESIGN EQUATIONS

3.0 SPECIALTY MIXES (Page 34)
   3.1 HIGH-EARLY-STRENGTH CONCRETE MIXTURES
   3.2 OTHER MIXTURES

4.0 TERNARY CONCRETE MIX DESIGNS (Page 36)

5.0 MASS CONCRETE MIX DESIGNS (Page 37)

6.0 CONCRETE MIX DESIGN—TRIAL MIXTURE (Page 38)
   6.1 SLUMP
   6.2 STRENGTH
   6.3 PROCEDURE FOR TRIAL MIXTURE

7.0 DETERMINING THE CONCRETE MIX DESIGN TARGET STRENGTH (Page 43)

8.0 REQUIREMENTS FOR CONCRETE DURABILITY TEST DATA (Page 45)

9.0 DEPARTMENT CONCRETE MIX DESIGN VERIFICATION (Page 46)
   9.1 VERIFICATION BY THE ENGINEER
   9.2 TESTING PERFORMED BY THE ENGINEER
       9.2.1 Procedure for Trial Batch
           9.2.1.1 Verification of Trial Batch, Voids Test, and Durability Test Data
TABLE OF CONTENTS
(Continued)

Appendices

Appendix A  Special Provision for Concrete Mix Design – Department Provided (BDE)
Appendix B  PCC Mix Design Computer Printout and Instructions
            PCC Mix Design Software Tutorial (Version 2.3.5.1)
Appendix C  Illinois Test Procedure 306 – Voids Test of Coarse Aggregate for Concrete Mixtures
Appendix D  Workability
Appendix E  Aggregate Blending
Appendix F  Cement Aggregate Mixture II (CAM II)
Appendix G  Controlled Low-Strength Material (CLSM)
Appendix H  Stamped or Integrally Colored Concrete
Appendix I  Concrete Revetment Mats
Appendix J  Insertion Lining of Pipe Culverts (Grout)
Appendix K  Insertion Lining of Pipe Culverts (Cellular Concrete)
Appendix L  Class SI Concrete Between Precast Concrete Box Culverts
Appendix M  Pervious Concrete
Appendix N  Average and Standard Deviation
Appendix O  Special Provision for Portland Cement Concrete (BDE)
Appendix P  Alkali-Silica Reaction Mitigation Flow Chart
Appendix Q  Special Provision for Quality Control/Quality Assurance of Concrete Mixtures (BDE)
DEFINITIONS

Absolute Volume — The solid volume, excluding the voids between the particles. It is expressed as the ratio of the loose materials mass (weight), to the solid mass (weight) per volume, of the same material.

Absorption — The moisture content at which the saturated surface-dry condition occurs.

Alkali-Silica Reaction — The reaction of alkalies in cement with siliceous material in some aggregates. The reaction requires water and produces a gel which expands and cracks the concrete.

Blended Cement — A hydraulic cement which meets the requirements of AASHTO M 240 (ASTM C 595). The hydraulic cement consists of portland cement and one or more inorganic constituents.

Cement Aggregate Mixture II (CAM II) — A lean (low cement and finely divided mineral) concrete mixture for stabilized subbase.

Cement Factor — The number of kilograms of cement per cubic meter (metric). The number of pounds of cement per cubic yard (English). Cement factor is the same as cement content. Cement is packaged in bags of 42.6 kg (94 lb.) nominal weight.

Cementitious Material — A general term to indicate fly ash, ground granulated blast-furnace slag, microsilica, or high-reactivity metakaolin. However, the term is misleading because none of these materials have cementitious characteristics. The term may be used interchangeably with Finely Divided Mineral.

Chips — The aggregate particle size range between the 4.75 mm (No.4) and 12.5 mm (1/2 in.) sieves.

Coarse Aggregate — A gradation number CA 1-19 as defined by the Standard Specifications. For an aggregate blend, the coarse aggregate portion is normally considered to be all material retained on or above the 4.75 mm (No. 4) sieve.

Concrete — A mixture consisting of cement, water, and aggregates as a minimum. Admixtures and finely divided minerals may be added.

Consistency — The ability of freshly mixed concrete to flow. Consistency is measured by the slump test.

Controlled Low-Strength Material (CLSM) — A self-consolidating mortar mixture, which is typically used as a backfill.

Final Set — The point of time where the concrete is no longer plastic and finishing no longer can take place. This will typically occur 5 to 8 hours after batching the concrete.

Fine Aggregate — A gradation number FA 1-10, 20, and 21 as defined by the Standard Specifications. For an aggregate blend, the fine aggregate portion is normally considered to be all material passing the 4.75 mm (No. 4) sieve.
Finely Divided Mineral — A general term to indicate fly ash, ground granulated blast-furnace slag, microsilica, or high-reactivity metakaolin. The term may be used interchangeably with Cementitious Material.

Fineness Modulus — The Fineness Modulus (FM) is an index of the fineness of an aggregate. The higher the FM, the coarser the aggregate. The Fineness Modulus is used to estimate proportions of fine and coarse aggregate in concrete mixtures.

Fly Ash — The fine residue that results from the combustion of ground or powdered coal.

Gap Graded — Aggregates which have specific particle sizes omitted, or the specific particle sizes are minimal.

Ground Granulated Blast-Furnace (GGBF) Slag — The glassy granular material formed when molten blast-furnace slag is rapidly chilled, and then finely ground.

High-Reactivity Metakaolin (HRM) — A manufactured product formed by calcining purified kaolinite, at a specific temperature range.

Hundredweight (cwt) — A unit of measure equal to 100 pounds.

Initial Set — The point of time where the concrete begins to become firm. This will typically occur 2 to 4 hours after batching the concrete.

Maximum Size — The smallest sieve on which 100 percent of the aggregate sample particles pass.

Microsilica — The extremely fine by-product that results from the manufacture of silicon or silicon alloys.

Mix Design Target Strength — The average strength the concrete mix must attain to ensure the specified strength is met.

Mortar — The fine aggregate, cement, finely divided minerals, water, and air in a concrete mixture.

Mortar Factor — The volume of mortar per volume of dry rodded coarse aggregate.

Nominal Maximum Size — The largest sieve which retains any of the aggregate sample particles.

Oven-Dry Condition — The aggregates have been heated until completely dry. There is no free moisture on the surface of the individual aggregate particles. There is no absorbed moisture in the pores of the individual aggregate particles.

Oven-Dry Specific Gravity — The ratio of the mass (weight) of a volume of oven dry material, to the mass (weight) of an equal volume of water.

Paste — The cement, finely divided minerals, water, and air in a concrete mixture.

Plasticity — The ease of molding the concrete. A plastic concrete mixture will maintain suspension of the aggregates.
Pervious Concrete — A permeable concrete that allows water to infiltrate the concrete and drain into the soil beneath it. The zero slump concrete mixture has little or no fine aggregate.

Portland Cement — A hydraulic cement which meets the requirements of AASHTO M 85 (ASTM C 150).

Saturated Surface-Dry Condition — There is no free moisture on the surface of the individual aggregate particles. All possible moisture which can be absorbed into the pores of the individual aggregate particles has occurred.

Saturated Surface-Dry Specific Gravity — The ratio of the mass (weight) of a volume of saturated surface-dry material, to the mass (weight) of an equal volume of water.

Standard Specifications — The Standard Specifications for Road and Bridge Construction.

Supplementary Cementitious Material — See definition for Cementitious Material.

Ternary Mix Design — A mix design consisting of cement and two finely divided minerals. The finely divided mineral in portland-pozzolan cement or portland blast-furnace slag cement shall count as one of the two finely divided minerals allowed.

Trial Batch — A batch of concrete tested by the Engineer to verify the Contractor’s mix design will meet specification requirements.

Trial Mixture — A batch of concrete tested by the Contractor to verify the Contractor’s mix design will meet specification requirements.

Uniformly Graded — Aggregates which do not have a large deficiency or excess of any particle size.

Voids — The volume of voids per unit volume of dry rodded coarse aggregate. In other words, voids is the ratio of the volume of empty spaces in a unit volume of coarse aggregate to the unit volume of coarse aggregate.

Wash Water — Residual rinse water in the drum of a truck mixer or truck agitator.

Water/Cement Ratio — The mass (weight) of water, divided by the mass (weight) of cement. The water shall include mixing water, water in admixtures, free moisture on the aggregates, and water added at the job site.

When fly ash, ground granulated blast-furnace slag, microsilica, or high-reactivity metakaolin are used in a concrete mix, the water/cement ratio will be based on the total cement and finely divided minerals contained in the mixture.

Workability — A measure of how easy or difficult it is to place, consolidate, and finish concrete.

Yield — The volume of freshly mixed concrete from a known quantity of materials.
APPLICABLE SPECIFICATIONS

Standard Specifications for Road and Bridge Construction
The Level III PCC Technician shall be familiar with the following Sections or Articles of the January 1, 2012, Standard Specifications for Road and Bridge Construction.

- Article 285.05 Fabric Formed Concrete Revetment Mat
- Article 312.26 Proportioning (Cement Aggregate Mixture II)
- Article 540.06 Precast Concrete Box Culverts (Class SI Between Sections)
- Section 543 Insertion Lining of Pipe Culverts
- Section 1001 Cement
- Section 1003 Fine Aggregate
- Section 1004 Coarse Aggregate
- Section 1010 Finely Divided Minerals
- Section 1019 Controlled Low-Strength Material
- Section 1020 Portland Cement Concrete (Replaced by Special Provision)
- Section 1021 Concrete Admixtures

To view or download the Standard Specifications for Road and Bridge Construction on the Internet go to http://www.dot.il.gov/; Doing Business; Construction Guides; BDE Specifications/Special Provisions/Highway Standards. In addition to the Standard Specifications, it is important for the Level III PCC Technician to be familiar with the Supplemental Specifications and Recurring Special Provisions document and the Bureau of Design and Environment (BDE) Special Provisions. They are also found under BDE Specifications/Special Provisions/Highway Standards and may be downloaded. The Supplemental Specifications are a supplement to the Standard Specifications. The Recurring Special Provisions are frequently included by reference, in selected contracts. The BDE Special Provisions are frequently included, by insertion, in selected contracts.

Guide Bridge Special Provisions
The Level III PCC Technician shall also be familiar with the following Guide Bridge Special Provisions (GBSP).

- Deck Slab Repair
- Bridge Deck Microsilica Concrete Overlay
- Bridge Deck Latex Concrete Overlay
- Bridge Deck High-Reactivity Metakaolin (HRM) Concrete Overlay
- Concrete Wearing Surface
- High Performance Concrete Structures
- Structural Repair of Concrete
- Bridge Deck Fly Ash or Ground Granulated Blast-Furnace Slag Overlay

To view or download the GBSP, go to http://www.dot.il.gov/; Doing Business; Construction Guides; Guide Bridge Special Provisions (GBSP). The GBSP are frequently included, by insertion, in selected contracts.
# CLASS OF CONCRETE

<table>
<thead>
<tr>
<th>Class Designation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>Pavement</td>
</tr>
<tr>
<td>PP</td>
<td>PCC Patching</td>
</tr>
<tr>
<td>RR</td>
<td>Railroad Crossing</td>
</tr>
<tr>
<td>BS</td>
<td>Bridge Superstructure</td>
</tr>
<tr>
<td>PC</td>
<td>Various Precast Concrete Items</td>
</tr>
<tr>
<td>PS</td>
<td>Various Precast Prestressed Items</td>
</tr>
<tr>
<td>DS</td>
<td>Drilled Shaft</td>
</tr>
<tr>
<td>SC</td>
<td>Seal Coat</td>
</tr>
<tr>
<td>SI</td>
<td>Structures (except superstructure)</td>
</tr>
</tbody>
</table>

Refer to Article 1020.04 for additional information.
## UNITS OF MEASURE CONVERSION

<table>
<thead>
<tr>
<th>Conversion</th>
<th>From English</th>
<th>To Metric</th>
<th>Multiply Quantity by*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LENGTH</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>inch (in.)</td>
<td>millimeter (mm)</td>
<td>25.4</td>
<td></td>
</tr>
<tr>
<td>foot (ft)</td>
<td>millimeter (mm)</td>
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</tr>
<tr>
<td>foot (ft)</td>
<td>meter (m)</td>
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</tr>
<tr>
<td>yard (yd)</td>
<td>meter (m)</td>
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<tr>
<td><strong>AREA</strong></td>
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</tr>
<tr>
<td>square inch (in.²)</td>
<td>square mm (mm²)</td>
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</tr>
<tr>
<td>square foot (ft²)</td>
<td>square meter (m²)</td>
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</tr>
<tr>
<td>square yard (yd²)</td>
<td>square meter (m²)</td>
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<td><strong>VOLUME</strong></td>
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<tr>
<td>cubic inch (in.³)</td>
<td>cubic mm (mm³)</td>
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</tr>
<tr>
<td>cubic foot (ft³)</td>
<td>cubic meter (m³)</td>
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</tr>
<tr>
<td>cubic yard (yd³)</td>
<td>cubic meter (m³)</td>
<td>0.764555</td>
<td></td>
</tr>
<tr>
<td>gallon (gal)</td>
<td>liter (L)</td>
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<td><strong>MASS</strong></td>
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</tr>
<tr>
<td>ounces (oz.)</td>
<td>grams (g)</td>
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</tr>
<tr>
<td>pound (lb.)</td>
<td>kilogram (kg)</td>
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<td><strong>FORCE</strong></td>
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</tr>
<tr>
<td>pound (lb.)</td>
<td>Newton (N)</td>
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<tr>
<td><strong>MASS/AREA</strong></td>
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<td></td>
</tr>
<tr>
<td>oz./yd²</td>
<td>kg/m²</td>
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</tr>
<tr>
<td>lb./ft²</td>
<td>kg/m²</td>
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<tr>
<td>lb./yd²</td>
<td>kg/m²</td>
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<tr>
<td><strong>MASS/VOLUME</strong></td>
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<td>lb./ft³</td>
<td>kg/m³</td>
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</tr>
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<td>lb./yd³</td>
<td>kg/m³</td>
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</tr>
<tr>
<td><strong>TEMPERATURE</strong></td>
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<tr>
<td>English to Metric:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>°C = (°F - 32) / 1.8</td>
<td></td>
<td>Metric to English:  °F=1.8°C+32</td>
<td></td>
</tr>
</tbody>
</table>

* To convert from metric to English, divide metric quantity by value given in table. For example, 380 mm equals 15.0 in. (380 ÷ 25.4 = 14.96).
SIGNIFICANT DIGITS AND ROUNDEDING

Significant Digits:

Whole Number: Cement, Finely Divided Minerals, Coarse and Fine Aggregate, Batch Water

One Digit to Right of Decimal: Basic Water Requirement (English), Air Content

Two Digits to Right of Decimal: Specific Gravity, Unit Weight, Water/Cement Ratio,
                                Basic Water Requirement (Metric), Mortar Factor, Voids

Three Digits to Right of Decimal: Absolute Volume

Rounding:

When the digit beyond the last place to be retained (or reported) is equal to or greater than 5,
increase by 1 the digit in the last place retained.
# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>ACI</td>
<td>American Concrete Institute</td>
</tr>
<tr>
<td>ASR</td>
<td>Alkali-Silica Reaction</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>BDE</td>
<td>Bureau of Design and Environment</td>
</tr>
<tr>
<td>CA</td>
<td>Coarse Aggregate</td>
</tr>
<tr>
<td>CAM II</td>
<td>Cement Aggregate Mixture II</td>
</tr>
<tr>
<td>CCRL</td>
<td>Cement and Concrete Reference Laboratory</td>
</tr>
<tr>
<td>CLSM</td>
<td>Controlled Low-Strength Material</td>
</tr>
<tr>
<td>DEF</td>
<td>Delayed Ettringite Formation</td>
</tr>
<tr>
<td>DOT</td>
<td>Department of Transportation</td>
</tr>
<tr>
<td>FA</td>
<td>Fine Aggregate</td>
</tr>
<tr>
<td>FM</td>
<td>Fineness Modulus</td>
</tr>
<tr>
<td>FDM</td>
<td>Finely Divided Mineral</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>GBSP</td>
<td>Guide Bridge Special Provision</td>
</tr>
<tr>
<td>GGBF Slag</td>
<td>Ground Granulated Blast-Furnace Slag</td>
</tr>
<tr>
<td>HRM</td>
<td>High-Reactivity Metakaolin</td>
</tr>
<tr>
<td>MISTIC</td>
<td>Materials Integrated System for Test Information and Communication</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>PCA</td>
<td>Portland Cement Association</td>
</tr>
<tr>
<td>PCC</td>
<td>Portland Cement Concrete</td>
</tr>
<tr>
<td>QC/QA</td>
<td>Quality Control/Quality Assurance</td>
</tr>
<tr>
<td>SSD</td>
<td>Saturated Surface-Dry</td>
</tr>
</tbody>
</table>
1.0 MIX DESIGN OVERVIEW

1.1 VOLUMETRIC MIX DESIGN AND MIX DESIGN SUBMITTAL

Volumetric mix design is a proportioning method that produces an exact volume of concrete, commonly 1 cubic yard (1 cubic meter). Among these are methods published by the American Concrete Institute (ACI) and the Department. The mix design methods are based upon previously established properties of the materials and the intended use of the concrete. The original design criteria for the Department’s method can be found in the University of Illinois Engineering Experiment Station Bulletin No. 137, which was published in October, 1923. The document is entitled “The Strength of Concrete and Its Relation to the Cement Aggregates and Water” by Arthur N. Talbot and Frank E. Richart.

The requirements for providing a mix design are specified in Article 1020.05. This Article states, “For all Classes of concrete, it shall be the Contractor’s responsibility to determine mix design material proportions and to proportion each batch of concrete. A Level III PCC Technician shall develop the mix design for all Classes of concrete, except Classes PC and PS”. However, refer to Appendix A for a special provision that allows a District to provide a mix design. The special provision is intended to facilitate the eventual end to the Department providing mix designs. The special provision only applies when it is inserted into a contract.

The Contractor mix design submittal shall include the following: date, Class or type of concrete, source of materials, fine aggregate Type (a classification provided by Department’s District office that is related to water demand), gradation of fine and coarse aggregates, coarse aggregate voids (determined by the Contractor, unless provided by the District), specific gravities (provided by Department’s District office), material proportions (batch weights or mass), water/cement ratio, mortar factor, type and proposed dosage of admixtures, target slump, target air content, and mix design strength. The submittal of trial mixture and target strength information is recommended. For submittal of durability test data, refer to 8.0 “Requirements for Concrete Durability Test Data.”

For self-consolidating concrete, the submittal is the same except target slump flow (instead of slump), and target J-ring value or L-box blocking ratio are required.

Once the Engineer verifies the Contractor’s mix design according to 9.0 "Department Concrete Mix Design Verification", the mix design information will be entered into the Department’s Materials Integrated System for Test Information and Communication (MISTIC) database. The Contractor will be provided a printout of the mix design from MISTIC, which will include the Department’s mix design number. Refer to Appendix B for a copy of the printout and input instructions.

During construction, changes may occur which will affect the mix design. The following items will require a mix design to be re-submitted and verified by the Engineer:

- Voids of the coarse aggregate change more than 0.02 from the original mix design.
- Specific gravity of an aggregate changes more than 0.02 from the original mix design.
• Specific gravity of the cement or a finely divided mineral changes more than 0.04 from the original mix design.
• Mortar factor is changed more than 0.05 from the original mix design. The value shall not exceed specified limits.
• Water/cement ratio is increased more than 0.04 from the original mix design. The value shall not exceed specified limits.
• A change in materials.

1.2 MIX DESIGN SOFTWARE

1.2.1 Department Software

An Excel spreadsheet, “PCC Mix Design,” is available from the Department's internet site to facilitate the calculation and submittal of a PCC mix design using the IDOT method. To download the program, go to http://www.dot.il.gov/; Doing Business; Materials; Guides, Manuals, Mistic Reports & Miscellaneous Information.

1.2.2 Available Software Applications

For those individuals who want to expand their mix design knowledge, the following websites have useful information.

• COST, developed by the Federal highway Administration (FHWA) and the National Institute of Standards and Technology (NIST).

The website is http://ciks.cbt.nist.gov/cost/.

COST (Concrete Optimization Software Tool) is an online design/analysis system to assist in determining optimal mixture proportions for concrete.

• COMPASS, developed by The Transtec Group, Inc. through funding from FHWA.

The website is http://www.pccmix.com/.

COMPASS (Concrete Mixture Performance Analysis System Software) grew out of the web-based application tool COST. COMPASS has two key components, a knowledge base and a set of four computer modules. The knowledge base supplies information on concrete properties, testing methods, and material characteristics and compatibilities. The computer modules allow the user to define inputs such as importance of the project, type of pavement, climatic conditions, construction constraints, environmental exposures, and criteria (such as strength, cost, and permeability) that are specific to the project.

• ConcreteWorks developed at the Concrete Durability Center at the University of Texas as part of research funded by the Texas Department of Transportation.

The website is http://www.texasconcreteworks.com/.
The ConcreteWorks software includes ConcreteWorks and MixProportions. The ConcreteWorks program can calculate mass concrete temperature development. The MixProportions is a concrete mixture proportioning program based on the recommendations of ACI 211.

- **seeMIX, developed by The Shilstone Companies.**

  The website is [http://www.shilstone.com/software.htm](http://www.shilstone.com/software.htm).

  seeMIX is for concrete mixture design, analysis, proportioning and adjustments. Additional software is available at the website, which includes seeSTAT, seeMAT-A, seeMAT-C and seeMAT-P.

  seeSTAT is for concrete test results record-keeping and statistical analysis. seeMAT-A is for aggregate test results record-keeping, statistics and blending. seeMAT-C and seeMAT-P is for cement and pozzalan test results record-keeping and statistics.

  The above software applications are not to replace the Department’s software, but may be used to improve the Department’s mix design.
2.0 CONCRETE MIX DESIGN DEVELOPMENT USING IDOT METHOD

2.1 INTRODUCTION – ABSOLUTE VOLUME

The basic materials required for concrete are cement, finely divided minerals, fine and coarse aggregates, water, and entrained air. Concrete meeting the requirements of strength and durability will demand accurate proportioning of these basic materials.

The Department's mix design method is based on a volume of 1 cubic yard (1 cubic meter) of concrete. Therefore, the basis of concrete proportioning is determining the absolute volume of the component materials. Refer to the Portland Cement Concrete Level II Technician Course manual for additional information on volumetric proportioning.

Absolute volume is defined as the solid volume, excluding the voids between the particles. Therefore, 1 cubic yard (1 cubic meter) of concrete is the sum of the absolute volumes of all the materials.

2.2 CEMENT FACTOR

Through years of laboratory experimentation and field experience, the Department has determined the approximate amount of cement needed to meet durability requirements after construction. The cement factor is obtained from 2.2.1 “Cement Factor for Class or Type of Concrete.” The cement factor may be reduced based on the type of admixture used, refer to 2.2.2 “Allowable Cement Factor Reduction – Admixture.”

Note: For the various Classes of concrete, the portland cement content in the mixture shall be a minimum of 375 lbs/cu yd (222 kg/cu m). When the cement's total organic additions, inorganic additions, and limestone exceeds 5.0 percent, the minimum portland cement content in the mixture shall be 400 lbs/cu yd (237 kg/cu m). Refer to Article 1020.04 for additional information.

2.2.1 Cement Factor for Class or Type of Concrete

Refer to Table 2.2.1 for the required cement factor when using portland cement, portland-pozzolan cement, or portland blast-furnace slag cement.

2.2.2 Allowable Cement Factor Reduction – Admixture

For Class PV, PP-1, RR, SC, and SI concrete, a water-reducing admixture or a high range water-reducing admixture may reduce the cement factor a maximum 0.30 cwt/yd$^3$ (18 kg/m$^3$). However, a cement factor reduction will not be allowed for concrete placed underwater.
<table>
<thead>
<tr>
<th>Class or Type of Concrete</th>
<th>Minimum Cement Factor cwt/yd³ (kg/m³)</th>
<th>Maximum Cement Factor cwt/yd³ (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>5.65 (335)¹,²</td>
<td>7.05 (418)</td>
</tr>
<tr>
<td></td>
<td>6.05 (360)¹,³</td>
<td></td>
</tr>
<tr>
<td>PP-1</td>
<td>6.50 (385)¹</td>
<td>7.50 (445)</td>
</tr>
<tr>
<td></td>
<td>6.20 (365)¹,⁴</td>
<td>7.20 (425)⁴</td>
</tr>
<tr>
<td>PP-2</td>
<td>7.35 (435)</td>
<td>7.35 (435)</td>
</tr>
<tr>
<td>PP-3</td>
<td>7.35 (435)⁵</td>
<td>7.35 (435)⁵</td>
</tr>
<tr>
<td>PP-4</td>
<td>6.00 (355)⁶</td>
<td>6.25 (370)⁶</td>
</tr>
<tr>
<td>PP-5</td>
<td>6.75 (400)⁶</td>
<td>6.75 (400)⁶</td>
</tr>
<tr>
<td>RR</td>
<td>6.50 (385)¹</td>
<td>7.50 (445)</td>
</tr>
<tr>
<td></td>
<td>6.20 (365)¹,⁴</td>
<td>7.20 (425)⁴</td>
</tr>
<tr>
<td>BS</td>
<td>6.05 (360)</td>
<td>7.05 (418)</td>
</tr>
<tr>
<td>PC</td>
<td>5.65 (335)</td>
<td>7.05 (418)</td>
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<tr>
<td>PS</td>
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<td>DS</td>
<td>6.65 (395)</td>
<td>7.05 (418)</td>
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<tr>
<td>SC⁸</td>
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<td>7.05 (418)</td>
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<td></td>
<td>6.05 (360)¹,³</td>
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<td>SI</td>
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<td></td>
<td>6.05 (360)¹,³</td>
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</tr>
</tbody>
</table>

Deck Slab Repair Refer to PP-1, 2, 3, 4, and 5 Refer to PP-1, 2, 3, 4, and 5

Formed Concrete Repair Refer to Class BS Concrete Refer to Class BS Concrete

Concrete Wearing Surface Refer to Class BS Concrete Refer to Class BS Concrete

Bridge Deck Fly Ash or Ground Granulated Blast-Furnace Slag Concrete Overlay⁹ Refer to Class BS Concrete Refer to Class BS Concrete

Bridge Deck Microsilica Concrete Overlay¹⁰ 5.65 (335) 5.65 (335)

Bridge Deck High-Reactivity Metakaolin Concrete Overlay¹¹ 5.65 (335) 5.65 (335)

Bridge Deck Latex Concrete Overlay¹² 6.58 (390) 6.58 (390)

High Performance Concrete Structures 4.45 (264)¹³ 4.45 (264)¹³
                                      5.45 (323)¹⁴ 5.45 (323)¹⁴
### Table 2.2.1 Notes

1. Refer to 2.2.2 “Allowable Cement Factor Reduction – Admixture” for allowable cement factor reduction.
2. Central-mixed.
3. Truck-mixed or shrink-mixed.
4. Type III cement.
5. In addition to the Type III portland cement, 100 lb/yd$^3$ (60 kg/m$^3$) of ground granulated blast-furnace slag and 50 lb/yd$^3$ (30 kg/m$^3$) of microsilica (silica fume) shall be used. For an air temperature greater than 85 °F (30 °C), the Type III portland cement may be replaced with Type I or II cement.
6. The cement shall be a rapid hardening cement from the Department’s “Approved List of Packaged, Dry, Rapid Hardening, Cementitious Materials for Concrete Repair” for PP-4.
7. The cement shall be calcium aluminate cement for PP-5.
8. For Class SC concrete and for any class of concrete that is to be placed under water, except Class DS concrete, the cement factor shall be increased by ten percent.
9. The portland cement shall be replaced with 25 percent Class F fly ash, or 25-30 percent Class C fly ash, or 25-35 percent ground granulated blast-furnace slag.
10. In addition to the cement, 33 lb/yd$^3$ (20 kg/m$^3$) of microsilica is required in the mix design.
11. In addition to the cement, 37 lb/yd$^3$ (22 kg/m$^3$) of high-reactivity metakaolin is required in the mix design.
12. In addition to the cement, 24.5 gallons (121.3 liters) of latex admixture is required in the mix design.
13. First Option:
   In addition to the cement, 90 lb/yd$^3$ (53 kg/m$^3$) of Class C fly ash and 25 lb/yd$^3$ (15 kg/m$^3$) of microsilica are required in the mix design. The microsilica may be replaced with 27 lb/yd$^3$ (16 kg/m$^3$) of high-reactivity metakaolin.
   Second Option:
   In addition to the cement, 90 lb/yd$^3$ (53 kg/m$^3$) of ground granulated blast-furnace slag and 25 lb/yd$^3$ (15 kg/m$^3$) of microsilica are required in the mix design. The microsilica may be replaced with 27 lb/yd$^3$ (16 kg/m$^3$) of high-reactivity metakaolin.
14. In addition to the cement, either 25 lb/yd$^3$ (15 kg/m$^3$) of microsilica or 27 lb/yd$^3$ (16 kg/m$^3$) of high-reactivity metakaolin are required in the mix design.
2.3 CEMENT ABSOLUTE VOLUME CALCULATION

Cement is measured in hundredweights (kilograms). The number of hundredweights used per 1 cubic yard (kilograms per 1 cubic meter) of concrete is the cement factor. Using the cement factor, the absolute volume of the cement can be determined as follows:

**English:**

The absolute volume of cement per cubic yard of concrete

\[ \text{absolute volume of cement} = \frac{\text{weight of cement}}{\text{specific gravity of cement} \times \text{unit weight of water}} \]

The “weight of cement” is provided by the cement factor in hundredweights per cubic yard. To calculate absolute volume, convert the cement factor to pounds per cubic yard by multiplying hundredweights by 100. The “specific gravity of cement” is normally assumed to be 3.15, but the actual value may be used. The “unit weight of water” is 1,683.99 pounds per cubic yard.

**Metric:**

The absolute volume of cement per cubic meter of concrete

\[ \text{absolute volume of cement} = \frac{\text{mass of cement}}{\text{specific gravity of cement} \times \text{unit weight of water}} \]

The “mass of cement” is provided by the cement factor in kilograms per cubic meter. The “specific gravity of cement” is assumed to be 3.15, but the actual value may be used. The “unit weight of water” is 1,000.00 kilograms per cubic meter.

However, be advised that blended cement may have a specific gravity which is significantly different from 3.15, and this value should be verified with the District. If the specific gravity of the cement changes more than 0.04 from the original mix design value, a new mix design will be required.

2.4 FINELY DIVIDED MINERALS ABSOLUTE VOLUME CALCULATION

A portion of cement may be replaced with finely divided minerals. The replacement is commonly done for economic reasons, to mitigate for alkali-silica reaction, and to lower the heat of hydration. In other instances, finely divided minerals may be used to lower the concrete’s permeability, which will slow down chloride penetration.

Finely divided minerals (FDMs) are measured in pounds (kilograms). The absolute volume of a finely divided mineral is determined as follows:

**English:**

The absolute volume of a finely divided mineral per cubic yard of concrete

\[ \text{absolute volume of FDM} = \frac{\text{weight of FDM}}{\text{specific gravity of FDM} \times \text{unit weight of water}} \]

The “weight of FDM” is provided in pounds per cubic yard. The “unit weight of water” is 1,683.99 pounds per cubic yard.

**Metric:**

The absolute volume of a finely divided mineral per cubic meter of concrete

\[ \text{absolute volume of FDM} = \frac{\text{mass of FDM}}{\text{specific gravity of FDM} \times \text{unit weight of water}} \]

The “mass of FDM” is provided in kilograms per cubic meter. The “unit weight of water” is 1,000.00 kilograms per cubic meter.
The specific gravity of a finely divided mineral is obtained from the “Approved List of Suppliers for Finely Divided Minerals.” It is found under the “Average Specific Gravity” column. To view or download this list on the Internet, go to http://www.dot.il.gov; Doing Business; Materials; Approved Lists for Materials. If the specific gravity of a finely divided mineral changes more than 0.04 from the original mix design value, a new mix design will be required.

For Class PP-3 concrete, bridge deck fly ash or ground granulated blast-furnace slag overlay, bridge deck microsilica overlay, bridge deck high-reactivity metakaolin overlay, and high performance concrete structures, refer to 2.2.1 “Cement Factor for Class or Type of Concrete” for additional information regarding required use of finely divided minerals.

2.4.1 Cement Replacement with Finely Divided Minerals and The Optional Use of Microsilica and High Reactivity Metakaolin (HRM)

2.4.1.1 Fly Ash

The following information is according to Article 1020.05(c)(1).

Fly ash may partially replace portland cement in cement aggregate mixture II, Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete.

When Class F fly ash is used in cement aggregate mixture II, Class PV, BS, PC, PS, DS, SC, and SI concrete, the amount of cement replaced shall not exceed 25 percent by weight (mass).

When Class C fly ash is used in cement aggregate mixture II, Class PV, PP-1, PP-2, RR BS, PC,PS, DS, SC, and SI concrete, the amount of cement replaced shall not exceed 30 percent by weight (mass). Measurements of fly ash and cement shall be rounded up the nearest 5 lb/yd³ (2.5 kg/m³).

The following information is according to the applicable Guide Bridge Special Provisions (GBSP).

For bridge deck microsilica and high-reactivity metakaolin concrete overlays, only Class C fly ash may be used to replace portland cement. The amount of cement replaced shall not exceed 30 percent by weight (mass). For bridge deck fly ash or ground granulated blast-furnace slag concrete overlay, the portland cement content selected for the Class BS concrete shall be replaced with 25 percent Class F fly ash or 25 – 30 percent Class C fly ash.

2.4.1.2 Ground Granulated Blast-Furnace Slag

The following information is according to Article 1020.05(c)(2).

Ground granulated blast-furnace (GGBF) slag may partially replace portland cement in Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete. For Class PP-3 concrete, GGBF slag shall used according to Article 1020.04.
When GGBF slag is used in Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete, the amount of cement replaced by GGBF slag shall not exceed 35 percent by weight (mass).

Measurements of GGBF slag and cement shall be rounded up to the nearest 5 lb/ yd³ (2.5 kg/m³).

The following information is according to the applicable Guide Bridge Special Provisions (GBSP).

For bridge deck microsilica and high-reactivity metakaolin concrete overlays, the portland cement may be replaced with GGBF slag. The replacement shall not result in a mixture with cement content below the minimum specified in Article 1020.04. For bridge deck fly ash or ground granulated blast-furnace slag concrete overlay, the portland cement content selected for the Class BS concrete shall be replaced with 25 – 35 percent GGBF slag.

2.4.1.3 Microsilica

According to Article 1020.05(b)(3), at the Contractor’s option, microsilica may be added at a maximum 5.0 percent by weight (mass) of the cement and finely divided minerals summed together.

2.4.1.4 High Reactivity Metakaolin (HRM)

According to Article 1020.05(b)(4), at the Contractor’s option, HRM may be added at a maximum 5.0 percent by weight (mass) of the cement and finely divided minerals summed together.

2.4.2 Use of Finely Divided Minerals in Ternary Concrete Mix Designs

Refer to Appendix O for allowable use of finely divided minerals in ternary mix designs.

2.4.3 Mitigation of Alkali-Silica Reaction with Finely Divided Minerals

Alkali-silica reaction (ASR) is the reaction of alkalies in cement with siliceous material in some aggregates. The reaction requires water and produces a gel which expands and cracks the concrete. Refer to Appendix O for required use of finely divided minerals to mitigate alkali-silica reaction. Also, refer to Appendix P for the alkali-silica reaction specification flow chart.

2.4.4 Use of Finely Divided Minerals in Mass Concrete

Refer to Appendix O for use of finely divided minerals to reduce heat of hydration in massive structures.

2.5 WATER ABSOLUTE VOLUME CALCULATION

The Basic Water Requirement is measured in gallons per hundredweights (liters per kilograms) of total cement and finely divided minerals materials. The absolute volume of water is determined as follows:
**English:**

The absolute volume of water per cubic yard of concrete

\[ \text{weight of water} \div [\text{specific gravity of water} \times \text{unit weight of water}] \]

The “weight of water” is provided in pounds per cubic yard. One gallon of water equals 8.33 pounds. The “specific gravity of water” is 1.00. The “unit weight of water” is 1,683.99 pounds per cubic yard.

**Metric:**

The absolute volume of water per cubic meter of concrete

\[ \text{mass of water} \div [\text{specific gravity of water} \times \text{unit weight of water}] \]

The “mass of water” is provided in kilograms per cubic meter. One liter of water equals 1 kilogram. The “specific gravity of water” is 1.00. The “unit weight of water” is 1,000.00 kilograms per cubic meter.

2.5.1 Basic Water Requirement

Since the amount of cement and finely divided minerals used in concrete is specified for the various types of construction, the amount of water used is the most important variable of the design.

The Department determines the basic water requirement, and the resulting water/cement ratio, by the angularity of the aggregates. As the angularity of the particles increases, the amount of water required in the concrete increases.

2.5.1.1 Fine Aggregate Basic Water Requirement

For fine aggregate, the Department mix design method determines the basic water requirement and resulting water/cement ratio, by the classification (type) assigned to the fine aggregate. For fine aggregate angularity, the Department will classify it as a Type A, B, or C, according to the Illinois Method for Fine Aggregate Classification. A “Type A” fine aggregate is composed completely of rounded particles. A “Type C” fine aggregate is composed completely of angular particles. A “Type B” fine aggregate is composed of a mixture of rounded and angular particles. Therefore, a Type A fine aggregate has the least water demand, and a Type C fine aggregate has the highest water demand. This information is summarized as follows:

<table>
<thead>
<tr>
<th>FA Type</th>
<th>Basic Water Requirement for Cement* and Finely Divided Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.1 gal/cwt (0.42 L/kg)</td>
</tr>
<tr>
<td>B</td>
<td>5.3 gal/cwt (0.44 L/kg)</td>
</tr>
<tr>
<td>C</td>
<td>5.5 gal/cwt (0.46 L/kg)</td>
</tr>
</tbody>
</table>

*In MISTIC, A = 0.426 L/kg, B = 0.442 L/kg, and C = 0.459 L/kg.

If the mix design involves the blending of fine aggregates which are not the same Type, select the highest water requirement. The fine aggregate classification as a Type A, B, or C will be provided by the Department’s District office.
2.5.1.2 Coarse Aggregate Basic Water Requirement

For coarse aggregate, the Department mix design method determines the basic water requirement and resulting water/cement ratio, by the angularity of the coarse aggregate. For example, crushed aggregate will have a greater water demand than rounded aggregate. This is due to a greater surface area. Also, aggregate particles which are flat and elongated will increase water demand because of the greater surface area than a cubical particle. If necessary, Illinois Test Procedure 4791 is a test which can be used to determine the percentage of flat and elongated particles.

The Department allows an additional 0.1 to 0.4 gal/cwt (0.008 to 0.033 L/kg) for the coarse aggregate. The value is determined from experience, but 0 gal/cwt (0 L/kg) is commonly used for rounded gravel, and 0.2 gal/cwt (0.017 L/kg) is commonly used for crushed gravel and stone. For a lightweight slag aggregate, 0.4 gal/cwt (0.033 L/kg) is commonly used. Contact the Department’s District office if you have any questions.

2.5.1.3 Basic Water Requirement Total

For the Department’s mix design method, the basic water requirement total is the summation of the water required for the fine and coarse aggregate. An example calculation for determining basic water requirement is as follows:

Given:  Fine Aggregate: Type B
        Coarse Aggregate: Crushed Stone

Calculations:

\[
\text{English:} \quad \text{Basic Water Requirement Total} = 5.3_{FA} + 0.2_{CA} \\
= 5.5 \text{ gallons/cwt of cement and finely divided minerals}
\]

\[
\text{Metric:} \quad \text{Basic Water Requirement Total} = 0.44_{FA} + 0.017_{CA} \\
= 0.46 \text{ liter/kg of cement and finely divided minerals}
\]

2.5.2 Adjustment to Basic WaterRequirement

For the Department’s mix design method, Table 2.5.2 is used to adjust the basic water requirement. An example calculation for adjusting the basic water requirement is as follows:

Given: A water-reducing admixture is used, and the water content reduction is assumed to be 10 percent. The basic water requirement is 5.5 gal/cwt (0.46 L/kg) of cement and finely divided minerals for the IDOT method.

Calculations:

\[
\text{English:} \quad \text{Adjusted Basic Water Requirement} = 5.5 - (5.5 \times 0.10) \\
= 5.0 \text{ gal/cwt of cement and finely divided minerals}
\]
**Metric:**

Adjusted Basic Water Requirement

\[
= 0.46 - (0.46 \times 0.10) \\
= 0.41 \text{ L/kg of cement and finely divided minerals}
\]

If a significant amount of admixtures (includes latex) are being used, the Contractor shall take this into account when checking the water/cement ratio. Refer to 2.6 "Adjusted Basic Water Requirement and Water/Cement Ratio" for additional information.

### Table 2.5.2 Adjustment to Basic Water Requirement

<table>
<thead>
<tr>
<th>Water Adjustment</th>
<th>Suggested Range</th>
<th>Adjustment Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate shape and texture:</strong> (Note 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (cubical crushed stone)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rounded, smooth</td>
<td>(0%)</td>
<td></td>
</tr>
<tr>
<td>Flat, elongated, rough</td>
<td>(-5 to 0%)</td>
<td></td>
</tr>
<tr>
<td>(-10 to 0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat, elongated, rough</td>
<td>(0 to +5%)</td>
<td></td>
</tr>
<tr>
<td><strong>Combined aggregate grading:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well-graded</td>
<td>(-10 to 0%)</td>
<td></td>
</tr>
<tr>
<td>Gap-graded</td>
<td>(0 to +10%)</td>
<td></td>
</tr>
<tr>
<td><strong>Admixture(s):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air-entraining admixture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 3% air content</td>
<td>(0%)</td>
<td></td>
</tr>
<tr>
<td>4 to 5% air content</td>
<td>(-5%)</td>
<td></td>
</tr>
<tr>
<td>6 to 10% air content</td>
<td>(-10%)</td>
<td></td>
</tr>
<tr>
<td><strong>Normal range water-reducing admixture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-range water-reducing admixture</td>
<td>(-10 to -5%)</td>
<td></td>
</tr>
<tr>
<td>High range water-reducing admixture (superplasticizer) (Note 2)</td>
<td>(-15 to -8%)</td>
<td></td>
</tr>
<tr>
<td>High-Reactivity Metakaolin (HRM)</td>
<td>(-30 to -12%)</td>
<td></td>
</tr>
<tr>
<td><strong>Finely Divided Minerals:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fly Ash (Note 3)</td>
<td>(-10 to 0%)</td>
<td></td>
</tr>
<tr>
<td>Microsilica</td>
<td>(0 to +15%)</td>
<td></td>
</tr>
<tr>
<td>High-Reactivity Metakaolin (HRM)</td>
<td>(-5 to +5%)</td>
<td></td>
</tr>
<tr>
<td>Ground Granulated Blast-Furnace (GGBF) Slag</td>
<td>(0%)</td>
<td></td>
</tr>
<tr>
<td><strong>Other factors:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse cement, water/cement ratio &gt;0.45, concrete temperature &lt;60 °F (15 °C)</td>
<td>(-10 to 0%)</td>
<td></td>
</tr>
<tr>
<td>Fine cement, water/cement ratio &lt;0.40, concrete temperature &gt;80 °F (27 °C)</td>
<td>(0 to +10%)</td>
<td></td>
</tr>
</tbody>
</table>

Enter the sum of the adjustment percentages. The suggested maximum water reduction recognizing overlapping effects of individual factors is -30%. The required minimum water/cement ratio also needs to be considered.

**Notes:**

1. For aggregate shape and texture; it is recommended to make the adjustment as described in 2.5.1.2 “Coarse Aggregate Water Requirement” and 2.5.1.3 “Basic Water Requirement.”
2. A polycarboxylate high range water-reducing admixture may be able to reduce the water content up to 40%.
3. For each 10% of fly ash in the total cementitious, it is recommended to allow a water reduction of at least 3%.
2.5.3 Required Use of Admixtures

To view or download the Approved List of Air-Entraining Admixtures for Controlled Low-Strength Material (CLSM), Approved List of Concrete Admixtures, and Approved List of Corrosion Inhibitors on the Internet, go to http://www.dot.il.gov/; Doing Business; Materials; Approved Lists for Materials. The following information on admixtures is found in Article 1020.05(b).

Air-Entraining Admixture
Except for Class SC concrete (air entrainment optional) and bridge deck latex concrete overlay, all concrete and cement aggregate mixture II shall contain entrained air. Normally, an air-entraining admixture is used in lieu of air-entraining cement. For CLSM, based on the mix design selected, an air-entraining admixture may be required.

Retarding Admixture\(^1\)
When the atmospheric or concrete temperature is 65 °F (18 °C) or higher, a retarding admixture shall be used for Class BS concrete and concrete bridge deck overlays. For Class PP-4 concrete, a retarding admixture shall be used for stationary or truck-mixed concrete. For Class DS concrete, a retarding admixture shall be used. In addition for Class DS concrete, the concrete mixture shall be designed to remain fluid throughout the anticipated duration of the pour plus one hour.

Water-Reducing Admixture\(^1\)
A water-reducing admixture shall be used for cement aggregate mixture II. If Class C fly ash or ground granulated blast-furnace slag is used in Class PP-1 or RR concrete, a water-reducing or high range water-reducing admixture shall be used. For Class DS concrete involving dry excavations 10 ft (3 m) or less, a high range water-reducing admixture may be replaced with a water-reducing admixture if the concrete is vibrated.

High Range Water-Reducing Admixture (Superplasticizer)\(^1\)
A superplasticizer shall be used for Class PP-2, PP-3, PP-4, PP-5 concrete, formed concrete repair, a bridge deck, a concrete wearing surface, a bridge deck fly ash or ground granulated blast-furnace slag overlay, a bridge deck microsilica concrete overlay, or a bridge deck high-reactivity metakaolin concrete overlay. If Class C fly ash or ground granulated blast-furnace slag is used in Class PP-1 or RR concrete, a water-reducing admixture or superplasticizer shall be used. A superplasticizer shall be used for Class DS concrete, except a water-reducing admixture may be used as discussed in the previous paragraph.

Accelerating Admixture
A non-chloride accelerating admixture shall be used for Class PP-2, PP-3, and PP-5 concrete. For Class PP-2 concrete, the non-chloride accelerating admixture shall be calcium nitrite when the air temperature is less than 55 °F (13 °C). For Class PP-3 concrete, the accelerating admixture shall be calcium nitrite. A calcium chloride accelerator is allowed only by special provision in the contract. If a special provision is used, it normally involves Class PP-2 concrete.

\(^1\) Refer to 2.2.2 “Allowable Cement Factor Reduction – Admixture” for allowable cement factor reduction.
Latex Admixture
A latex admixture shall be used for a bridge deck latex concrete overlay. The latex admixture dosage is 24.5 gal/yd³ (121.1 L/m³).

Corrosion Inhibitor
In some instances the contract documents may require the use of a corrosion inhibitor. Refer to Article 1020.05(b)(10).

Other Applications
The Contractor shall be responsible for using admixtures and determining dosages for all Classes of concrete that will produce a mixture with suitable workability, consistency, and plasticity.

2.5.4 Optional Use of Admixtures

To view or download the “Approved List of Concrete Admixtures” on the Internet, go to http://www.dot.il.gov/; Doing Business; Materials; Approved Lists for Materials. The following information on admixtures is found in Article 1020.05(b).

Air-Entraining Admixture
Specifications mention that an air-entraining admixture may be used in Class SC concrete at the option of the Contractor.

Retarding Admixture
Specifications mention that a retarding admixture may be used in Class PP-4 concrete when using a mobile portland cement concrete plant, provided it is approved by the Engineer.

Water-Reducing Admixture
Specifications mention that a water-reducing admixture may be used in Class PV, PP-1, PP-2, PP-3, PP-4, RR, BS, SC, and SI concrete. This also applies to bridge deck microsilica concrete overlay and bridge deck high-reactivity metakaolin concrete overlay.

High-Range Water-Reducing Admixture (Superplasticizer)
Specifications mention that a high range water-reducing admixture may be used in Class PP-1 or RR concrete.

Accelerator
Specifications mention that a non-chloride accelerator may be used in Class PP-1 or RR concrete. The non-chloride accelerating admixture shall be calcium nitrite when the air temperature is less than 55 °F (13 °C).

Other Applications
The Contractor has the option to determine the use of additional admixtures in the various concrete Classes and other applications. However, the Contractor shall obtain the approval from the Engineer to use an accelerator when the concrete temperature is greater than 60 °F (16 °C). This accelerator approval will not be required for Class PP, RR, PC, and PS concrete. In addition, a calcium chloride accelerator is only allowed by special provision.
2.6 ADJUSTED BASIC WATER REQUIREMENT AND WATER/CEMENT RATIO

The water/cement ratio is defined as the weight (mass) of water, divided by the weight (mass) of cement. The water shall include mixing water, water in admixtures, free moisture on the aggregates (i.e. water on the surface of the individual aggregate particles), and water added at the job site.

When fly ash, ground granulated blast-furnace slag, microsilica, or high-reactivity metakaolin are used as part of the cement in a concrete mix, the water/cement ratio will be based on the total cement and finely divided minerals material contained in the mixture.

Refer to 2.6.1 “Water/Cement Ratio” for the specified water/cement ratio. Many mix designs use a water/cement ratio in the 0.40 to 0.44 range to ensure complete hydration of the cement, and to reduce the dependence on admixtures for workability when the water/cement ratio falls below 0.40. If a maximum water/cement ratio is not specified for a mix design, it shall not exceed 0.45 to ensure durability of the concrete. In addition, the water content shall not be reduced to a level which restricts cement hydration. A water-cement ratio shall not be lower than 0.32, except as allowed for bridge deck latex concrete overlay.

The Level III PCC Technician is reminded to consider the water content in admixtures, which is most often significant when using a high range water-reducing admixture (superplasticizer), calcium chloride accelerator, or latex admixture. When water from admixtures is significant, Article 1020.05(b) states the Contractor shall calculate 70 percent of the admixture dosage as water, except a value of 50 percent shall be used for a latex admixture used in bridge deck latex concrete overlays.

A new mix design will be required if the water/cement ratio is increased more than 0.04 from the original mix design value.

If the adjusted basic water requirement exceeds the maximum water/cement ratio permitted, then the cement factor will have to be increased, or the mix re-designed. If a significant amount of admixtures (includes latex) are being used, the Contractor shall take this into account when checking the water/cement ratio. Refer to the Portland Cement Concrete Level II Technician Course manual for additional information on water in admixtures.

An example calculation for determining water/cement ratio is as follows:

**Given:**
- Adjusted Basic Water Requirement
  - 5.0 gal/cwt (0.41 L/kg) of cement and finely divided minerals
  - 1 gallon of water = 8.33 lbs of water
  - 1 liter of water = 1 kg of water

**English:**

**Calculation:**

\[
\text{Water/Cement Ratio} = \left( \frac{5.0 \text{ gal/cwt} \times 8.33 \text{ lb/gal}}{100 \text{ lb/cwt}} \right)
\]

Water/Cement Ratio = 0.42

**Metric:**

**Calculation:**

\[
\text{Water/Cement Ratio} = \left( \frac{0.41 \text{ L/kg} \times 1 \text{ kg/L}}{1 \text{ kg/L}} \right)
\]

Water/Cement Ratio = 0.41
2.6.1 Water/Cement Ratio

<table>
<thead>
<tr>
<th>Class or Type of Concrete</th>
<th>Water/Cement Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>0.32 – 0.42</td>
</tr>
<tr>
<td>PP-1</td>
<td>0.32 – 0.44</td>
</tr>
<tr>
<td>PP-2</td>
<td>0.32 – 0.38</td>
</tr>
<tr>
<td>PP-3</td>
<td>0.32 – 0.35</td>
</tr>
<tr>
<td>PP-4</td>
<td>0.32 – 0.50</td>
</tr>
<tr>
<td>PP-5</td>
<td>0.32 – 0.40</td>
</tr>
<tr>
<td>RR</td>
<td>0.32 – 0.44</td>
</tr>
<tr>
<td>BS</td>
<td>0.32 – 0.44</td>
</tr>
<tr>
<td>PC</td>
<td>0.32 – 0.44 (Wet Cast)</td>
</tr>
<tr>
<td></td>
<td>0.25 – 0.40 (Dry Cast)</td>
</tr>
<tr>
<td>PS</td>
<td>0.32 – 0.44</td>
</tr>
<tr>
<td>DS</td>
<td>0.32 – 0.44</td>
</tr>
<tr>
<td>SC</td>
<td>0.32 – 0.44</td>
</tr>
<tr>
<td>SI</td>
<td>0.32 – 0.44</td>
</tr>
<tr>
<td>Deck Slab Repair</td>
<td>Refer to PP-1, 2, 3, 4, and 5</td>
</tr>
<tr>
<td>Formed Concrete Repair</td>
<td>Refer to Class SI Concrete</td>
</tr>
<tr>
<td>Concrete Wearing Surface</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Fly Ash or Ground Granulated Blast-Furnace Slag Concrete Overlay</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Microsilica Concrete Overlay</td>
<td>0.37 – 0.41</td>
</tr>
<tr>
<td>Bridge Deck High-Reactivity Metakaolin Concrete Overlay</td>
<td>0.37 – 0.41</td>
</tr>
<tr>
<td>Bridge Deck Latex Concrete Overlay</td>
<td>0.30 – 0.40</td>
</tr>
<tr>
<td>High Performance Concrete Structures</td>
<td>0.38 – 0.44</td>
</tr>
</tbody>
</table>

Notes:
1. In addition to the water/cement ratio, the maximum water (including free moisture on the fine and coarse aggregates) is 157 lbs (93.1 kg).

2.7 AIR CONTENT ABSOLUTE VOLUME CALCULATION

Knowing the amount of cement, finely divided minerals, and water needed, the next step is choosing the percent of air to be entrained into the mix. 2.7.1 “Air Content” contains a listing of specification ranges for all Department mix design classes and types. To select an air content value, use the midpoint of the range. However, since it is more difficult to entrain air when slipforming Class PV, BS, and SI concrete, a value lower than the midpoint may be used in these cases.

While the specification limits for air content are in terms of the total volume of concrete, the volume of air is based on what is required to provide adequate air entrainment in the paste (water, cement, and finely divided minerals). The specification air content is in terms of the total volume because it is a value that is easy to measure.

The absolute volume of air is determined as follows:

*English (Metric):*

The absolute volume of air per cubic yard (cubic meter) of concrete = percent air ÷ 100
### 2.7.1 Air Content

<table>
<thead>
<tr>
<th>Class or Type of Concrete</th>
<th>Air Content, Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV^2</td>
<td>5.0 – 8.0</td>
</tr>
<tr>
<td>PP-1</td>
<td>4.0 – 7.0</td>
</tr>
<tr>
<td>PP-2</td>
<td>4.0 – 6.0</td>
</tr>
<tr>
<td>PP-3</td>
<td>4.0 – 6.0</td>
</tr>
<tr>
<td>PP-4</td>
<td>4.0 – 6.0</td>
</tr>
<tr>
<td>PP-5</td>
<td>4.0 – 6.0</td>
</tr>
<tr>
<td>RR</td>
<td>4.0 – 7.0</td>
</tr>
<tr>
<td>BS^2</td>
<td>5.0 – 8.0</td>
</tr>
<tr>
<td>PC</td>
<td>5.0 – 8.0</td>
</tr>
<tr>
<td>PS</td>
<td>5.0 – 8.0</td>
</tr>
<tr>
<td>DS</td>
<td>5.0 – 8.0</td>
</tr>
<tr>
<td>SC</td>
<td>Optional 6.0 Maximum¹</td>
</tr>
<tr>
<td>Steepled Slab Repair</td>
<td>Refer to PP-1, 2, 3, 4, and 5</td>
</tr>
<tr>
<td>Formed Concrete Repair</td>
<td>Refer to Class SI Concrete</td>
</tr>
<tr>
<td>Concrete Wearing Surface</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Fly Ash or Ground Granulated Blast-Furnace Slag Concrete Overlay</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Microsilica Concrete Overlay</td>
<td>5.0 – 8.0</td>
</tr>
<tr>
<td>Bridge Deck High-Reactivity Metakaolin Concrete Overlay</td>
<td>5.0 – 8.0</td>
</tr>
<tr>
<td>Bridge Deck Latex Concrete Overlay</td>
<td>7 Maximum</td>
</tr>
<tr>
<td>High Performance Concrete Structures</td>
<td>Refer to Class SI Concrete</td>
</tr>
</tbody>
</table>

Notes:

1. When not using an air-entraining admixture, 2.0 percent air content is assumed.
2. For slipform construction, the minimum air content is 5.5 percent.

### 2.7.2 Minimum Air Content

If the required air content is not specified for a concrete mix design, a value can be calculated. For moderate or extreme freeze/thaw exposures, the total air volume should be a minimum 18 percent of the volume of water, cement, and finely divided minerals. In other words, the total paste volume shall have a minimum 18 percent air. The following formula may be used to calculate the air content that meets this criteria:

**English (Metric):**

Minimum Air Content (%) = \[0.18 \times (V_{Water} + V_{Cement} + V_{FDM})\] \times 100

Where:
- \(V_{Water}\) = Absolute Volume of Water per yd^3 (m^3),
- \(V_{Cement}\) = Absolute Volume of Cement per yd^3 (m^3), and
- \(V_{FDM}\) = Absolute Volume of Finely Divided Minerals per yd^3 (m^3)
2.8 FINE AND COARSE AGGREGATE ABSOLUTE VOLUME CALCULATIONS

Knowing the amount of cement, finely divided minerals, water and air needed, only the absolute volumes of the fine and coarse aggregates are unknown. In order to determine these volumes, certain characteristics of the coarse aggregate must first be examined.

2.8.1 Voids in Coarse Aggregate

The first characteristic concerning the coarse aggregate is the volume of voids contained in the aggregate. Voids (V) is defined as the volume of voids per unit volume of dry rodded coarse aggregate. In other words, voids is the ratio of the volume of empty spaces in a unit volume of coarse aggregate to the unit volume of coarse aggregate. Refer to Figure 2.8.1.

\[
1.00_{(\text{Aggregate Volume})} = 0.40_{(\text{Voids Volume})} + 0.60_{(\text{Solids Volume})}
\]

**Figure 2.8.1 Voids in Coarse Aggregate**

For the Department mix design method, the amount of voids in the coarse aggregate shall be determined. The voids test determines the amount of voids in a unit of material.

The coarse aggregate voids are determined by the Contractor according to Illinois Test Procedure 306. Refer to Appendix C for additional information on how to perform the voids test. The test shall be performed at least twice to ensure an accurate value is obtained.

It is important to know that a change in coarse aggregate particle shape will change the voids. Refer to the Portland Cement Concrete Level II Technician Course for additional information on aggregate particle shape. If the voids of a coarse aggregate change more than 0.02 from the original mix design value, a new mix design will be required. A change of 0.02 in voids will change the coarse aggregate weight (mass) approximately 3 times more than a similar change in saturated surface-dry (SSD) specific gravity.

If the coarse aggregate is furnished in two or more sizes, the voids test shall be performed on the combination of the coarse aggregates.

The coarse aggregate voids are to be provided to the Department’s District office. However, the District may provide a value to use. The coarse aggregate voids will typically range from 0.36 to 0.41 for non-crushed gravel and 0.39 to
0.45 for crushed gravel or crushed stone. The coarse aggregate overall range is normally from 0.30 to 0.50.

2.8.2 Mortar Factor

2.8.2.1 General Concept

The second characteristic concerning the coarse aggregate is the amount of mortar used to fill the voids between, as well as disperse, the coarse aggregate particles. Refer to Appendix D “Workability” for additional information. Mortar is the total amount of fine aggregate, cement, finely divided minerals, water, and air (i.e. everything but the coarse aggregate) in a concrete mixture. The volume of mortar per volume of dry rodded coarse aggregate in a unit volume of concrete is called the Mortar Factor. In other words, mortar factor is the ratio of total volume of fine aggregate, cement, finely divided minerals, water and air per total volume of coarse aggregate solids and voids.

Imagine a unit of concrete consisting entirely of coarse aggregate. Everything else in the concrete mixture (i.e., mortar) would be limited to filling the spaces (voids) between coarse aggregate particles.

A concrete mixture consisting entirely of coarse aggregate and only enough mortar to fill the voids between coarse aggregate particles would have poor workability.

To increase workability, the coarse aggregate particles need to be dispersed. Thus, in order to maintain the same unit of concrete, some of the coarse aggregate needs to be removed.

If we add mortar to replace what was removed (i.e., coarse aggregate), we will have a more workable concrete mixture because the mortar will disperse and lubricate the remaining coarse aggregate particles.

\[
\text{MORTAR FACTOR} = \frac{\text{Volume of Mortar}}{\text{Volume of Dry, Rodded Coarse Aggregate}}
\]
2.8.2.2 Volume Fraction Concept

From determining the volume of voids ($V$) in a unit volume of dry rodded coarse aggregate, the volume fraction of coarse aggregate solids can be calculated as follows:

\[
\text{English (Metric):}
\]

\[
\text{Volume Fraction of Coarse Aggregate Solids} = 1 - V
\]

Now, thinking in terms of a concrete mixture, add mortar to the unit volume of dry rodded coarse aggregate. The mortar can fill the voids between coarse aggregate particles, but this will not result in a workable mixture.

By adding an additional volume of mortar per unit volume of dry rodded coarse aggregate, the mixture of coarse aggregate and mortar becomes workable.

The volume fraction of mortar to fill the voids plus the volume fraction of mortar added for workability is the Mortar Factor ($0.40 + 0.50 = 0.90$). Thus, the volume fraction of mortar per unit volume of concrete can be determined as follows:

\[
\text{Volume Fraction of Mortar per Unit Volume of Concrete} = \frac{\text{Mortar Factor}}{\text{CA Solids} + \text{CA Voids} + \text{Additional Mortar}}
\]

\[
= \frac{0.90}{0.60 + 0.40 + 0.50} = 0.60
\]
Alternatively, knowing the mortar factor is 0.90 and the volume fraction of coarse aggregate solids is 0.60, the volume fraction of mortar per unit volume of concrete can be determined as follows:

\[
\text{Volume Fraction of Mortar Per Unit Volume of Concrete} = \frac{\text{Mortar Factor}}{\text{CA Solids} + \text{Mortar Factor}} = \frac{0.90}{0.60 + 0.90} = 0.60
\]

In summary, starting with a unit volume of coarse aggregate, mortar is added to fill the voids between coarse aggregate particles. In order to obtain a workable concrete mixture, an additional fraction of mortar is needed to disperse and lubricate the coarse aggregate particles. With this larger volume of material (coarse aggregate solids, mortar to fill voids, and additional mortar for workability), the volume fraction of mortar per unit volume of concrete can be determined.

2.8.2.3 Design Mortar Factor

For the Department mix design method, mortar factors are selected on the basis of construction application and experience with local materials. A higher mortar factor is used to facilitate placement and finishing, and to improve the finish of the formed surface. A higher mortar factor may also be needed to have sufficient sand to entrain air. Refer to Appendix D “Workability” for additional information, and to Table 2.8.2.3 for the allowable mortar factor range. A new mix design will be required if the mortar factor is changed ± 0.05 or more from the original mix design value.
### Table 2.8.2.3 Design Mortar Factor

<table>
<thead>
<tr>
<th>Class or Type of Concrete</th>
<th>Coarse Aggregate Gradation</th>
<th>Mortar Factor Range for Department Mix Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>CA 5 &amp; CA 7, CA 5 &amp; CA 11, CA 7, CA 11, or CA 14</td>
<td>0.70 – 0.905</td>
</tr>
<tr>
<td>PP-1&lt;sup&gt;2&lt;/sup&gt;, PP-2&lt;sup&gt;2&lt;/sup&gt;, PP-3&lt;sup&gt;2&lt;/sup&gt;, PP-4&lt;sup&gt;2&lt;/sup&gt;, PP-5&lt;sup&gt;2&lt;/sup&gt;</td>
<td>CA 7, CA 11,</td>
<td>0.70 – 0.935</td>
</tr>
<tr>
<td></td>
<td>CA 13, CA 14, or CA 16</td>
<td></td>
</tr>
<tr>
<td>RR</td>
<td>CA 7, CA 11, or CA 14</td>
<td>0.70 – 0.905</td>
</tr>
<tr>
<td>BS&lt;sup&gt;2,3,7&lt;/sup&gt;</td>
<td>CA 7, CA 11, or CA 14</td>
<td>0.70 – 0.865&lt;sup&gt;5,6&lt;/sup&gt;</td>
</tr>
<tr>
<td>PC&lt;sup&gt;7&lt;/sup&gt;</td>
<td>CA 11&lt;sup&gt;4&lt;/sup&gt;, CA 13, CA 14, or CA 16&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.70 – 0.905</td>
</tr>
<tr>
<td>PS&lt;sup&gt;7&lt;/sup&gt;</td>
<td>CA 11&lt;sup&gt;4&lt;/sup&gt;, CA 13, CA 14, or CA 16&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.79 – 0.995</td>
</tr>
<tr>
<td>DS&lt;sup&gt;7,8&lt;/sup&gt;</td>
<td>CA 13, CA 14, CA 16, or a blend of these gradations</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>SC</td>
<td>CA 3 &amp; CA 7, CA 3 &amp; CA 11, CA 5 &amp; CA 7, CA 5 &amp; CA 11, CA 7, or CA 11</td>
<td>0.79 – 0.905</td>
</tr>
<tr>
<td>SI&lt;sup&gt;7,9&lt;/sup&gt;</td>
<td>CA 3 &amp; CA 7, CA 3 &amp; CA 11, CA 5 &amp; CA 7, CA 5 &amp; CA 11</td>
<td>0.71 – 0.83</td>
</tr>
<tr>
<td></td>
<td>CA 7, CA 11, CA 13, CA 14, or CA 16</td>
<td>0.70 – 0.905</td>
</tr>
<tr>
<td>Deck Slab Repair</td>
<td>Refer to PP-1, 2, 3, 4, and 5</td>
<td>Refer to PP-1, 2, 3, 4, and 5</td>
</tr>
<tr>
<td>Formed Concrete Repair</td>
<td>CA 16</td>
<td>Refer to Class SI Concrete</td>
</tr>
<tr>
<td>Concrete Wearing Surface</td>
<td>Refer to Class BS Concrete</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Fly Ash or Ground Granulated Blast-Furnace Slag Concrete Overlay</td>
<td>CA 11, CA 13, CA 14, or CA 16</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Microsilica Concrete Overlay</td>
<td>CA 11, CA 13, CA 14, or CA 16</td>
<td>0.88 – 0.92</td>
</tr>
<tr>
<td>Bridge Deck High-Reactivity Metakaolin Concrete Overlay</td>
<td>CA 11, CA 13, CA 14, or CA 16</td>
<td>0.88 – 0.92</td>
</tr>
<tr>
<td>Bridge Deck Latex Concrete Overlay&lt;sup&gt;10&lt;/sup&gt;</td>
<td>CA 13, CA 14, or CA 16</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>High Performance Concrete Structures</td>
<td>Refer to Class SI Concrete</td>
<td>0.83 – 0.86</td>
</tr>
</tbody>
</table>
### Table 2.8.2.3 Notes

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Alternate combinations of gradation sizes may be used with the approval of the Engineer. Refer also to Article 1004.02(d) for additional information on combining sizes.</td>
</tr>
<tr>
<td>2.</td>
<td>For Class BS or PP concrete used in bridge deck patching, the coarse aggregate gradation shall be CA 13, CA 14, or CA 16, except CA 11 may be used for full-depth patching.</td>
</tr>
<tr>
<td>3.</td>
<td>When Class BS concrete is to be pumped, the coarse aggregate gradation shall have a minimum of 45 percent passing the 1/2 in. (12.5 mm) sieve. The Contractor may combine two or more coarse aggregate sizes, consisting of CA 7, CA 11, CA 13, CA 14, and CA 16, provided a CA 7 or CA 11 is included in the blend.</td>
</tr>
<tr>
<td>4.</td>
<td>The nominal maximum size permitted is 3/4 in. Nominal maximum size is defined as the largest sieve which retains any of the aggregate sample particles.</td>
</tr>
<tr>
<td>5.</td>
<td>If the fine aggregate is one hundred percent stone sand, the maximum mortar factor shall be 0.85.</td>
</tr>
<tr>
<td>6.</td>
<td>May be increased to 0.95 if slipformed.</td>
</tr>
<tr>
<td>7.</td>
<td>For self-consolidating concrete, the coarse aggregate gradations shall be CA 11, CA 13, CA 14, CA 16, or a blend of these gradations. However, the final gradation when using a single coarse aggregate or combination of coarse aggregates shall have 100 percent pass the 1 in. (25 mm) sieve, and minimum 95 percent pass the 3/4 in. (19 mm) sieve. The fine aggregate proportion shall be a maximum 50 percent by weight (mass) of the total aggregate used. Therefore, the maximum mortar factor shall not apply.</td>
</tr>
<tr>
<td>8.</td>
<td>The coarse aggregate shall be 55 to 65 percent by weight (mass) of total aggregate. The only exception is self-consolidating concrete. See Note 7.</td>
</tr>
<tr>
<td>9.</td>
<td>CA 3 or CA 5 may be used when the nominal maximum size does not exceed two-thirds the clear distance between parallel reinforcement bars, or between the reinforcement bar and the form. Nominal maximum size is defined in Note 4.</td>
</tr>
<tr>
<td>10.</td>
<td>The coarse aggregate shall be 42 to 50 percent by weight (mass) of total aggregate.</td>
</tr>
</tbody>
</table>
2.8.3 Coarse Aggregate Absolute Volume Calculation

Knowing the volume fraction of mortar, the absolute volume of coarse aggregate can be determined as follows:

*English (Metric):*

\[
\text{Absolute Volume of CA per cubic yard (cubic meter) of concrete} = 1 - \text{Volume Fraction of Mortar}
\]

For example, from 2.8.2.2 “Volume Fraction Concept”:

\[
\text{Absolute Volume of Coarse Aggregate per cubic yard (cubic meter) of concrete} = 1 - 0.60 = 0.40
\]

The absolute volume of coarse aggregate per cubic yard (cubic meter) of concrete is a total encompassing all coarse aggregates used. If more than one coarse aggregate is used, the total coarse aggregate absolute volume is divided by the percentage of each coarse aggregate to be used. This will provide the absolute volume of each coarse aggregate. Typically, two coarse aggregates are blended to improve a gap graded coarse aggregate. The more uniformly graded combined aggregate will reduce water demand, and improve the pumping characteristics of the mix. Refer to Appendix E “Aggregate Blending” for additional information.

Note: The equation below is used in the Excel PCC Mix Design program available on the Department’s website, as well as in MISTIC to simplify the calculation from two steps (calculating volume fraction of mortar to calculate absolute volume of coarse aggregate) to one.

\[
\text{Absolute Volume of Coarse Aggregate per cubic yard (cubic meter) of concrete} = \frac{1}{1 + \left(\frac{\text{Mortar Factor}}{1 - \text{Voids}}\right)}
\]

2.8.4 Fine Aggregate Absolute Volume Calculation

Knowing the amount of cement, finely divided minerals, water, air, and coarse aggregate needed, the only unknown is the absolute volume of fine aggregate. This is easily found by subtracting all of the known absolute volumes from 1.

*English (Metric):*

The absolute volume of fine aggregate per cubic yard (cubic meter) of concrete

\[
= 1 - [\text{cement volume + finely divided minerals volume + water volume + air volume + coarse aggregate volume}]
\]

The absolute volume of fine aggregate per cubic yard (cubic meter) of concrete is a total encompassing all fine aggregates used. If more than one fine aggregate is used, the total fine aggregate absolute volume is divided by the percentage of each fine aggregate to be used. This will provide the absolute volume of each fine aggregate. Two fine aggregates may be blended for economic purposes such as a natural sand and a stone sand. Blending of fine aggregate may also be
done to improve the overall gradation of the mix for air entrainment and pumping. Refer to Appendix E “Aggregate Blending” for additional information.

2.8.5 Converting Aggregate Absolute Volume to Weight (Mass)

To convert the absolute volume of an aggregate to pounds (kilograms), the saturated surface-dry (SSD) specific gravity of the aggregate is required, which will be provided by the Department's District office. If it is suspected that the SSD specific gravity has changed or is incorrect, notify the District. Whenever the specific gravity of any aggregate deviates by more than 0.02 from the original mix design value, a new mix design will be required. Refer to the Portland Cement Concrete Level II Technician Course manual for additional information on SSD specific gravity.

**English:**
pounds of aggregate = absolute volume × SSD specific gravity × unit weight of water
Where the “unit weight of water” is 1,683.99 pounds per cubic yard.

**Metric:**
kilograms of aggregate = absolute volume × SSD specific gravity × unit weight of water
Where the “unit weight of water” is 1,000.00 kilograms per cubic meter.

2.9 EXAMPLE PROBLEM

**Given:**
- Continuous reinforced Portland cement concrete pavement to be built using central mixed concrete and slipform equipment.
- Type I cement with >0.60 alkalies will be used.
- Class C fly ash with a calcium oxide of 25.1 percent and specific gravity of 2.61 will be used.
- A Type B fine aggregate (FA 1) with a saturated surface-dry specific gravity of 2.66 will be used. The alkali-silica reaction expansion for the fine aggregate sand is in the >0.16% - 0.27% range.
- A non-crushed gravel coarse aggregate (CA 7) with a saturated surface-dry specific gravity of 2.68 will be used. The coarse aggregate voids are 0.37. The alkali-silica reaction expansion for the coarse aggregate limestone is an assigned value of 0.05%. The aggregate is freeze/thaw durable.
- A water-reducing admixture will be used to take advantage of a cement reduction and meet the water/cement ratio requirement. The target water reduction is 6 percent.

**Significant Digits:**
- Whole Number: Cement, Batch Water, Finely Divided Minerals, Coarse and Fine Aggregate
- One Digit to Right of Decimal: Basic Water Requirement (English), Air Content
- Two Digits to Right of Decimal: Specific Gravity, Unit Weight, Water/Cement Ratio, Basic Water Requirement (Metric), Mortar Factor, Voids
- Three Digits to Right of Decimal: Absolute Volume

**Rounding:**
- When the digit next beyond the last place to be retained is equal to or greater than 5, increase by 1 the digit in the last place retained.
2.9.1 Example Using English Units

Step 1 Determine the absolute volume of cement.

- From 2.2.1 “Cement Factor for Type or Class of Concrete,” the cement factor is 5.65 cwt/yd³ for Class PV concrete from a central mixed plant.
- From 2.2.2 “Allowable Cement Factor Reduction – Admixture,” a 0.30 cwt/yd³ cement reduction may be taken when using a water-reducing admixture.

The resulting cement factor is $5.65 - 0.30 = 5.35$ cwt/yd³

- From 2.4.1.1 “Fly Ash,” the Class C fly ash can replace 30 percent of the cement. From 2.4.3 “Mitigation of Alkali-Silica Reaction with Finely Divided Minerals”, it is determined that the aggregate is in Group II. Thus, a minimum 25.0 percent Class C fly ash is required to reduce the risk of a deleterious alkali-silica reaction. It is decided to use 30 percent fly ash since fly ash is cheaper than cement, and will provide the most economical mix.

The calculation is $5.35 \times 0.30 = 1.61$ cwt/yd³ of fly ash.

The calculation for the cement is $5.35 - 1.61 = 3.74$ cwt/yd³

After rounding up to the nearest 5 lb/yd³, the values are 3.75 cwt/yd³ for cement and 1.65 cwt/yd³ for fly ash. However, it is important to note that according to Article 1020.04, the portland cement content in a mixture shall be a minimum of 375 lbs/cu yd. Fortunately, the mixture meets this requirement.

The absolute volume of cement per cubic yard of concrete

$= (3.75 \text{ cwt/yd}^3 \times 100 \text{ lb./cwt}) \div (3.15 \times 1,683.99 \text{ lb./yd}^3) = 0.071$

Step 2 Determine the absolute volume of fly ash.

The absolute volume of fly ash per cubic yard of concrete

$= (1.65 \text{ cwt/yd}^3 \times 100 \text{ lb./cwt}) \div (2.61 \times 1,683.99 \text{ lb./yd}^3) = 0.038$

Step 3 Determine the absolute volume of water. Note: The water from admixtures is not considered significant in this example.

- From 2.5.1.1 “Fine Aggregate Basic Water Requirement,” the fine aggregate water requirement is 5.3 gallons/cwt of cement and fly ash.
- From 2.5.1.2 “Coarse Aggregate Basic Water Requirement,” the coarse aggregate water requirement is 0.0 gallon/cwt of cement and fly ash.
- From 2.5.1.3 “Basic Water Requirement Total,” the design water = $5.3 + 0.0 = 5.3$ gallons/cwt of cement and fly ash.
- As given, the target water reduction is 6 percent.

The design water based on using a water-reducing admixture

$= 5.3 - (5.3 \times 0.06) = 5.0$ gallons/cwt of cement and fly ash when rounded.

The alternate method to calculate this is based on 94% of the original water.

$= 5.3 \times 0.94 = 5.0$ gallons/cwt of cement and fly ash when rounded.
Additional adjustments to the design water, which are allowed by 2.5.2 “Adjustment to Basic Water Requirement” were ignored.

- Verify the water/cement ratio is not exceeded in 2.6.1 “Water/Cement Ratio.”

  The initial calculation is \((5.0 \text{ gallons/cwt} \times 8.33 \text{ lb./gallon}) = 41.7 \text{ lb./cwt}\)

  Then, the water/cement ratio is easily obtained from the 41.7 pounds of water per hundredweight (or 100 lb.) of cement and fly ash. Remember that water/cement ratio is pounds of water divided by pounds of cement and fly ash.

  The calculation is \(41.7 \text{ lb./cwt} \div 100 \text{ lb./cwt} = 0.417\) or 0.42, after rounding, for the water/cement ratio.

  The alternate method to calculate water/cement ratio is to determine the number of pounds of water in one cubic yard and divide by the number of pounds of cement and fly ash in one cubic yard.

  The number of pounds of water per cubic yard
  \[= (5.0 \text{ gallons/cwt} \times 8.33 \text{ lb./gallon}) \times (3.75 \text{ cwt/yd}^3 + 1.65 \text{ cwt/yd}^3)\]
  \[= 225 \text{ lb./yd}^3\]

  The number of pounds of cement plus fly ash per cubic yard
  \[= (3.75 \text{ cwt/yd}^3 + 1.65 \text{ cwt/yd}^3) \times 100 \text{ lb./cwt}\]
  \[= 540 \text{ lb./yd}^3\]

  The water cement ratio = \(225 \text{ lb./yd}^3 \div 540 \text{ lb./yd}^3 = 0.42\) after rounding.

  This value meets the 0.42 maximum water/cement ratio allowed for Class PV concrete in 2.6.1 “Water/Cement Ratio.”

  The absolute volume of water per cubic yard of concrete
  \[= \frac{[41.7 \text{ lb./cwt} \times (3.75 \text{ cwt/yd}^3 + 1.65 \text{ cwt/yd}^3)]}{(1.00 \times 1,683.99 \text{ lb./yd}^3)}\]
  \[= 0.134\]

  **Step 4** Determine the absolute volume of air.

  - From 2.7.1 “Air Content,” the midpoint of the air content range for Class PV concrete is 6.5 percent.

    The absolute volume of air per cubic yard of concrete = 6.5 percent \(\div 100 = 0.065\)

  **Step 5** Determine the absolute volume of coarse aggregate.

  Select a mortar factor for Class PV concrete from 2.8.2.1 “Design Mortar Factor.” A mortar factor value of 0.83 is a good starting point. The coarse aggregate voids are 0.37.

  The absolute volume of coarse aggregate per cubic yard of concrete
  \[= \frac{1}{1 + \left(\frac{0.83}{1 - 0.37}\right)} = 0.432\]
Another way to determine absolute volume of coarse aggregate is to calculate percent mortar volume in decimal form and subtract it from 1. If it is not mortar, it must be coarse aggregate.

The absolute volume of coarse aggregate per cubic yard of concrete

\[ = 1 - \text{Volume Fraction of Mortar} \]

\[ = 1 - \frac{M_o}{M_o + (1 - V)} \]

\[ = 1 - \frac{0.83}{0.83 + (1 - 0.37)} = 0.432 \]

Step 6 Determine the absolute volume of fine aggregate.

The absolute volume of fine aggregate is found by subtracting all of the known volumes from 1. Therefore,

The absolute volume of fine aggregate per cubic yard

\[ = 1 - (0.071 + 0.038 + 0.134 + 0.065 + 0.432) = 0.260 \]

Step 7 Convert the absolute volume of the coarse and fine aggregate to pounds.

Coarse aggregate = 0.432 yd\(^3\) \(\times\) 2.68 \(\times\) 1,683.99 lb./yd\(^3\) = 1,950 lb./yd\(^3\)

Fine aggregate = 0.260 yd\(^3\) \(\times\) 2.66 \(\times\) 1,683.99 lb./yd\(^3\) = 1,165 lb./yd\(^3\)

Step 8 Summarize the mix design.

Cement (3.15\*) = 3.75 cwt/yd\(^3\) or 375 lb./yd\(^3\)
Fly Ash (2.61\*) = 1.65 cwt/yd\(^3\) or 165 lb./yd\(^3\)
Batch Water = 5.0 gallons/cwt of cement and fly ash
= 5.0 gallons/cwt \(\times\) (3.75 cwt/yd\(^3\) + 1.65 cwt/yd\(^3\)) = 27 gal/yd\(^3\)
or
= 41.7 lb./cwt of cement and fly ash
= 41.7 lb./cwt (3.75 cwt/yd\(^3\) + 1.65 cwt/yd\(^3\)) = 225 lb./yd\(^3\)
Air Content (Target) = 6.5 percent
Coarse Aggregate (2.68\*) = 1,950 lb./yd\(^3\)
Fine Aggregate (2.66\*) = 1,165 lb./yd\(^3\)
Admixture = water-reducing admixture (target reduction of 10 percent)
Mortar Factor = 0.83
Voids = 0.37
Slump (Target) = 1-1/2 inch**
Strength (Minimum) = 3500 psi
Water/Cement Ratio = 0.42

* Specific Gravity
** Experience has been that the slump at the paver will most likely be 1-1/2 inches to aid in achieving a smooth pavement.
2.9.2 Example Using Metric Units

Step 1 Determine the absolute volume of cement.

- From 2.2.1 “Cement Factor for Type or Class of Concrete,” the cement factor is 335 kg/m³ for Class PV concrete from a central mixed plant.
- From 2.2.2 “Allowable Cement Factor Reduction – Admixture,” an 18 kg/m³ cement reduction may be taken when using a water-reducing admixture.

The resulting cement factor is 335 – 18 = 317 kg/m³

- From 2.4.1.1 “Fly Ash,” the Class C fly ash can replace 30 percent of the cement. From 2.4.3 “Mitigation of Alkali-Silica Reaction with Finely Divided Minerals”, it is determined that the aggregate is in Group II. Thus, a minimum 25.0 percent Class C fly ash is required to reduce the risk of a deleterious alkali-silica reaction. It is decided to use 30 percent fly ash since fly ash is cheaper than cement, and will provide the most economical mix.

The calculation is 317 × 0.30 = 95 kg/m³ of fly ash

The calculation for the cement is 317 – 95 = 222 kg/m³

After rounding up to the nearest 2.5 kg/m³, the values are 222.5 kg/m³ for cement and 95 kg/m³ for fly ash. However, it is important to that according to Article 1020.04, the portland cement content in a mixture shall be a minimum of 222 kg/m³. Fortunately, the mixture meets this requirement.

The absolute volume of cement per cubic meter of concrete
\[= \frac{222.5 \text{ kg/m}^3}{(3.15 \times 1,000.00 \text{ kg/m}^3)} = 0.071\]

Step 2 Determine the absolute volume of fly ash.

The absolute volume of fly ash per cubic meter of concrete
\[= \frac{95 \text{ kg/m}^3}{(2.61 \times 1,000.00 \text{ kg/m}^3)} = 0.036\]

Step 3 Determine the absolute volume of water. Note: The water from admixtures is not considered significant in this example.

- From 2.5.1.1 “Fine Aggregate Basic Water Requirement,” the fine aggregate water requirement is 0.44 liter/kg of cement and fly ash.
- From 2.5.1.2 “Coarse Aggregate Basic Water Requirement,” the coarse aggregate water requirement is 0.00 liter/kg of cement and fly ash.
- From 2.5.1.3 “Basic Water Requirement Total,” the (design water) \[= 0.44 + 0.00 = 0.44 \text{ liter/kg of cement and fly ash}\]
- As given, the target water reduction is 6 percent.

The design water based on using a water-reducing admixture
\[= 0.44 - (0.44 \times 0.06) = 0.41 \text{ liter/kg of cement and fly ash when rounded.}\]

The alternate method to calculate this is based on 94% of the original water.
\[= 0.44 \times 0.94 = 0.41 \text{ liter/kg of cement and fly ash when rounded.}\]
Additional adjustments to the design water, which are allowed by 2.5.2 “Adjustment to Basic Water Requirement” were ignored.

- Verify the water/cement ratio is not exceeded in 2.6.1 “Water/Cement Ratio.”

The water/cement ratio is easily obtained from the 0.41 liter of water per kilogram of cement and fly ash. Remember that water/cement ratio is kilograms of water divided by kilograms of cement and fly ash. In addition, remember that 1 liter of water equals 1 kilogram of water.

The calculation is 0.41 kg ÷ 1 kg = 0.41 for the water/cement ratio.

The alternate method to calculate water/cement ratio is to determine the number of kilograms of water in one cubic meter and divide by the number of kilograms of cement and fly ash in one cubic meter.

The number of kilograms of water per cubic meter
= (0.41 liter/kg × 1 kg/liter) × (222.5 kg/m³ + 95 kg/m³)
= 130 kg/m³

The number of kilograms of cement and fly ash per cubic meter
= (222.5 kg/m³ + 95 kg/m³)
= 317.5 kg/m³

The water cement ratio = 130 kg/m³ ÷ 317.5 kg/m³ = 0.41 after rounding.

- This value meets the 0.42 maximum water/cement ratio allowed for Class PV concrete in 2.6.1 “Water/Cement Ratio.”

The absolute volume of water per cubic meter of concrete
= [(0.41 liter/kg × 1 kg/liter) × (222.5 kg/m³ + 95 kg/m³)] ÷ (1.0 × 1,000.00 kg/m³) = 0.130

Step 4 Determine the absolute volume of air.

- From 2.7.1 “Air Content,” the midpoint of the air content range for Class PV concrete is 6.5 percent.

The absolute volume of air per cubic meter of concrete = 6.5 percent ÷ 100 = 0.065

Step 5 Determine the absolute volume of coarse aggregate.

- Select a mortar factor for Class PV concrete from 2.8.2.1 “Design Mortar Factor.”

A mortar factor value of 0.83 is a good starting point. The coarse aggregate voids are 0.37.

The absolute volume of coarse aggregate per cubic meter of concrete
= \[
\frac{1}{1 + \left(\frac{0.83}{1 - 0.37}\right)} = 0.432
\]
Another way to determine absolute volume of coarse aggregate is to calculate percent mortar volume in decimal form and subtract it from 1. If it is not mortar, it must be coarse aggregate.

The absolute volume of coarse aggregate per cubic yard of concrete

\[ = 1 - \text{Volume Fraction of Mortar} \]

\[ = 1 - \frac{M_o}{M_o + (1 - V)} \]

\[ = 1 - \frac{0.83}{0.83 + (1 - 0.37)} = 0.432 \]

Step 6 Determine the absolute volume of fine aggregate.

The absolute volume of fine aggregate is found by subtracting all of the known volumes from 1. Therefore,

The absolute volume of fine aggregate per cubic meter

\[ = 1 - (0.071 + 0.036 + 0.130 + 0.065 + 0.432) = 0.266 \]

Step 7 Convert the absolute volume of the coarse and fine aggregate to kilograms.

Coarse aggregate = 0.432 m\(^3\) \(\times\) 2.68 \(\times\) 1,000.00 kg/m\(^3\) = 1,158 kg/m\(^3\)

Fine aggregate = 0.266 m\(^3\) \(\times\) 2.66 \(\times\) 1,000.00 kg/m\(^3\) = 708 kg/m\(^3\)

Step 8 Summarize the mix design.

Cement (3.15*) = 222.5 kg/m\(^3\)
Fly Ash (2.61*) = 95 kg/m\(^3\)
Batch Water = 0.41 liter/kg of cement and fly ash
= 0.41 liter/kg \(\times\) (222.5 kg/m\(^3\) + 95 kg/m\(^3\))
= 130.2 liters/m\(^3\)
or
= 130.2 kg/m\(^3\) since 1 liter of water = 1 kilogram

Air Content (Target) = 6.5 percent
Coarse Aggregate (2.68*) = 1,158 kg/m\(^3\)
Fine Aggregate (2.66*) = 708 kg/m\(^3\)
Admixture = water-reducing admixture (target reduction of 10 percent)
Mortar Factor = 0.83
Voids = 0.37
Slump (Target) = 38 mm**
Strength (Minimum) = 24,000 kPa**
Water/Cement Ratio = 0.41

* Specific Gravity
** Experience has been that the slump at the paver will most likely be 38 mm to aid in achieving a smooth pavement.
## 2.10 SUMMARY OF MIX DESIGN EQUATIONS

### Volume of Cement & Finely Divided Minerals

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{Cement}}$</td>
<td>Absolute Volume of Cement, $\text{yd}^3$ ($\text{m}^3$)</td>
</tr>
<tr>
<td>$V_{\text{FDM}}$</td>
<td>Absolute Volume of Finely Divided Minerals, $\text{yd}^3$ ($\text{m}^3$)</td>
</tr>
<tr>
<td>$W$</td>
<td>Weight of Material (lb.)</td>
</tr>
</tbody>
</table>

#### English

- **Absolute Volume**,
  
  $V_{\text{Cement}} = \frac{\text{Weight}}{G_{\text{sp}} \times 1,683.99}$
  
  $V_{\text{FDM}} = \frac{\text{Weight}}{G_{\text{sp}} \times 1,683.99}$

#### Metric

- **Absolute Volume**,
  
  $V_{\text{Cement}} = \frac{\text{Mass}}{G_{\text{sp}} \times 1,000.00}$
  
  $V_{\text{FDM}} = \frac{\text{Mass}}{G_{\text{sp}} \times 1,000.00}$

### Basic Water Requirement—IDOT Method

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{\text{Basic}}$</td>
<td>Basic Water Requirement, gal/cwt (L/kg)</td>
</tr>
<tr>
<td>$W_{\text{FA}}$</td>
<td>Fine Aggregate Water Requirement, gal/cwt (L/kg)</td>
</tr>
<tr>
<td>$W_{\text{CA}}$</td>
<td>Coarse Aggregate Water Requirement, gal/cwt (L/kg)</td>
</tr>
</tbody>
</table>

#### English & Metric

- **Basic Water Requirement**,
  
  $W_{\text{Basic}} = W_{\text{FA}} + W_{\text{CA}}$

### Adjusted Basic Water Requirement

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{\text{Adj}}$</td>
<td>Adjusted Basic Water Requirement, gal/cwt (L/kg)</td>
</tr>
<tr>
<td>$W_{\text{Basic}}$</td>
<td>Basic Water Requirement, gal/cwt (L/kg)</td>
</tr>
<tr>
<td>$%\text{Adjustment}$</td>
<td>Adjustment (± percent)</td>
</tr>
</tbody>
</table>

#### English & Metric

- **Adjusted Basic Water Requirement**,
  
  $W_{\text{Adj}} = W_{\text{Basic}} - \left( W_{\text{Basic}} \times \frac{\%\text{Adjustment}}{100} \right)$

### Water/Cement Ratio

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W/C$</td>
<td>Water/Cement Ratio</td>
</tr>
<tr>
<td>$W_{\text{Adj}}$</td>
<td>Adjusted Basic Water Requirement (gal/cwt)</td>
</tr>
<tr>
<td>$8.33$</td>
<td>Conversion Factor (lb/gal)</td>
</tr>
<tr>
<td>$100$</td>
<td>Conversion Factor (lb/cwt)</td>
</tr>
</tbody>
</table>

#### English & Metric

- **Water/Cement Ratio**,
  
  $W/C = \frac{W_{\text{Adj}} \times 8.33}{100}$

### Volume of Water

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{Water}}$</td>
<td>Absolute Volume of Water, $\text{yd}^3$ ($\text{m}^3$)</td>
</tr>
<tr>
<td>$W$</td>
<td>Weight of Material (lb.)</td>
</tr>
</tbody>
</table>

#### English

- **Absolute Volume**,
  
  $V_{\text{Water}} = \frac{\text{Weight}}{1,683.99}$

#### Metric

- **Absolute Volume**,
  
  $V_{\text{Water}} = \frac{\text{Mass}}{1,000.00}$

### Volume of Entrained Air

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{Air}}$</td>
<td>Absolute Volume of Air, $\text{yd}^3$ ($\text{m}^3$)</td>
</tr>
<tr>
<td>$%\text{Air}$</td>
<td>Air Content (percent)</td>
</tr>
</tbody>
</table>

#### English & Metric

- **Absolute Volume**,
  
  $V_{\text{Air}} = \frac{\%\text{Air}}{100}$
### Minimum Percent Air Content

<table>
<thead>
<tr>
<th>English &amp; Metric</th>
<th>Definition</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Percent Air</td>
<td>(0.18 \times (V_{\text{Water}} + V_{\text{Cement}} + \Sigma V_{\text{FDM}}) \times 100)</td>
<td>(V_{\text{Water}})</td>
<td>Absolute Volume of Water, (yd^3 (m^3))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{\text{Cement}})</td>
<td>Absolute Volume of Cement, (yd^3 (m^3))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(\Sigma V_{\text{FDM}})</td>
<td>Sum Total of Absolute Volumes of Finely Divided Minerals, (yd^3 (m^3))</td>
</tr>
</tbody>
</table>

### Volume Fraction of Coarse Aggregate & Mortar

<table>
<thead>
<tr>
<th>English &amp; Metric</th>
<th>Definition</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of Coarse Aggregate Solids,</td>
<td>(1 - V)</td>
<td>(V)</td>
<td>Voids in Coarse Aggregate</td>
</tr>
<tr>
<td>Volume Fraction of Mortar</td>
<td>(\frac{M_o}{M_o + F_{CA}})</td>
<td>(M_o)</td>
<td>Mortar Factor</td>
</tr>
</tbody>
</table>

### Volume of Coarse Aggregate

<table>
<thead>
<tr>
<th>English &amp; Metric</th>
<th>Definition</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{\text{CA}})</td>
<td>(1 - V_{\text{Fraction of Mortar}})</td>
<td>(V_{\text{CA}})</td>
<td>Absolute Volume of Coarse Aggregate, (yd^3 (m^3))</td>
</tr>
<tr>
<td>(M_o)</td>
<td>Mortar Factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V)</td>
<td>Voids in Coarse Aggregate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Volume of Fine Aggregate

<table>
<thead>
<tr>
<th>English &amp; Metric</th>
<th>Definition</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{\text{FA}})</td>
<td>(1 - (V_{\text{Cement}} + \Sigma V_{\text{FDM}} + V_{\text{Water}} + V_{\text{Air}} + V_{\text{CA}}))</td>
<td>(V_{\text{FA}})</td>
<td>Absolute Volume of Fine Aggregate, (yd^3 (m^3))</td>
</tr>
<tr>
<td>(V_{\text{Cement}})</td>
<td>Absolute Volume of Cement, (yd^3 (m^3))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Sigma V_{\text{FDM}})</td>
<td>Sum Total of Absolute Volume of Finely Divided Minerals, (yd^3 (m^3))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_{\text{Water}})</td>
<td>Absolute Volume of Water, (yd^3 (m^3))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_{\text{Air}})</td>
<td>Absolute Volume of Air, (yd^3 (m^3))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_{\text{CA}})</td>
<td>Absolute Volume of Coarse Aggregate, (yd^3 (m^3))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Aggregate Content

<table>
<thead>
<tr>
<th>English</th>
<th>Definition</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of Aggregate (lb./yd²)</td>
<td>(V_{\text{CA}} \times G_{\text{SSD}} \times 1,683.99)</td>
<td>(V_{\text{CA}})</td>
<td>Absolute Volume of Coarse Aggregate, (yd^3 (m^3))</td>
</tr>
<tr>
<td>(V_{\text{FA}} \times G_{\text{SSD}} \times 1,683.99)</td>
<td>(V_{\text{FA}})</td>
<td>Absolute Volume of Fine Aggregate, (yd^3 (m^3))</td>
<td></td>
</tr>
<tr>
<td>(G_{\text{SSD}})</td>
<td>Specific Gravity of Aggregate @ Saturated Surface-Dry Condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of Aggregate (kg/m³)</td>
<td>(V_{\text{CA}} \times G_{\text{SSD}} \times 1,000.00)</td>
<td>(V_{\text{CA}})</td>
<td>Absolute Volume of Coarse Aggregate, (yd^3 (m^3))</td>
</tr>
<tr>
<td>(V_{\text{FA}} \times G_{\text{SSD}} \times 1,000.00)</td>
<td>(V_{\text{FA}})</td>
<td>Absolute Volume of Fine Aggregate, (yd^3 (m^3))</td>
<td></td>
</tr>
<tr>
<td>(1,683.99)</td>
<td>Unit Weight of Water (lb/yd³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1,000.00)</td>
<td>Unit Weight of Water (kg/m³)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* For cement and finely divided minerals, there are no pores for the material to absorb water. Therefore, a saturated surface-dry condition cannot exist as it can for aggregates. Thus, the term “apparent specific gravity” is used to describe this type of specific gravity.
3.0 SPECIALTY MIXTURES

3.1 HIGH-EARLY STRENGTH CONCRETE MIXTURES

Projects will frequently have requirements for high-early-strength portland cement concrete pavement (jointed and continuously reinforced), base course, and base course widening. A high-early-strength portland cement concrete mix is defined as follows: “A concrete mix that will meet mix design strength requirements prior to the test of record. Typically, the concrete strength is obtained in 3 days or less.”

Projects requiring high-early-strength concrete mixtures frequently involve intersections and entrances to business establishments. In addition, portland cement concrete railroad crossings are always a high-early-strength mixture because the required strength is to be obtained in 48 hours. The accelerated strength is needed to minimize disruptions to the public. The following options are used to obtain a high-early-strength concrete mixture. The Contractor may submit other options for approval by the Engineer.

- Option 1. Replace the normal strength gaining cement with a Type III high-early-strength cement.
- Option 2. Increase the amount of normal strength gaining cement to a 7 bag mix. This would be 658 lb/yd³ (390 kg/m³). However, mix designs typically use 650 lb/yd³ (386 kg/m³) or 655 lb/yd³ (389 kg/m³).

In addition, limit the fine aggregate water requirement to 4.9 gal/cwt (0.41 L/kg), except that slightly more may be permitted when warranted by the angularity of the coarse aggregate. As a result of the water limitation, a water-reducing admixture is frequently used.

- Option 3. Use a non-chloride accelerator. Normally, only a non-chloride accelerator is allowed in new concrete construction. For concrete repairs, the District has the option to allow a chloride accelerator which is normally only done for Class PP-2. Refer also to 2.5.3 “Required Use of Admixtures” and 2.5.4 “Optional Use of Admixtures” for additional information on accelerators.

3.2 OTHER MIXTURES

The following appendices provide additional information on other specialty mixtures:

- Appendix F “CEMENT AGGREGATE MIXTURE (CAM) II”
- Appendix G “CONTROLLED LOW STRENGTH MATERIAL (CLSM)”
- Appendix H “STAMPED OR INTEGRALLY COLORED CONCRETE”
- Appendix I “CONCRETE REVETMENT MATS”
- Appendix J “INSERTION LINING OF PIPE CULVERTS (GROUT)”
- Appendix K “INSERTION LINING OF PIPE CULVERTS (CELLULAR CONCRETE)”
- Appendix L “CLASS SI CONCRETE BETWEEN PRECAST CONCRETE BOX CULVERTS”
- Appendix M “PERVIOUS CONCRETE”
3.3 SYNTHETIC FIBERS

The Department may require synthetic fibers for thin concrete overlays. The fibers are used as a reinforcement, which will improve the concrete’s resistance to cracking. Contractors also have the option to use synthetic fibers in slipformed concrete for gutter, curb, median, and paved ditch. The synthetic fibers reduce concrete tearing, which is a labor savings for finishing operations.

In terms of doing a mix design, it is suggested to ensure adequate mortar is available to coat the fibers. This may require a slightly higher mortar factor, or a small increase in the total amount of cement and finely divided minerals in the mixture. It is best to consult with the supplier of the fibers when developing the mix design. The Level III PCC Technician is also reminded that the slump test is not a good indicator of workability for a mixture containing fiber reinforcement.
4.0 TERNARY CONCRETE MIX DESIGNS

A ternary concrete mix design consists of cement and two finely divided minerals. The finely divided mineral in portland-pozzolan cement or portland blast-furnace slag cement shall count as one of the two finely divided minerals. Article 1020.05(c)(5) provides the specification for mixtures with multiple finely divided minerals. Refer to Appendix O. The specification allows the combination of finely divided minerals to be a maximum of 35.0 percent of the total cement plus finely divided minerals. The Department encourages the use of a high percentage of finely divided minerals in a mix design for the following reasons:

- The risk of alkali-silica reaction is further reduced.
- The concrete permeability will be lower which increases the time before steel reinforcement will corrode.
- Improved workability and less slump loss in hot weather.
- Higher long term strengths.
- A more economical and environmentally friendly mix.

The one disadvantage of concrete mixtures with a high percentage of finely divided minerals is when cool weather occurs. The cooler temperatures will cause slower strength gain, which is typically not suitable for today’s fast paced construction.
5.0 MASS CONCRETE MIX DESIGNS

According to Article 1020.15 (refer to Appendix O), the Contractor shall control the heat of hydration for concrete structures when the least dimension for a drilled shaft, foundation, footing, substructure, or superstructure concrete pour exceeds 5.0 ft (1.5 m). The primary purpose is to control volume changes induced by the high concrete temperatures. Excessive volume changes may crack the concrete. Very high concrete temperatures may also produce a phenomenon known as delayed ettringite formation (DEF). This ettringite will form after the concrete has hardened, provided there is adequate moisture. The ettringite is an expansive distress that will crack the concrete.

In terms of designing a mass concrete pour mix design, specifications recommend a uniformly graded mix with preference given to larger size aggregate. The purpose is to reduce the total amount of cement and finely divided minerals required to coat the aggregate surface area, which will also help reduce the total heat of hydration. Per Department specifications, the total required cement and finely divided minerals may be lower for mass concrete pours.

Mass concrete pour mix designs will also normally have a high percentage of finely divided minerals to control the heat of hydration. For example, the finely divided minerals may constitute a maximum of 65.0 percent of the total cement and finely divided minerals in a mix design.

If the Level III PCC Technician is required to develop a mass concrete pour mix design, the Department recommends the use of a Consultant that specializes in this area. Various field methods for pre-cooling and post-cooling the concrete are available, and these methods will dictate the required mix design.
6.0  CONCRETE MIX DESIGN—TRIAL MIXTURE

Once a mix design is completed, a trial mixture is recommended to verify the mix design will meet slump, air content, and strength requirements as summarized in 6.1 “Slump”, 2.7.1 “Air Content”, and 6.2 “Strength.” If a trial mixture is performed, it is a good idea to notify the Department’s District office. The District may wish to observe the trial mixture or possibly perform some of its own testing.

6.1  SLUMP

The slump test (Illinois Modified AASHTO T 119) is used to determine the batch-to-batch consistency of concrete. Per Article 1020.04, different slump ranges are specified for different construction applications. Refer to Table 6.1.

Mix design target slump values near the maximum of the specified range are recommended to aid finishing and handwork, as well as potentially improving the effectiveness of air-entraining admixtures (that is, additional water benefits air-entraining admixtures). Furthermore, high slumps at the plant can help anticipate slump loss due to high temperature and long haul time, which otherwise could result in a mixture that may be difficult to place and finish in the field. For example, experience has shown that for slipformed pavement construction on a very hot day, a slump of 2-1/2 inches (64 mm) at the plant can fall up to 1-1/2 inches (38 mm) by the time it reaches the paver. A slump of 1/2 to 1-1/2 inches (13 to 38 mm) at the paver is typical for slipform construction, but many Contractors desire 1-1/2 inches (38 mm) to obtain a smooth pavement.

6.2  STRENGTH

One of the most important properties of concrete is its strength. The purpose of strength testing is to verify the strength potential of the concrete. Per Article 1020.04, different minimum strengths are specified for different construction applications. Refer to Table 6.2.
### Table 6.1 Slump

<table>
<thead>
<tr>
<th>Class or Type of Concrete</th>
<th>Slump inches (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>2-4 (50-100)</td>
</tr>
<tr>
<td>PP-1</td>
<td>2-4 (50-100)</td>
</tr>
<tr>
<td>PP-2</td>
<td>2-6 (50-150)</td>
</tr>
<tr>
<td>PP-3</td>
<td>2-4 (50-100)</td>
</tr>
<tr>
<td>PP-4</td>
<td>2-6 (50-150)</td>
</tr>
<tr>
<td>PP-5</td>
<td>2-8 (50-200)</td>
</tr>
<tr>
<td>RR</td>
<td>2-4 (50-100)</td>
</tr>
<tr>
<td>BS</td>
<td>2-4 (50-100)</td>
</tr>
<tr>
<td>PC</td>
<td>1-4 (25-100)</td>
</tr>
<tr>
<td>PS</td>
<td>0-1 (0-25)</td>
</tr>
<tr>
<td>DS</td>
<td>1-4 (25-100)</td>
</tr>
<tr>
<td>SC</td>
<td>6-8 (150-200)</td>
</tr>
<tr>
<td>SI</td>
<td>3-5 (75-125)</td>
</tr>
<tr>
<td>Deck Slab Repair</td>
<td>Refer to PP-1, 2, 3, 4, and 5</td>
</tr>
<tr>
<td>Formed Concrete Repair</td>
<td>5-7 (125-175)</td>
</tr>
<tr>
<td>Concrete Wearing Surface</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Fly Ash or Ground Granulated Blast-Furnace Slag Concrete Overlay</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Microsilica Concrete Overlay</td>
<td>3-6 (75-150)</td>
</tr>
<tr>
<td>Bridge Deck High-Reactivity Metakaolin Concrete Overlay</td>
<td>3-6 (75-150)</td>
</tr>
<tr>
<td>Bridge Deck Latex Concrete Overlay</td>
<td>3-6 (75-150)</td>
</tr>
<tr>
<td>High Performance Concrete Structures</td>
<td>Refer to Class SI Concrete</td>
</tr>
</tbody>
</table>

**Notes:**

1. The slump range for slipform construction shall be 1/2-2 1/2 in. (13-64 mm).
2. The maximum slump may be increased to 6 in. (150 mm), when a high range water-reducing admixture is used.
3. The maximum slump may be increased to 7 in. (175 mm), when a high range water-reducing admixture is used.
4. For Class PS, the 7 in. (175 mm) maximum slump may be increased to 8 1/2 in. (215 mm) if the high range water-reducing admixture is the polycarboxylate type.
5. If concrete is placed to displace drilling fluid, or against temporary casing, the slump shall be 8-10 in. (200-250 mm) at the point of placement. If a water-reducing admixture is used in lieu of a high range water-reducing admixture according to Article 1020.05(b)(7), the slump shall be 2-4 in. (50-100 mm).
6. The maximum slump may be increased to 200 mm (8 in.), when a high range water-reducing admixture is used.
### Table 6.2 Strength

<table>
<thead>
<tr>
<th>Class or Type of Concrete</th>
<th>Compressive Strength</th>
<th>Flexural Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>3,500 (24,000) 1,2</td>
<td>650 (4,500) 1,2</td>
</tr>
<tr>
<td>PP-1</td>
<td>3,200 (22,100) 3,8</td>
<td>600 (4,150) 3,8</td>
</tr>
<tr>
<td>PP-2</td>
<td>3,200 (22,100) 4,8</td>
<td>600 (4,150) 4,8</td>
</tr>
<tr>
<td>PP-3</td>
<td>3,200 (22,100) 5,8</td>
<td>600 (4,150) 5,8</td>
</tr>
<tr>
<td>PP-4</td>
<td>3,200 (22,100) 6,8</td>
<td>600 (4,150) 6,8</td>
</tr>
<tr>
<td>PP-5</td>
<td>3,200 (22,100) 7,8</td>
<td>600 (4,150) 7,8</td>
</tr>
<tr>
<td>RR</td>
<td>3,500 (24,000) 3</td>
<td>650 (4,500) 3</td>
</tr>
<tr>
<td>BS</td>
<td>4,000 (27,500) 1</td>
<td>675 (4,650) 1</td>
</tr>
<tr>
<td>PC</td>
<td>Refer to Section 1042</td>
<td>Refer to Section 1042</td>
</tr>
<tr>
<td>PS</td>
<td>Refer to Section 1020</td>
<td>Refer to Section 1020</td>
</tr>
<tr>
<td>DS</td>
<td>4,000 (27,500) 1</td>
<td>675 (4,650) 1</td>
</tr>
<tr>
<td>SC</td>
<td>3,500 (24,000) 1</td>
<td>650 (4,500) 1</td>
</tr>
<tr>
<td>SI</td>
<td>3,500 (24,000) 1</td>
<td>650 (4,500) 1</td>
</tr>
<tr>
<td>Deck Slab Repair</td>
<td>Refer to PP-1, 2, 3, 4, and 5</td>
<td>Refer to PP-1, 2, 3, 4, and 5</td>
</tr>
<tr>
<td>Formed Concrete Repair</td>
<td>4,000 (27,500) 1</td>
<td>675 (4,650) 1</td>
</tr>
<tr>
<td>Concrete Wearing Surface</td>
<td>Refer to Class BS Concrete 9</td>
<td>Refer to Class BS Concrete 9</td>
</tr>
<tr>
<td>Bridge Deck Fly Ash or Ground Granulated Blast-Furnace Slag Concrete Overlay</td>
<td>Refer to Class BS Concrete</td>
<td>Refer to Class BS Concrete</td>
</tr>
<tr>
<td>Bridge Deck Microsilica Concrete Overlay</td>
<td>4,000 (27,500) 1</td>
<td>675 (4,650) 1</td>
</tr>
<tr>
<td>Bridge Deck High-Reactivity Metakaolin Concrete Overlay</td>
<td>4,000 (27,500) 1</td>
<td>675 (4,650) 1</td>
</tr>
<tr>
<td>Bridge Deck Latex Concrete Overlay</td>
<td>4,000 (27,500) 1</td>
<td>675 (4,650) 1</td>
</tr>
<tr>
<td>High Performance Concrete Structures</td>
<td>Refer to Class SI Concrete</td>
<td>Refer to Class SI Concrete</td>
</tr>
</tbody>
</table>

**Notes:**

1. 14 day strength
2. If Type III cement is used, the indicated strength shall be achieved in 3 days.
3. 48 hour strength
4. 24 hour strength
5. 16 hour strength
6. 8 hour strength
7. 4 hour strength
8. For Class PP concrete used in bridge deck patching, the mix design shall have 72 hours to obtain a 4,000 psi (27,500 kPa) compressive or 675 psi (4,650 kPa) flexural strength.
9. When Steel Bridge Rail is used in conjunction with concrete wearing surface, the 14 day mix design shall be replaced by a 28 day mix design with a compressive strength of 5,000 psi (34,500 kPa) and a flexural strength of 800 psi (5,500 kPa).
6.3 PROCEDURE FOR TRIAL MIXTURE

The applicable test methods for a conventional concrete trial mixture are Illinois Modified AASHTO T 22, T 23, T 119, T 121, T 141, T 152, T 177, T 196, and T 309. Testing shall be performed by an individual who has successfully completed the Portland Cement Concrete Level I Technician training. For self-consolidating concrete, applicable test methods for a trial mixture are Illinois Test Procedures SCC-1, SCC-2, SCC-3, SCC-4, SCC-6, and Illinois Modified AASHTO T 22, T 23, T 121, T 141, T 152, T 177, T 196, and T 309. A unit weight test (Illinois Modified AASHTO T 121), which also provides yield, should be performed to check the accuracy of proportioning. Refer to Appendix O (Article 1020.04) to review the self-consolidating concrete specifications.

The Contractor is reminded that when a trial mixture is done, the water in admixtures shall be taken into account. Refer to 2.6 “Adjusted Basic Water Requirement and Water/Cement Ratio”.

A trial mixture may be mixed in the laboratory according to AASHTO R 39 or in the field with actual equipment that will be used. The volume of the laboratory trial mixture is determined by the laboratory equipment. The volume of the field trial mixture shall be a minimum of 2 yd$^3$ (1.5 m$^3$), but 4 yd$^3$ (3.0 m$^3$) is strongly recommended to more accurately evaluate the influence of mixing.

The Portland Cement Concrete (PCC) Laboratory used to perform a trial mixture shall be approved according to the Bureau of Materials and Physical Research Policy Memorandum, “Minimum Private Laboratory Requirements for Construction Materials Testing or Mix Design.” Field equipment used to perform a trial mixture shall be approved according to the Bureau of Materials and Physical Research Policy Memorandum, “Approval of Concrete Plants and Delivery Trucks.”

For the trial mixture, it is recommended to batch the mixture at or near the maximum water/cement ratio. The air content should be within 0.5 percent of the maximum allowable specification value. Since it is difficult to entrain air in slipformed concrete, a value below the midpoint of the range is permissible. The slump should be within the allowable specification range. If batching self-consolidating concrete (SCC), applicable SCC tests should be within the allowable specification range. Determine the concrete temperature and if desired, perform a unit weight test which also provides yield.

It needs to be mentioned that concrete temperature will have a significant influence on strength gain. If a cold weather concrete mix is being developed, a temperature in the 50 to 60 °F (10 to 16 °C) range may be more appropriate for the trial mixture. The same may be said for developing a warm weather concrete mix with a concrete temperature in the 80 to 90 °F (27 to 32 °C) range.

Once the mix design is within the allowable tolerance for slump and air content, or applicable SCC tests, evaluate the mix for consistency, plasticity, and workability. After this is done, make strength specimens. The Contractor has the option to make compressive, or flexural, or compressive and flexural strength specimens. The Contractor is advised that in some instances flexural strength is specified, and compressive strength may be used only with the approval of the Engineer. Refer to Articles 503.05 and 503.06 of the Standard Specifications for this situation. As a minimum, make strength specimens to determine the test of record. The test of record shall be the day indicated in the Standard Specifications, and is the minimum
required strength. However, the Department recommends the development of a strength curve with testing at 3, 7, 14, 28, and 56 days. (Note: A 56 day break is not needed for a cement only mixture.) In the case of patching mixes, testing is measured in terms of hours. Therefore, a strength curve should be generated as recommended by the Engineer. An average of a minimum of two strength breaks are required for the test of record, or for testing at other times.

After the Contractor has evaluated the test results for specification compliance and the characteristics of the mix for field placement, the Contractor has three options. The mix design can be accepted, adjusted, or re-designed. If the mix design is adjusted or re-designed, another trial mixture is recommended.

Since the Department’s mix design method is very conservative, including replacement of cement with finely divided minerals at lower levels, a statistical analysis of strength test results is not normally performed. This is due to strength test results which far exceed the minimum strength requirement. However, the American Concrete Institute (ACI) has developed a statistical method to determine a mix design target strength. Thus, a statistical analysis of strength is recommended for the Department’s mix design method. Refer to 7.0 “Determining the Mix Design Target Strength” for additional information.
7.0 DETERMINING THE CONCRETE MIX DESIGN TARGET STRENGTH

A statistical analysis of strength is strongly recommended when the mix design lacks Department historical data on the proposed proportions or materials being used.

The mix design target strength is defined as the average strength the concrete mix must attain to ensure the specified strength is met. In other words, the mix design target strength is a value higher than the minimum strength requirement. The mix design target strength is based on statistics, and will vary between concrete producers. The purpose of the target strength is to allow for variations in water, air content, aggregate gradation, concrete mixing, producer quality control, and other parameters which affect strength. The mix design target strength ensures that the variations will not cause the strength test results to drop below the minimum specification strength requirement.

The mix design target strength must be adjusted high enough above the minimum specification strength requirements to ensure acceptable concrete. In order to ensure this, the average strength of a concrete mix must be greater than the minimum required strength. Note, “average” strength implies that half of the samples tested are stronger than the average, and half of the samples tested are weaker than the average. Ultimately, the adjustment of the average to obtain the target strength for a given mix design depends on the precision of test results. The precision is quantified as the standard deviation from a series of test results on a similar mix design. Refer to Appendix N “Average and Standard Deviation” for additional information.

Procedures for determining the mix design target strength from the minimum specification strength requirement can be found in the ACI Building Code (ACI 318), summarized below:

- The average strength of any three consecutive tests* may not be below the specified value of compressive strength, $f'_c$.
- The strength of any one test* may not exceed 500 psi (3,450 kPa) below $f'_c$ when $f'_c$ is 5000 psi (34,475 kPa) or less; or may not exceed 0.10 $f'_c$ below $f'_c$ when $f'_c$ is more than 5000 psi (34,475 kPa).

* A test is the average of two cylinders.

To achieve these criteria, the mix design target strength ($f'_{cr}$) is adjusted upwards of $f'_c$.

Using the above criteria, there is only a 1 in 100 (1 percent) chance that the average of any three consecutive test values will be less than the specified strength. In addition, there is only a 1 in 100 (1 percent) chance that the strength of any one test will be more than 500 psi (3,450 kPa) below the specified strength when $f'_c$ is 5000 psi (34,475 kPa) or less; or will be more than 0.10 $f'_c$ below the specified strength when $f'_c$ is more than 5000 psi (34,475 kPa).

In order to calculate the mix design target strength, the standard deviation ($S$) must be determined. The standard deviation shall be based on: actual tests of the mix design using materials, quality control procedures, and conditions similar to those expected; test results within 1,000 psi (6,900 kPa) of the strength requirement for the mix design; and at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests are
required. For 30 tests, this means that 30 separate batches of concrete have been tested. The time period for the 30 tests may be up to one year, or as determined by the Engineer.

The standard deviation shall be based on at least 30 test results. Smaller data sets may be used when a modification factor is applied to $S$ as follows:

<table>
<thead>
<tr>
<th>Number of Tests</th>
<th>Modification Factor for $S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 30$</td>
<td>1.00</td>
</tr>
<tr>
<td>25</td>
<td>1.03</td>
</tr>
<tr>
<td>20</td>
<td>1.08</td>
</tr>
<tr>
<td>15</td>
<td>1.16</td>
</tr>
</tbody>
</table>

After the standard deviation is determined, the mix design target strength can be calculated using the larger value from the following two equations:

For $f'_c \leq 5000$ psi (34,475 kPa):
- $f'_{cr} = f'_c + (1.34 \times S)$ (English and Metric), or
- $f'_{cr} = f'_c + (2.33 \times S) - 500$ psi (English); $f'_{cr} = f'_c + (2.33 \times S) - 3,450$ kPa (Metric)

For $f'_c > 5000$ psi (34,475 kPa):
- $f'_{cr} = f'_c + (1.34 \times S)$ (English and Metric), or
- $f'_{cr} = 0.90f'_c + (2.33 \times S)$ (English and Metric)

If there are less than 15 tests or no test data available, the mix design target strength is determined as follows:

<table>
<thead>
<tr>
<th>Less Than 15 Tests or No Test Data Available:</th>
<th>Mix Design Target Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>If $f'_c &lt; 3,000$ psi</td>
<td>$f_{cr} = f'_c + 1,000$ psi</td>
</tr>
<tr>
<td>If $f'_c$ is 3,000 – 5,000 psi</td>
<td>$f_{cr} = f'_c + 1,200$ psi</td>
</tr>
<tr>
<td>If $f'_c &gt; 5,000$ psi</td>
<td>$f_{cr} = 1.10f'_c + 700$ psi</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Less Than 15 Tests or No Test Data Available:</th>
<th>Mix Design Target Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>If $f'_c &lt; 20,685$ kPa</td>
<td>$f_{cr} = f'_c + 6,895$ kPa</td>
</tr>
<tr>
<td>If $f'_c$ is 20,685 – 34,475 kPa</td>
<td>$f_{cr} = f'_c + 8,274$ kPa</td>
</tr>
<tr>
<td>If $f'_c &gt; 34,475$ kPa</td>
<td>$f_{cr} = 1.10f'_c + 4,826$ kPa</td>
</tr>
</tbody>
</table>

Per ACI, $f'_c$ is based on 28 day tests or as otherwise specified. For Department mix designs, $f'_c$ will frequently be based on 14 day tests for 4000 psi (4,650 kPa) or less and 28 days for greater than 4000 psi (4,650 kPa).
8.0 REQUIREMENTS FOR CONCRETE DURABILITY TEST DATA

The Department does not normally test concrete for freeze/thaw and salt scaling durability because of the following requirements:

- Concrete mix design procedures are specified.
- Concrete mix design parameters are specified, such as minimum cement, maximum finely divided minerals, maximum water/cement ratio and amount of air entrainment.
- Concrete coarse and fine aggregates are specified to be Class A Quality, and coarse aggregates must be freeze/thaw durable for certain construction items.

This is also why the Department does not normally perform trial mixtures, calculate target strengths, or require trial batches for non-experimental mix designs.

If the Contractor desires to create a new concrete mix design which is not within the mortar factor limits as listed in 2.8.2.3 “Design Mortar Factor”, durability test data will be required by the Engineer. In no case shall the mortar factor exceed 0.86 for Class BS concrete, or the fine aggregate portion exceed a maximum 50 percent by weight (mass) of the total aggregate used.

The Contractor shall have the durability tests performed by an independent laboratory accredited by the AASHTO Materials Reference Laboratory (AMRL) for Portland Cement Concrete. Durability test data shall consist of the following:

- The new concrete mix design shall be tested according to Illinois Modified AASHTO T 161, Procedure A or B. The new concrete mix design shall have a relative dynamic modulus of elasticity which is 80 percent of the initial modulus, after 300 cycles.
- The new concrete mix design shall be tested according to Illinois Modified ASTM C 672. An identical control mix shall be tested except it shall have 565 lb/ yd³ (335 kg/m³) of cement and no finely divided minerals. The average visual rating of the control mix design, divided by the average visual rating of the new mix design shall not exceed 0.8 after 60 cycles.
9.0 DEPARTMENT CONCRETE MIX DESIGN VERIFICATION

9.1 VERIFICATION BY THE ENGINEER

A new portland cement concrete (PCC) mix design will be verified by the Engineer from test information provided by the Contractor (optional), testing performed by the Engineer, applicable Department historical test data, target strength calculations, and previous Department experience.

For a PCC mix design previously developed by the Engineer or Contractor, the Engineer will verify the mix design if the Department’s historical test data shows compliance with specification requirements.

9.2 TESTING PERFORMED BY THE ENGINEER

For a new PCC mix design to be verified, the Engineer may require the Contractor to provide a batch of concrete for testing if one of the following applies:

- Any time the Engineer has a concern the mix design will not meet minimum strength requirements. As an example, this may occur for a mix that will be used in cool weather or requires high-early-strength.

- Any time the Engineer has a concern the mix design will not provide adequate workability, consistency, and plasticity in the field. As an example, this may occur when the mix is to be pumped or stone sand is to be used.

- Any time the District lacks experience or historical test data for the design parameters, gradations, or material sources used in the mix design. The Contractor has submitted a mix design which meets all Department requirements.

- Except for Class BS concrete, any time the Contractor desires to use a mortar factor outside the limits as listed in 2.8.2.1 “Design Mortar Factor”. Refer to 8.0 “Requirement for Concrete Durability Test Data” for additional information.

In addition, the Engineer may require the Contractor to provide a trial batch per Articles 1001.01(b), 1001.01(c), 1020.04 Note 12, 1020.05(c)(1)d., and 1020.05(c)(2)c..

The batch of concrete shall be provided at no cost to the Department.

The Engineer may require the Contractor to provide a sample of coarse aggregate, at no cost to the Department, to check the Contractor’s coarse aggregate voids test value.

The Engineer may require the Contractor to provide material, at no cost to the Department, to perform Illinois Modified AASHTO T 161, Procedure B and Illinois Modified ASTM C 672 to check the Contractor’s durability test data.
9.2.1 Procedure for Trial Batch

The procedure that follows shall be used to perform a trial batch unless specified otherwise in the contract plans.

The trial batch shall be performed in the presence of the Engineer, and the Engineer will perform all tests. The Contractor has the option to perform their own tests. The volume of the trial batch shall be a minimum of 2 yd$^3$ (1.5 m$^3$), but 4 yd$^3$ (3.0 m$^3$) is strongly recommended to more accurately evaluate the influence of mixing. If the mixer has a capacity less than 2 yd$^3$ (1.5 m$^3$), then the volume of the trial batch shall be no less than the capacity of the mixer.

For the conventional concrete trial batch, batch at or near the maximum water/cement ratio as requested by the Engineer. The air content should be within 0.5 percent of the maximum allowable specification value or as requested by the Engineer. Since it is difficult to entrain air in slipformed concrete, consult with the Engineer on an acceptable value. The slump should be within the allowable specification range. Strength will be determined for the test of record, or at other times determined by the Engineer. The test of record shall be the day indicated in Article 1020.04 or as specified. In all cases, strength will be based on the average of a minimum of two breaks. In addition to slump, air, and strength testing, concrete temperature will be determined by the Engineer. Testing will be performed according to Illinois Modified AASHTO T 23, T 119, T 141, T 152 or T 196, T 22 or T 177, and T 309. As an option for additional information, Illinois Modified AASHTO T 121 may be performed.

For the self-consolidating concrete trial batch, batch at or near the maximum water/cement ratio or as requested by the Engineer. The air content should be within 0.5 percent of the maximum allowable specification value or as requested by the Engineer. The slump flow, visual stability index, and J-ring value or L-box blocking ration should be within the allowable specification range. Strength will be determined for the test of record, or at other times determined by the Engineer. The test of record shall be the day indicated in Article 1020.04 or as specified. In all cases, strength will be based on the average of a minimum of two breaks. In addition to the previously mentioned tests, hardened visual stability index and concrete temperature will be determined by the Engineer. Testing will be performed according to Illinois Test Procedures SCC-1, SCC-2, SCC-3, SCC-4, SCC-6, and Illinois Modified AASHTO T 23, T 141, T 152 or T 196, T 22 or T 177, and T 309. As an option for additional information, Illinois Modified AASHTO T 121 may be performed. Refer to Appendix O (Article 1020.04) to review the self-consolidating concrete specifications.
9.2.1.1 Verification of Trial Batch, Voids Test, and Durability Test Data

The trial batch will be verified by the Engineer if Department test results meet specification requirements. The coarse aggregate voids will be verified by the Engineer if the Department test result is within 0.02 of the Contractor’s value. The Contractor’s durability test data will be verified by the Engineer if Department test results meet the requirements of 8.0 “Requirements for Concrete Durability Test Data.”

Note: Based on the concrete temperature used in the trial batch, the Engineer may request another trial batch to take into consideration the year round use of a mix design. For example, a mix design evaluated at a warm concrete temperature may need another evaluation at a cool concrete temperature to show the mix design is appropriate for cold weather.
PORTLAND CEMENT
CONCRETE
LEVEL III
TECHNICIAN COURSE

APPENDICES

Effective: December 1, 1995
Revised: December 1, 2012
APPENDIX A

CONCRETE MIX DESIGN – DEPARTMENT PROVIDED (BDE)

Effective: January 1, 2012

For the “Portland Cement Concrete (BDE)” special provision included in this project, specifically Article 1020.05(a), the Contractor has the option to request the Engineer determine mix design material proportions for Class PV, PP, RR, BS, DS, SC, and SI concrete. A single mix design for each class of concrete will be provided. Acceptance by the Contractor to use the mix design developed by the Engineer shall not relieve the Contractor from meeting specification requirements.

80277
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# APPENDIX B

## PCC MIX DESIGN

### COMPUTER PRINTOUT AND INSTRUCTIONS

**PROGRAM:** DTGMIRFD  **PCC MIX DESIGN**  **MMTY3110.DOC**

**TRANS:** 110  **CREATE, UPDATE, DELETE SCREEN**

**SCREEN:** DTY03110  *(NEW 7/09/96)*

**ACTIVATED:** /FOR DTY03110

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NOTES: 1). Messages:
- ?? indicates required info is missing.
- $$ indicates illegal field contents.
- highlighted fields must be numeric.

**LEGEND**
- / - Represent Calculated fields; '/'s would NOT display on Create\Update screen.
- ^ - Represent the decimal position within a field; '^'s would NOT display on screen.
- > - Represent new fields and or labels; '>'s would not appear on the screen.
- _ - Represent INPUT fields and locations; would be displayed on Create screen.
1. **Create**: This field may be left blank or a “Y” may be entered. As soon as this screen is fully metricated, the cursor will start in the “Calc” field. Since this is a create transaction, update and delete are not available. Once a mix design has been used, it should never be deleted.

2. **Cal**: Calculation flag. Enter “Y” to have the screen calculate the design. Type “N” and press “Enter” in order to manually enter data into all fields. Once “Enter” has been pressed, the “Calc” field may not be changed in the create mode. This is a new field that is not currently displayed but will be after the screen conversion is complete.

3. **PCC Mix #**: Mix design number. Example: 82PCC1234. Any combination of letters and numbers may be used in the last four digits.

4. **Material**: Material code for the concrete mix. This should always be metric. Example: 21601M or 21605M.

5. **Material code name**: Based on the input material code, MISTIC displays the associated material code name.

6. **Effect**: Effective date of the mix design, “mmddyy.” This represents the date the mix design was available for use.

7. **Ref Design #**: Reference mix design number. If the mix design that is being created is similar to another one, then the similar design number can be entered here. When the “Enter” key is pressed all the design, component and remarks data will be automatically pulled from the referenced design into the new design. The data can be adjusted after entering a “N” in the process field. This will be working in the near future.

8. **Class**: Class of concrete. Example: BD for bridge deck (see spec book, pages 678-681). This field has five occurrences

9. **Last Yr Used**: This is the last year the mix design was used. **This is not an input field.** In the future, the year will be inserted/updated automatically each time the 654 screen creates a new record.

10. **Term**: Termination date of the mix design, “mmddyy.” If a 654 or 655 transaction uses a sample date greater than the termination date of a mix design, then a warning message will be displayed.

11. **Resp**: Responsible location. Enter the digit “9” followed by the district number. Based on the number entered, MISTIC will generate the responsible location name.

12. **Resp Name**: Based on the input responsible location number, MISTIC will display the associated responsible location name.

13. **Lab**: Laboratory associated with the creation of the design. Based on the number entered, MISTIC will generate the laboratory name. Example: FP, for district paper designs; DI, for district laboratory; PP, for producer paper designs; PL, producer laboratory designs etc. This field is not required but it should be used.
14. **Lab Name:** Based on the input lab acronym, MISTIC displays the associated lab name.

15. **Reviewed by:** Name of the person that has reviewed the design.

16. **Dflag:** Delete flag. A "D" should be entered if the mix design is no longer valid or no longer being used.

17. **Mix Prod:** Concrete mix producer number, Example: 1945-01. Based on the number entered, MISTIC will display the concrete mix producer name when the screen is processed. Optional field.

18. **Mix Prod Name:** Based on the input mix producer number, MISTIC will display the associated mix producer name.

19. **Contract:** Contract number. This may be filled in for a contract specific mix design. Optional field.

20. **Batch, CU m:** Batch size in cubic meters. This field should always be filled in with the number "1".

21. **Adx:** Admixture type. Enter as follows: "W" = water reducer, "S" = superplasticizer, "R" = Retarder

22. **H₂O% Red:** Percentage of water reducer used. Example: 2.5.

23. **Fine Mod:** Fineness modulus of the fine aggregate used in the mix design. Example: 2.36. Optional field.

24. **% Air:** Percentage of air entraining. Example: 1.5.

25. **% Voids:** Percentage of voids in the coarse aggregate used in the mix design, entered as a decimal. Example: 0.42.

26. **(Z) Cement:** Theoretical or original/target cement quantity in kilograms per cubic meter. This will not be the actual cement quantity if the mix contains any cement replacement products (fly ash, GGBF slag, microsilica, etc.) Conversion Example: 6.05 cwt/yd³ * 59.327583 = 359 kg/m³, 605 lbs./yd³ * 0.593276 = 359 kg/m³.

27. **Mortar Factor:** Ratio of the volume of the mortar to the coarse aggregate volume. Example: .80

28. **Type, Ash:** Single letter designation for the type of fly ash used in the mix design. Use "C" or "F".

29. **Type, FA:** Single letter designation for the type of fine aggregate. Related to the relative angularity. Use "A", "B", or "C".
30. * H₂O L/kg, FA: Water requirement for fine aggregate in liters per kilogram of cement/cementitious materials. This value is based on what letter is used in the "Type, FA" field. “A” = .426 (5.1), “B” = .442 (5.3), “C” = .459 (5.5) Conversion: gallons/cwt * .0834541 = liters/kg

31. * H₂O L/kg, CA: Water requirement for coarse aggregate in liters per kilogram of cement/cementitious material. For gravel, “0” is commonly used; for crushed stone, “0.2” is commonly used. Use the same metric conversion as fine aggregate 0.2 gal/cwt * .0834541 = 0.017 liters/kg.

32. Abs. Vol, CA,B: Absolute volume of coarse aggregate per cubic meter of concrete. Calculated field. The letter “B” is also known as \( V_{CA} \) in 2.10 “Summary of Mix Design Equations”.

33. Abs. Vol, FA,A: Absolute volume of fine aggregate per cubic meter of concrete. Calculated field. The letter “A” is also known as \( V_{FA} \) in 2.10 “Summary of Mix Design Equations”.

34. * Material: Component material codes. There are six occurrences of this field. All material codes must be metric (“M” in the 6th position). All aggregate material codes should be “A” quality or superstructure quality. Fly ash, ground granulated blast furnace slag, or microsilica should be input in the 5th occurrence. The cement material code should always be in the 6th occurrence. MISTIC will check the component material for being an acceptable product under the producer

35. * Prod No: Component material producer number. It is required for all aggregate and fly ash components but it is not required for cement.

36. Prod Name: Component material producer name. This is not an input field. Based on the producer number input, MISTIC will display the associated producer name.

37. * Sp G: Specific gravity of each component material. The specific gravity value should be entered to the nearest .001. Example: 2.675. The specific gravity to be used for cement is 3.150.

38. * %Blend/Z Ratio: This field has two uses: 1) %Blend for aggregate components - when using a blend of coarse aggregates or a blend of fine aggregates, the blend percentage must be entered for each component type that has a blend. Example: blending CA11 and CA16 @ 75%/25%—a 75 must be entered for the CA11 and a 25 for the CA16. The same would be true for fine aggregates. If there is not a blend, then the value should be “100”. Each component must have a value or the weights will not be calculated! 2) Z Ratio for Fly ash and Cement components - when using fly ash the percentage of cement being replaced should be entered in this field for the fly ash material code. The remaining percentage should be entered for the cement. Example: 15 for fly ash and 85 for cement. If there is not any fly ash in the mix, then the value for cement should be “100”.

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39. **% Moist/Repl:** This field has two uses: 1) % Moisture for aggregate components - the percentage moisture greater or less than saturated surface dry must be entered using a “+” or “-” sign. Example: +1.00. If the value is zero, it should be entered as “0” without a “+” or “-” sign. 2) Replacement for fly ash and cement - for fly ash enter the replacement ratio. Example: +1.5 or +1.25. A “+1”, should always be entered for cement. The requirement for the “+” will be removed in the near future.

40. **kg/CU m, SSD:** The saturated surface dry weight in kilograms per cubic meter for each component. Conversion: lbs/yard³ * .593276 = kg/m³. Calculated field.

41. **kg/CU m, ADJ:** The moisture adjusted weight in kilograms per cubic meter for each component. Calculated field.

42. **lbs/CU YD:** The weight of each component in pounds per cubic yard. Calculated field.

43. **ADJ H₂O, kg:** Adjusted water content in kilograms per cubic meter. Conversion: lbs/yard³ * .593276 = kg/m³. Calculated field.

44. **ADJ H₂O, lbs:** Adjusted water content in pounds per cubic yard. Calculated field.

45. **Mix-H₂O:** Mix water in liters per kilogram of cement. This is the sum of the water requirements for fine (FA,A) and coarse (CA,B) aggregate. Calculated field.

46. **Ash/Cmt Wt:** Ratio of the weight of fly ash (kg) to the weight of cement (kg) per cubic meter. Calculated field.

47. **Total Batch Wt, kg:** Total weight of the components (including water) in kilograms per cubic meter. Calculated field.

48. **Total Batch Wt, lbs:** Total weight of the components (including water) in pounds per cubic yard. Calculated field.

49. **Red Mix H₂O:** Reduced mix water. This is the mix water reduced by the amount of water reducer that has been added to the mix. Calculated field.

50. **Total Cementitious Matl:** This is the weight of the cement and the fly ash per cubic meter. This value is the sum of the cement and fly ash from the adjusted weight column. If only cement is used, then this value will be the same as the “Z Factor”. If both cement and fly ash are used, then this value will be larger than the “Z Factor”. Calculated field.

51. **Theo. Water, kg:** Theoretical water in kilograms per cubic meter. Calculated field.

52. **Theo. Water, lbs:** Theoretical water in pounds per cubic yard. Calculated field.

53. **Remarks:** First remarks line. When required to mitigate against alkali-silica reaction (ASR), indicate the mixture option selected for reducing the risk of deleterious reaction. Additionally, if applicable, indicate if synthetic fibers will be used in the mixture.

54. **Theo H₂O (Gal):** Theoretical water in gallons per hundredweight of cement. Calculated field.
55. **Remarks:** Second remarks line.

56. **Adj H₂O (Gal):** Adjusted water in gallons per hundredweight of cement. Calculated field.

**Footnotes:**

* - Denotes a required input field

**Additional Note:**

Any fields labeled “calculated” are currently input fields but will become calculated fields after the enhancement of this screen is completed (in the very near future).
APPENDIX B-A

PCC MIX DESIGN SOFTWARE TUTORIAL

(Version 2.3.5.1)

For help, comments, and/or suggestions, please contact:

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Springfield, Illinois 62704
Phone: (217) 782-7200
e-mail: DOT.PCCMIX@illinois.gov

!!! IMPORTANT !!! This spreadsheet utilizes macros. Depending on Excel’s security settings, the macros may not be enabled. To change the macros settings for Excel, refer to the steps found at the end of this tutorial.

General
This spreadsheet is designed to calculate and report PCC mix designs for submittal to IDOT. The spreadsheet is comprised of data inputs based on the mix design methodology provided in the PCC Level III Technician course manual.

Buttons are provided for ease of navigation through the design process, and use of these buttons is recommended as they insure proper operation throughout the design process. However, use of the worksheet tabs, found at the bottom of the Excel screen, will work just as well.

The blue-shaded areas are cells which require data input, green-shaded areas are optional (unless required by your District), and white cells are calculation fields, which are password protected from accidental overwriting.

Throughout the spreadsheet, comments have been interspersed to offer hints on where to find relevant information. To view comments, hold the cursor over the red tags found in the upper right hand corner of commented cells, as shown below. These comments generally refer to sections of the Course Manual; however, it should be noted that the Department’s Standard Specifications and Special Provisions take precedence.

Figure 1. Example of a comment; note red flag, which indicates the cell has a comment.

Tutorial Mix Design
This tutorial also includes notes for how to input the example mix design discussed in Section 2.9 “EXAMPLE PROBLEM” of the Course Manual. If you follow the notes in order as they are presented herein, you should successfully create a basic PCC paving mix design while also being introduced to all of the spreadsheet’s functions and capabilities.
Step 1. Design Information

The Design Information page is important to understanding the who-what-where of the mix design. This is where the designer decides in which units of measure the mix will be designed, what type of concrete it is, for what Classes of concrete it is valid, and those responsible for the mix design.

Fit to Screen [button]: Click this button to optimize each page of the mix design program for viewing on your screen.

English/Metric [toggle]: Toggle button for selecting the units of measure for the mix design’s inputs. From this point on, all data inputs will have to be entered in the chosen units of measure. However, the design will be reported in both units of measure on the different design reports generated.

EXAMPLE PROBLEM
Assuming most of us are more comfortable using English units of measure (lbs, yd³, etc.), the example mix design will be designed using English units.

Click on the ENGLISH toggle button.

Mix Design No.: Alphanumeric designation (up to nine characters in length) provided by the designer. This is the Producer’s or Contractor’s self-designated mix design number; this is not the mix design number assigned by IDOT, see “IDOT Mix Design No.” below.

EXAMPLE PROBLEM
Because this is the Producer’s or Contractor’s mix design number, any reasonably succinct and unique identifier can be used here, as long as it is no more than nine characters long. For this example, we will use PMC0001PV (i.e., Pave Masters Co. paving mix #1).

IDOT Mix Design No.: Nine character alphanumeric mix design number reported to the Department’s MISTIC database. This number will be assigned by your District to all approved mix designs.

EXAMPLE PROBLEM
Because this mix design number is assigned by the District upon approval, this cell reads Not yet assigned.

Date Created: The date the mix design was created.
Concrete Code: Select the material code for the concrete mix. This code is used by the Department’s MISTIC database to designate the type of concrete.

**EXAMPLE PROBLEM** Because this mix will utilize Type I portland cement and Class C fly ash, the appropriate Concrete Code to select from the drop-down list is 21605.

Class: Select up to five Classes of concrete, for example, “PV” for PCC pavement.

**EXAMPLE PROBLEM** Because this mix will be used for a continuous reinforced portland cement concrete pavement, the appropriate Class to select is PV.

Responsible Location: District responsible for mix design’s use; for example, “91” for District 1.

**EXAMPLE PROBLEM** Select one of the nine IDOT Districts with which you typically work; for example, select 91 if you often work with District 1 in the Chicago area.

Lab: Laboratory associated with the creation and/or testing of the design. For example: DI for district mix designs, or PP for producer mix designs. Contractors and Producers are to use "Producer" Lab codes. Consultants are to use "Independent" Lab codes.

  **Company Name**: Name of laboratory responsible for creation and/or testing of mix design.
  **Location**: Nearest municipality.

Designer: Name, phone number, and email of person that created the design.

Mix Design Producer: MISTIC number and name of producer of the mix design.

IDOT Engineer: This is the IDOT District representative to whom this mix design should be submitted for approval. Consult your District’s Mixtures Control Engineer for more information. See the yellow table to the right of the main input area to modify the names available in the drop-down list.

Contract No.: Optional. Either the five digit contract number, or if it is a local agency contract without a five digit number, then enter the 16 or 17 character MFT (Motor Fuel Tax) contract number.
Step 2. Design Variables
The Design Variables page is where the designer first begins to determine the mix design’s parameters that factor into the mix design calculations.

<table>
<thead>
<tr>
<th>2. Design Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Batch Size</strong></td>
</tr>
<tr>
<td><strong>Cement Factor</strong></td>
</tr>
<tr>
<td><strong>Mortar Factor</strong></td>
</tr>
<tr>
<td><strong>Target Air Content</strong></td>
</tr>
<tr>
<td><strong>Target Slump</strong></td>
</tr>
</tbody>
</table>

Batch Size: Batch size in cubic yards (cubic meters). All mix designs will be created in terms of 1 yd³ (m³).

Cement Factor: Cement quantity in hundredweight per cubic yard (kilograms per cubic meter). Adjustments based on admixture use or underwater placement can be applied using the Cement Factor Adjustment table.

**EXAMPLE PROBLEM**
From Table 2.2.1 in the Course Manual, the cement factor for Class PV concrete from a central mixed plant is 5.65 cwt/yd³.

Also, from Section 2.2.2, a cement factor reduction of 0.30 cwt/yd³ can be applied because a water-reducing admixture will be used. Enter 0.30 in the appropriate box of the Cement Factor Adjustment table.

Thus, the final, adjusted cement factor is reduced to 5.35 cwt/yd³.

Mortar Factor: Refer to Table 2.8.2.3 Design Mortar Factor in the Course Manual.

**EXAMPLE PROBLEM**
From Table 2.8.2.3 in the Course Manual, a mortar factor can be selected for Class PV concrete.

Enter 0.83 as a reasonable starting point.

Target Air Content: Percentage of entrained air in the concrete to improve durability. Refer to Table 2.7.1 Air Content in the Course Manual.

**EXAMPLE PROBLEM**
From Table 2.7.1 in the Course Manual, the midpoint of the air content range for Class PV concrete is 6.5%.

Target Slump: Enter the target slump in inches (mm). Refer to Table 6.1 Slump in the Course Manual.

**EXAMPLE PROBLEM**
From Table 6.1 in the Course Manual, the slump range for Class PV concrete is 2 to 4 inches, except when slipform it is 1/2 to 2 1/2 inches (Table 6.1, Note 1). As noted in Section 6.1, experience has shown that a slump of 1/2 to 1 1/2 inches at the paver is typical for slipformed pavement construction, but many Contractors desire 1-1/2 inches to obtain a smooth pavement. Enter 1.5 inches.
**Determine Water Content**
First, using the toggle switch, select either the **Standard Method** or the **w/c Ratio Method**.

The **Standard method** requires the designer to enter fine and coarse aggregate water requirements, as well as percent water reduction. Refer to Section 2.5.1 Water Requirement in the Course Manual for more information.

Alternatively, the **w/c Ratio Method** will determine mix water based on the water/cement ratio (w/c) entered and the total content of cement and finely divided minerals. No water adjustment needs to be entered as it will be back-calculated based on the w/c ratio and aggregate water requirement inputs.

*If the Standard Method has been selected, refer to the following inputs:*

<table>
<thead>
<tr>
<th>Determine Water Content:</th>
<th>Typical FA Water Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA Type:</td>
<td>Type A 5.1 gal/cwt</td>
</tr>
<tr>
<td></td>
<td>Type B 5.3 gal/cwt</td>
</tr>
<tr>
<td></td>
<td>Type C 5.5 gal/cwt</td>
</tr>
</tbody>
</table>

| FA Water Req.: Water requirement for fine aggregate in gallons per hundredweight (liters per kilogram) of cement and finely divided minerals. This value is based on the type of fine aggregate. For example, 5.1 gal/cwt (0.426 L/kg) is typical for Type “A” fine aggregate, as shown in the table, Typical FA Water Requirements. |
|---------------|-------------------------------|
| EXAMPLE PROBLEM | Because this mix will utilize a Type “B” fine aggregate, select B from the drop-down list. |

| CA Water Req.: Water requirement for coarse aggregate in gallons per hundredweight (liters per kilogram) of cement and finely divided minerals material. This value is based on the type of coarse aggregate. Typical values are provided in the table, Typical CA Water Requirements. |
|---------------|-------------------------------|
| EXAMPLE PROBLEM | Because this mix will utilize a non-crushed gravel coarse aggregate, the typical water requirement is 0.0 gal/cwt. |

| Water Reduction: Percentage of water adjustment (typically a reduction) taking into account various factors, such as admixture use, cement and finely divided mineral content, air content, etc. Note that because this input is referred to as a “reduction”, the value entered may seem counter-intuitive; that is, a water reduction should be entered as a positive value, while a water addition should be entered as a negative value. For example, enter “10.0” for a 10 percent water reduction, and enter “-10.0” for a 10 percent water addition. |
|---------------|-------------------------------|
| EXAMPLE PROBLEM | Because this mix will utilize a water-reducing admixture to provide a target water reduction of 6%, enter 6.0.  
Note: If for some reason this mix needed a 6 percent water addition, you would have entered -6.0. |
If the W/C Ratio Method has been selected:

Enter W/C Ratio: When w/c Ratio Method is toggled, this field appears. Enter the target water/cement ratio that the design water will be based on; for example, 0.42.

It is still important to select the appropriate FA Type, as well enter the CA Water Requirement, so as to allow the spreadsheet to back-calculate the water reduction on the mix design reports.

### EXAMPLE PROBLEM

Another way to determine mix water is based on inputting a target water/cement ratio (w/c):

In this example, per Table 2.6.1 in the Course Manual, the maximum w/c for Class PV concrete is 0.42.

Also, by selecting the appropriate fine aggregate type (“B”) and entering a reasonable water requirement for the coarse aggregate, the water reduction will be back-calculated on the final mix design reports.

Fineness Mod: (Optional) Fineness modulus of the fine aggregate used in the mix design; for example, 2.36. Fineness modulus is for informational purposes only; fineness modulus does not factor into proportioning calculations.

Admixture: Choose an admixture type.

### EXAMPLE PROBLEM

Because this mix will utilize a water-reducing admixture to meet the water/cement ratio requirement, select **W – Water Reducer** from the drop-down list.

Fly Ash Class: Choose the fly ash type used in the mix design, if applicable.

### EXAMPLE PROBLEM

Because this mix will utilize Class C fly ash, select **C** from the drop-down list. If this example did not utilize any fly ash, you would select “n/a”.
### Step 3. Aggregate Information

The Aggregate Information page is where the designer enters all fine and coarse aggregate information. Note that although up to six aggregate materials can be accommodated by this spreadsheet program, the Department’s MISTIC database only allows a total of six materials, including cement and finely divided minerals. For example, four aggregates, one cement, and one finely divided mineral (e.g., fly ash); or three aggregates, one cement, and two finely divided minerals (e.g., fly ash and microsilica).

#### Material:
Aggregate material codes. Coarse and fine aggregates may be entered in any order, except as required by your District. For more information regarding aggregate material codes, refer to form BMPR MI504 “Field/Lab Gradations”.

**EXAMPLE PROBLEM**
Although in practice you should know the material codes for your aggregate components, for the example problem as given in the Course Manual, we will have to assume valid material codes.

- Fine aggregate: Because this mix is utilizing a Type B FA 1, a reasonable material code is 027FA01, which is the code for an “A” quality natural sand meeting the gradation criteria for FA 1 per Article 1003.01(c).

- Coarse aggregate: Because this mix is utilizing a non-crushed gravel CA 7, we can reasonably assume the material code is 020CA07, which is an “A” quality gravel (non-crushed) meeting the gradation criteria for CA 7 per Article 1004.01(c).

#### Producer Number:
Aggregate producer number. This field is required for all aggregate components.

#### Producer Name:
Aggregate producer name.

#### Specific Gravity:
Saturated Surface Dry (SSD) specific gravity of each aggregate.

**EXAMPLE PROBLEM**
The example problem as given in the Course Manual indicates that the saturated surface-dry specific gravities for the fine and coarse aggregate components are 2.66 and 2.68, respectively.
**Agg. Moisture (%):** Moisture of aggregates relative to SSD condition. If the percentage moisture is drier than SSD, it must be entered using a negative value (e.g., -1.00).

**EXAMPLE PROBLEM** | No aggregate moisture is indicated in the example problem as given in the Course Manual. Thus, it can be left blank.

**% Blend:** Percent blend for aggregate components. If only using one coarse aggregate and one fine aggregate material, enter “100” for each. On the other hand, if blending coarse aggregate materials, say, CA 11 and CA 16 at 75 and 25 percent, respectively, enter a "75" for the CA 11 and a "25" for the CA 16. Similarly, if blending fine aggregate materials. Do not blend coarse and fine aggregate, except as noted below for CAM II:

**Note:** For CAM II designs only—Recommended % Blend of coarse-to-fine aggregate: 50-50 when using CA 7, CA 9, or CA 11; 75-25 when using CA 6; and 100-0 (i.e. no fine aggregate) when using CA 10. For example, when using CA 6 and FA 1, enter “75” for the CA 6 and “25” for the FA 1.

**EXAMPLE PROBLEM** | Because this mix is utilizing one coarse aggregate component and one fine aggregate component (and the mix is not CAM II), enter 100 for coarse aggregate and 100 for fine aggregate, as well.

---

**Step 3a. Voids in Coarse Aggregate**

The Designer has the option to either enter the Voids in Coarse Aggregate directly or calculate the voids by performing Illinois Test Procedure 306, Voids Test of Coarse Aggregate for Concrete Mixtures, which can be found in the Manual of Test Procedures for Materials. However, some Districts may provide a value for general aggregate types, such as “0.36” for gravels.

If calculating the Voids in Coarse Aggregate, enter the “% Absorption”, “Net Weight of Aggregate”, and “Volume of Measure” as determined while following Illinois Test Procedure 306. Consult your District for coarse aggregate “% Absorption.” (The Calibration of Measure is not required for every mix design, but is included for convenience.)

**EXAMPLE PROBLEM**
The example problem as given in the Course Manual notes that the Voids for the coarse aggregate is 0.37.

---

If entering the Voids directly, toggle the “Enter Directly” button and input the appropriate value in the “User-defined” box. **Important:** Enter “1.00” for any mix design that does not contain coarse aggregate.
### Step 4. Finely Divided Minerals & Admixtures Information

This page is where the designer enters all information pertaining to cement and finely divided minerals, as well as chemical admixtures (e.g. air-entraining or water-reducing admixtures).

#### 4. Cement and Finely Divided Minerals Information

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Producer Code</th>
<th>Producer Name</th>
<th>Specific Gravity</th>
<th>Percent Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>37601 Type I, Portland</td>
<td>555-05</td>
<td>City Electric Co.</td>
<td>3.150</td>
<td>70.0</td>
</tr>
<tr>
<td>37801 Fly Ash Class C</td>
<td>555-05</td>
<td>City Electric Co.</td>
<td>2.610</td>
<td>30.0</td>
</tr>
</tbody>
</table>

**Material:** Cement and finely divided mineral (FDM) material codes. Each line is dedicated to a specific material: Line 1 for cement, Line 2 for fly ash, Line 3 for GGBF slag, and Line 4 for miscellaneous (e.g., microsilica).

**EXAMPLE PROBLEM**
Because this mix will utilize a Type I cement and Class C fly ash, Lines 1 and 2 will be used.
- **Cement:** Because this mix is utilizing a Type I cement, select **37601 Type I, Portland** from the drop-down list.
- **Fly ash:** Because this mix is utilizing a Class C fly ash, select **37801 Fly Ash Class C** from the drop-down list.

**Producer Number:** Material producer number. This field is required for all finely divided minerals.

**Producer Name:** Material producer name.

**Specific Gravity:** Specific gravity of each material. The specific gravity of cement is normally assumed to be 3.15. However, for a blended cement, this value should be verified with the District. Specific gravity values for finely divided minerals can be obtained from the Approved List of Suppliers for Finely Divided Minerals.

**EXAMPLE PROBLEM**
The example problem as given in the Course Manual notes that the specific gravity for the fly ash component is **2.61**. Although no specific gravity is given for the cement component, from Section 2.3 in the Course Manual, the specific gravity of cement is normally assumed to be **3.15**.
Percent Blend: When using a blend of cement and finely divided minerals, the blend percentage must be entered for each material. For example, when blending fly ash and cement at 20 and 80 percent, respectively, enter a “20” for the fly ash and an “80” for the cement. If mix is cement only, then enter a “100” for the cement.

**EXAMPLE PROBLEM**

From Section 2.4.1.1 in the Course Manual, the Class C fly ash component can replace up to 30 percent of the cement.

However, we first have to determine if we need to mitigate against alkali-silica reaction (ASR):

From Section 2.4.3 in the Course Manual, it is determined that the component aggregates are Group II (fine aggregate expansion in the >0.16% - 0.27% range and coarse aggregate expansion ≤0.16%). Thus, we are required to use Mix Option 1, 2, 3, 4, or 5.

Because the example problem as given notes that the mix will utilize a cement with alkali content >0.60% and a Class C fly ash, we will use Mix Option 2.

Mix Option 2 requires a minimum 25.0 percent Class C fly ash.

It is decided to use **30 percent** fly ash since fly ash is cheaper than cement, and will provide the most economical mix.

Because the total Percent Blend must equal 100, enter **70.0** for the cement and **30.0** for the fly ash.

---

**Step 5. Admixtures Information**

**Material Code:** Enter admixture material codes here. The 5-digit material code for admixtures can be found on the Approved List of Concrete Admixtures.

**Admixture Type:** Choose admixture type.

**Admixture Name:** Enter admixture product name here.

**Remarks:** Enter key information regarding proposed dosage rates, dosing procedures, etc.

**Step 6. General Mixture Remarks**

**Remarks:** Enter any pertinent information not already covered. When required to mitigate against alkali-silica reaction (ASR), indicate the mixture option selected.

**EXAMPLE PROBLEM**

Because we are required to mitigate against alkali-silica reaction, we must indicate the mixture option selected.

Enter **ASR Mix Option 2, 30% fly ash.**
**Design Report**

Given the inputs, the batch weights are calculated and reported. Three design reports are generated: one in English units of measure, one in metric (SI), and one formatted per the Department’s MISTIC database requirements. Please consult your District for which report(s) to submit for approval.

### ENGLISH UNITS DESIGN REPORT

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PROD NO</th>
<th>PROD NAME</th>
<th>SP G</th>
<th>% BLEN D</th>
<th>% MOIST / REPL</th>
<th>SSD</th>
<th>ADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>027FA01</td>
<td>54321-01</td>
<td>LITTLE ROCKS CO</td>
<td>2.560</td>
<td>100.0</td>
<td>0.00</td>
<td>1160</td>
<td>1160</td>
</tr>
<tr>
<td>020CA07</td>
<td>12345-05</td>
<td>BIG ROCK CO</td>
<td>2.880</td>
<td>100.0</td>
<td>0.00</td>
<td>1947</td>
<td>1947</td>
</tr>
<tr>
<td>37601</td>
<td>566-05</td>
<td>CITY ELECTRIC CO</td>
<td>3.150</td>
<td>70.0</td>
<td>1.00</td>
<td>375</td>
<td>375</td>
</tr>
<tr>
<td>37801</td>
<td>566-05</td>
<td>CITY ELECTRIC CO</td>
<td>2.610</td>
<td>30.0</td>
<td>1.00</td>
<td>165</td>
<td>165</td>
</tr>
</tbody>
</table>

Total cementitious material: 5.40

Theo H2O (gal. lbs): 27.2

Producer: EVERYMAN REDI-MIX CO

### METRIC UNITS DESIGN REPORT

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PROD NO</th>
<th>PROD NAME</th>
<th>SP G</th>
<th>% BLEN D</th>
<th>% MOIST / REPL</th>
<th>SSD</th>
<th>ADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>027FA01</td>
<td>54321-01</td>
<td>LITTLE ROCKS CO</td>
<td>2.560</td>
<td>100.0</td>
<td>0.00</td>
<td>1160</td>
<td>1160</td>
</tr>
<tr>
<td>020CA07</td>
<td>12345-05</td>
<td>BIG ROCK CO</td>
<td>2.880</td>
<td>100.0</td>
<td>0.00</td>
<td>1947</td>
<td>1947</td>
</tr>
<tr>
<td>37601</td>
<td>566-05</td>
<td>CITY ELECTRIC CO</td>
<td>3.150</td>
<td>70.0</td>
<td>1.00</td>
<td>375</td>
<td>375</td>
</tr>
<tr>
<td>37801</td>
<td>566-05</td>
<td>CITY ELECTRIC CO</td>
<td>2.610</td>
<td>30.0</td>
<td>1.00</td>
<td>165</td>
<td>165</td>
</tr>
</tbody>
</table>

Total cementitious material: 325

Theo H2O (kg. lbs): 130.5

Producer: EVERYMAN REDI-MIX CO

### Additional Information

Lab: PAVE MASTERS CO
Location: CHICAGO
Target: 36.1

Designer: SMITH
Design Phone: 555-555-5555
Designer Email: jsmith@gmail.com

Printed: 12/7/2012
Note: The MISTIC Report has three input fields to be completed upon receiving approval from the District.

Additionally, there is a tab for help determining the percent water adjustment taking into account various factors. However, this table is for informational purposes only. The water adjustment calculated using this table is not referenced by any of the spreadsheet’s mix design calculations. To use the water adjustment calculated using this table, the value must be entered on the Design Variable tab.
Changing Macro Security Settings in Microsoft Excel

Note: Any macro settings changes you make in Excel apply only to Excel and do not affect any other Office program.

To change the macro security settings in Excel 2007/2010:

2. In the Macro Settings category, under Macro Settings, click the 2nd option to Disable all macros with notification.
   This option initially disables macros, but alerts you if macros are present. This way, you can choose when to enable the macros on a case by case basis.
3. Now, close Excel, and re-open the PCC Mix Design spreadsheet.
   You should now get a Security Warning (below), click the Options button, then click to Enable this content, and finally click OK to close the window.

* If the Developer tab is not displayed…

For Excel 2007:
1. Click the Microsoft Office Button.
2. Click Excel Options (bottom right corner)
3. In the Popular category, under Top options for working with Excel, click Show Developer tab in the Ribbon.

For Excel 2010:
1. Click the File tab, click Options, and then click the Customize Ribbon category.
2. In the Main Tabs list, check the Developer, and then click OK.
3. Click any other tab to return to your file.

To change the macro security settings in Excel 2013:

When you open a file that has macros, a yellow Security Warning (above) appears with a shield icon and an Enable Content button: click Enable Content. The file opens and is a trusted document.
Changing Macro Security Settings in Microsoft Excel
(continued)

Older versions of Excel:

1. To access the macro security settings in older version of Excel, go to the Tools menu, Options, Security tab, and click on the Macro Security button. The Security window will open as shown:

![Security Window]

2. Click on Medium, then click OK, and close Excel.

3. Re-open the PCC Mix Design spreadsheet. At Medium, whenever you open a file that has macros, a Security Warning (below) appears: click Enable Macros. The file opens and is a trusted document:

![Security Warning]

Macros may contain viruses. It is usually safe to disable macros, but if the macros are legitimate, you might lose some functionality.
APPENDIX C

Illinois Test Procedure 306
Effective Date: April 1, 2008

VOIDS TEST OF COARSE AGGREGATE
FOR CONCRETE MIXTURES

Reference Test Procedure(s):

1. Illinois Specification 101, Minimum Requirements for Electronic Balances
2. AASHTO M 231, Weighing Devices Used in the Testing of Materials
3. AASHTO T 255 (Illinois Modified), Total Moisture Content of Aggregate by Drying
4. ASTM E 29 (Illinois Modified), Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

To maintain brevity in the text, the following will apply:

Example: AASHTO T 255 (Illinois Modified) will be designated as “T 255.”
ASTM E 29 (Illinois Modified) will be designated as “ASTM E 29.”

1. GENERAL

The volume of voids per unit volume of dry rodded coarse aggregate relates experimental data to the theory of proportioning, which produces the amount of coarse aggregate needed in a concrete mixture. Voids may also be defined as the ratio of the volume of empty spaces in a unit volume of dry rodded coarse aggregate to the unit volume of dry rodded coarse aggregate.

All rounding shall be according to ASTM E 29.

2. EQUIPMENT

a. The measure shall be metal, cylindrical, watertight, and of sufficient rigidity to retain its form under rough usage. The top and bottom of the measure shall be true and even, and its sides should be provided with handles. The measure shall have a capacity of 0.014 or 0.028 m$^3$ (0.5 or 1.0 ft$^3$).

b. Tamping Rod—A round, straight steel rod 16 mm (5/8 in.) in diameter and at least 584 mm (23 in.) in length, having the tamping end or both ends rounded to a hemispherical tip the diameter of which is 16 mm (5/8 in.).

c. The balance or scale shall conform to M 231 and Illinois Specification 101. Refer to the requirements for unit weight.
3. PROCEDURE

a. Fill the measure with water at room temperature and cover with a piece of plate glass in such a way as to eliminate bubbles and excess water. The measure shall be calibrated by accurately determining the mass (weight) of water, to the nearest 0.05 kg (0.1 lb.), required to fill it. Calculate the Measure Volume according to Section 5.0.

b. The sample of aggregate shall be obtained and dried according to T 255, and shall be thoroughly mixed. When more than one size coarse aggregate is to be used in a mixture, the test shall be performed on the combination.

c. The measure shall be filled in three equal lifts. Level each lift with the fingers. Each layer shall be rodded 25 times when the measure’s capacity is 0.014 m³ (0.5 ft³) or 50 times when the measure’s capacity is 0.028 m³ (1.0 ft³).

Rodding shall be evenly distributed over the surface of the aggregate. The rodding should knead the layers together by the tamping rod extending slightly into the previous layer. Care shall be taken to rod immediately above the bottom of the measure without striking it.

d. With the final layer, the measure shall be filled to overflowing, rodded, and the surplus aggregate struck off, using the tamping rod as a straightedge.

e. The Net Mass (Weight) of the aggregate in the measure shall then be determined to the nearest 0.05 kg (0.1 lb.).

4. CALCULATIONS

a. The Unit Weight of the coarse aggregate is the Net Mass (Weight) of the coarse aggregate in the measure divided by the Measure Volume. Determine the Unit Weight to the nearest 0.01 kg/m³ (0.01 lb/ft³).

b. The volume of voids per unit volume of oven-dry rodded coarse aggregate is calculated to the nearest 0.01 as follows:

**Metric:**

$$Voids, \ V = \frac{(G_a \times 1000.00) - \text{Unit Wt.}}{G_a \times 1000.00}$$

**English:**

$$Voids, \ V = \frac{(G_a \times 62.37) - \text{Unit Wt.}}{G_a \times 62.37}$$

$$G_a = \frac{G_s}{1 + \frac{A}{100}}$$
Where:  \( \text{Unit Wt.} \) is the unit weight of the coarse aggregate

\( G_a \) is the oven-dry specific gravity calculated to the nearest 0.01

\( G_s \) is the saturated surface-dry specific gravity of the coarse aggregate to the nearest 0.01, which is obtained from the Department’s District office.

\( A \) is the percent absorption of the coarse aggregate to the nearest 0.1, which is obtained from the Department’s District office.

When more than one size coarse aggregate is used in a mixture, calculate the oven-dry specific gravity for each aggregate. Then obtain a weighted average of the oven-dry specific gravity using the following formula.

\[
WAG_a = \left( \frac{a}{100} \times A \right) + \left( \frac{b}{100} \times B \right) + \left( \frac{c}{100} \times C \right) + \ldots
\]

Where: \( WAG_a \) = Weighted Average of Oven-dry Specific Gravity

\( a, b, c \ldots \) = Percent of Total Coarse Aggregate

\( A, B, C \ldots \) = Oven-dry Specific Gravity

The weighted average of the oven-dry specific gravity shall then be used in the Voids formula.

c. The test shall be performed at least twice. Test results with the same measure should check within 0.01.

5. CALIBRATION OF MEASURE

The Measure Volume is calculated to the nearest 0.01 m\(^3\) (0.001 ft\(^3\)) as follows:

\[
\text{Measure Volume} = \frac{M}{W}
\]

Where:  \( M \) = mass (weight) of water required to fill measure, kg (lb.)

\( W \) = unit weight of water (refer to Table 1), kg/m\(^3\) (lb/ft\(^3\))

<table>
<thead>
<tr>
<th>Temperature of Water</th>
<th>kg / m(^3)</th>
<th>lb / ft(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>°F</td>
<td></td>
</tr>
<tr>
<td>15.6</td>
<td>60</td>
<td>999.01</td>
</tr>
<tr>
<td>18.3</td>
<td>65</td>
<td>998.54</td>
</tr>
<tr>
<td>21.1</td>
<td>70</td>
<td>997.97</td>
</tr>
<tr>
<td>23.0</td>
<td>73.4</td>
<td>997.54</td>
</tr>
<tr>
<td>23.9</td>
<td>75</td>
<td>997.32</td>
</tr>
<tr>
<td>26.7</td>
<td>80</td>
<td>996.59</td>
</tr>
<tr>
<td>29.4</td>
<td>85</td>
<td>995.83</td>
</tr>
</tbody>
</table>
This Page Reserved
APPENDIX D

WORKABILITY

1.0 PRINCIPLE FACTORS OF WORKABILITY

Workability is related to the ease of motion of one coarse aggregate particle relative to adjacent particles. The lubricating ability of the mortar depends on the thickness of the mortar layer and the viscosity of the mortar. Refer Figure 1.0.

The thickness of the mortar layer depends on:
- Volume of coarse aggregate.
- Size and surface area of coarse aggregate.
- Shape and surface texture of aggregate particles.
- Volume of mortar.

The mortar volume depends on:
- Water content.
- Volume of cement and finely divided minerals.
- Volume of air.
- Volume of fine aggregate.

The viscosity of the mortar depends on:
- Water content.
- Volume of cement and finely divided minerals.
- Particle shape and fineness of cement and finely divided minerals.
- Shape and fineness of fine aggregate.
- Air content.
- Water-reducing admixtures.
- Rate of hydration (accelerating and retarding admixtures, concrete temperature, cement type and type of finely divided minerals).

Figure 1.0 Mortar Layer Around Coarse Aggregate Particles
2.0 MORTAR AND WORKABILITY

The following sections illustrate the role of mortar and its influence on workability.

2.1 Mortar Illustration

Concrete with low mortar content. This results in increased contact between coarse aggregate particles and decreases workability.

Concrete with high mortar content. This results in decreased contact between coarse aggregate particles and increases workability.

2.2 Mortar and Wall Effect

A higher mortar content is required at rigid boundaries, where the “wall effect” occurs. Examples of boundaries include structural members and pipe walls for pumping.
2.2.1 Mortar and Structural Member
The volume of mortar required for a smooth finish against formed surfaces (i.e. without honeycombing or “bug” holes) depends on the surface area to concrete volume ratio. For example, the volume of concrete decreases as the width of the structural member decreases (assuming all other dimensions are unchanged). However, the wall surface area remains the same. Thus, the reduced concrete volume has less mortar available to ensure a smooth finish. Therefore, a thinner structural member will require a higher mortar content.

As another example, two different structural members may have different dimensions, but require the same volume of concrete. A higher mortar content is required for the structural member with the higher surface area.

2.2.2 Mortar and Pipe Wall
A higher mortar content is required for smaller diameter concrete pump pipelines. For example, a 4 inch (102 mm) diameter pipe has a higher surface area to concrete volume ratio than a 5 in. (127 mm) diameter pipe.
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APPENDIX E

AGGREGATE BLENDING

1.0 AGGREGATE BLENDING

The grading or particle size distribution of an aggregate can have a significant influence on a concrete mixture. The two types of grading are as follows:

- Uniformly Graded – Aggregates which do not have a large deficiency or excess of any particle size.
- Gap Graded – Aggregates which have specific particle sizes omitted, or the specific particle sizes are minimal.

Many Illinois coarse aggregates are gap graded. Illinois gap graded coarse aggregates typically have a small amount of material passing the 1/2 in. (12.5 mm) sieve. Experience has shown that when the percent finer than 1/2 in. (12.5 mm) drops below 40 percent, placement problems (such as for pumping) may occur. In order to improve workability and minimize potential problems, a second coarse aggregate is used.

The grading of both the coarse and fine aggregate has a significant impact on several mix characteristics. The ease of placing, pumping, consolidating, and finishing, as well as water demand of the mix, are all influenced by the combined aggregate gradation.

Blending of aggregates may be specified as per Article 1004.02(d). In addition, alternate combinations of gradation sizes may be used with the approval of the Engineer. This is per Article 1020.04, Table 1, Note 14. This provides an opportunity for blending of aggregates.

1.1 Fineness Modulus

To measure the uniformity of grading for an aggregate, fineness modulus is used. The fineness modulus is a factor used to describe the fine or coarse aggregate gradation. As the fineness modulus factor increases, the aggregate gradation becomes coarser. Fineness modulus is defined in ASTM C 125 as “a factor obtained by adding the percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100: No. 100 (0.15 mm), No. 50 (0.3 mm), No. 30 (0.6 mm), No. 16 (1.18 mm), No. 8 (2.36 mm), No. 4 (4.75 mm), 3/8 in. (9.5 mm), 3/4 in. (19.0 mm), 1 1/2 in. (37.5 mm), 3 in. (75 mm), 6 in. (150 mm).” Fineness modulus for fine aggregate is calculated by dividing by 100 the sum of the cumulative percents retained on the sieves listed in Table 1.1.1. For fine aggregates, the fineness modulus ranges from 2.00 to 4.00, while coarse aggregates range from 6.50 to 8.00, when all material is finer than 1 1/2 in. (38.1 mm). Combined gradations will range from 4.00 to 7.00.
Table 1.1.1 Sieves Required to Calculate Fineness Modulus for Fine Aggregate

<table>
<thead>
<tr>
<th>Sieve Size (English)</th>
<th>Sieve Size (metric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 inch</td>
<td>9.5 mm</td>
</tr>
<tr>
<td>No. 4</td>
<td>4.75 mm</td>
</tr>
<tr>
<td>No. 8*</td>
<td>2.36 mm*</td>
</tr>
<tr>
<td>No. 16</td>
<td>1.18 mm</td>
</tr>
<tr>
<td>No. 30*</td>
<td>600 μm*</td>
</tr>
<tr>
<td>No. 50</td>
<td>300 μm</td>
</tr>
<tr>
<td>No. 100</td>
<td>150 μm</td>
</tr>
</tbody>
</table>

* The sieve is not required by the “Required Sampling and Testing Equipment for Concrete” document, and would have to be acquired.

Table 1.1.2 Calculating Fineness Modulus for Fine Aggregate

<table>
<thead>
<tr>
<th>Sieve Size (English)</th>
<th>Sieve Size (metric)</th>
<th>Percent Passing</th>
<th>Percent Retained</th>
<th>Cumulative Percent Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 inch</td>
<td>9.5 mm</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. 4</td>
<td>4.75 mm</td>
<td>98</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>No. 8</td>
<td>2.36 mm</td>
<td>85</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>No. 16</td>
<td>1.18 mm</td>
<td>65</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>No. 30</td>
<td>600 μm</td>
<td>45</td>
<td>20</td>
<td>55</td>
</tr>
<tr>
<td>No. 50</td>
<td>300 μm</td>
<td>21</td>
<td>24</td>
<td>79</td>
</tr>
<tr>
<td>No. 100</td>
<td>150 μm</td>
<td>3</td>
<td>18</td>
<td>97</td>
</tr>
</tbody>
</table>

Sum = 283
Calculation = 283/100
FM = 2.83

The fineness modulus factor is not normally used to characterize coarse aggregates or combined gradations. However, the fineness modulus factor is frequently used to characterize fine aggregates. The fineness modulus allows an individual to quickly identify a change in fine aggregate gradation. A good application for fineness modulus occurs when concrete is pumped. ACI Committee 304 recommends the fine aggregate fineness modulus to be between 2.40 and 3.00. In addition, a fineness modulus between 2.7 and 3.5 is recommended for slipform paving. A very coarse sand with a fineness modulus between 3.5 and 3.8 may also work, but a test batch is recommended. If the fine aggregate fineness modulus changes more than 0.2, changes in the mix proportions are probably needed to provide the same workability. In addition, a fine aggregate with a high fineness modulus may result in a tendency for the concrete mixture to lose air.
1.2 Aggregate Blending Characterization

A number of analytical methods have been developed to characterize the combined aggregate gradation or blend, and two methods will be discussed further in this section. These two methods are the “8-18” Rule and the 0.45 Power Curve.

Before the two analytical methods are discussed, it is necessary to know how to calculate the aggregate blend when coarse and fine aggregates are combined. The formula for determining the total blend on a particular sieve, is as follows:

\[ TB = \left( \frac{a}{100} \times A \right) + \left( \frac{b}{100} \times B \right) + \left( \frac{c}{100} \times C \right) + \ldots \]

Where: \( TB \) = Total Blend of Aggregate either Passing or Retained on the Sieve, \( a, b, c\ldots \) = Percent of Total Aggregate, and \( A, B, C\ldots \) = Percent of Aggregate either Passing or Retained on the Sieve

For example, the percent passing the 3/8 in. (9.5 mm) sieve of the aggregate blend described in Table 1.2.2 is calculated as follows:

\[ TB = \left( \frac{45}{100} \times 11\% \right) + \left( \frac{15}{100} \times 96\% \right) + \left( \frac{40}{100} \times 100\% \right) \]

\[ TB = 4.95 + 14.4 + 40 \]

\[ TB = 59.35, \text{ or } 59 \text{ percent after rounding} \]

Table 1.2.1 is an illustration of a single gap graded coarse aggregate. As described in Table 1.2.2, a second coarse aggregate (in this case, CA 16) is used to improve the aggregate blend. This data will be used to illustrate the “8-18” Rule and 0.45 Power Curve.

<table>
<thead>
<tr>
<th>Sieve Size (English)</th>
<th>Sieve Size (metric)</th>
<th>CA 07, a = 60%</th>
<th>FA 01, b = 40%</th>
<th>Aggregate Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% Passing A</td>
<td>% Retained A</td>
<td>% Passing B</td>
</tr>
<tr>
<td>1</td>
<td>25 mm</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3/4</td>
<td>19 mm</td>
<td>86</td>
<td>14</td>
<td>100</td>
</tr>
<tr>
<td>1/2</td>
<td>12.5 mm</td>
<td>37</td>
<td>49</td>
<td>100</td>
</tr>
<tr>
<td>3/8</td>
<td>9.5 mm</td>
<td>11</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>4.75 mm</td>
<td>2</td>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>No. 8</td>
<td>2.36 mm</td>
<td>2</td>
<td>0</td>
<td>89</td>
</tr>
<tr>
<td>No. 16</td>
<td>1.18 mm</td>
<td>2</td>
<td>0</td>
<td>77</td>
</tr>
<tr>
<td>No. 30</td>
<td>600 μm</td>
<td>2</td>
<td>0</td>
<td>53</td>
</tr>
<tr>
<td>No. 50</td>
<td>300 μm</td>
<td>2</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>No. 100</td>
<td>150 μm</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>No. 200</td>
<td>75 μm</td>
<td>1.4</td>
<td>0.6</td>
<td>0.5</td>
</tr>
</tbody>
</table>
### Table 1.2.2 Blended Aggregate Mix Design

<table>
<thead>
<tr>
<th>Sieve Size (English)</th>
<th>Sieve Size (metric)</th>
<th>CA 07, $a = 45%$</th>
<th>CA 16, $b = 15%$</th>
<th>FA 01, $c = 40%$</th>
<th>Aggregate Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3/4</td>
<td>86</td>
<td>14</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>1/2</td>
<td>37</td>
<td>49</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3/8</td>
<td>11</td>
<td>26</td>
<td>96</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>2</td>
<td>9</td>
<td>28</td>
<td>68</td>
<td>97</td>
</tr>
<tr>
<td>No. 8</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>23</td>
<td>89</td>
</tr>
<tr>
<td>No. 16</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>77</td>
</tr>
<tr>
<td>No. 30</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>53</td>
</tr>
<tr>
<td>No. 50</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>No. 100</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>No. 200</td>
<td>1.4</td>
<td>0.6</td>
<td>1.9</td>
<td>0.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### 1.2.1 The “8-18” Rule

The “8-18” Rule is one method to characterize an aggregate blend. In this rule, the percent retained on every sieve except the top two specified sieves (maximum size and nominal maximum size) and the bottom two specified sieves should be between 8 and 18 percent. Refer to Figure 1.2.1.1. This ensures that the peaks and valleys are not too severe. Figure 1.2.1.2 illustrates a typical gap graded aggregate mix design, using Table 1.2.1. Figure 1.2.1.3 illustrates the benefits of blending another aggregate to normalize the peaks and valleys, using Table 1.2.2.

![Figure 1.2.1.1 The “8-18” Rule](image-url)
Illinois aggregates cannot normally be combined to stay within the “8-18” rule, but they can be blended to lower the peak typically present on the 1/2 in. (12.5 mm) sieve. A CA 16 aggregate can be blended with a gap graded CA 07 or CA 11 to reduce the amount of material that would be retained on the 1/2 in. (12.5 mm) sieve. As a rule of thumb, it is recommended to keep the difference between two sieves at 13 percent or less.
With most FA 01 and FA 02 aggregates, there will be a peak at the No. 50 (300 μm) sieve and a valley just before this peak, between the No. 8 (2.36 mm) and No. 16 (1.18 mm) sieves. Knowing this, it is important to remember that the amount of material passing the No. 30 (0.6 mm) sieve, but retained on the No. 50 (0.3 mm) sieve, is critical for holding entrained air bubbles in the mix. In addition, material from the No. 30 (0.6 mm) to No. 100 (0.15 mm) sieve is the most effective for entraining air.

As a final comment on the “8-18” rule, the 8 percent and 18 percent limits should be used only as a guide. Aggregate angularity (round vs. angular) and aggregate particle shape (flat and elongated) are not reflected in the “8-18” rule. For example, if the 3/8 in. (9.5 mm) to No. 16 (1.18 mm) sieve range contains 18 percent angular material, the concrete mixture would be gritty and difficult to finish. If the aggregate is flat and elongated, it may be more appropriate to have 4 to 8 percent retained on a given sieve.

1.2.2 The 0.45 Power Curve

The 0.45 Power Curve is another method to characterize an aggregate blend. Gap graded aggregate and blended aggregate gradation mix designs are plotted together on the 0.45 power curve in Figure 1.2.2, using Tables 1.2.1 and 1.2.2. When a second coarse aggregate material (CA 16) is blended with the gap graded aggregate, the plotted line shifts closer to the theoretical optimum, indicating a more uniform combined gradation. The theoretical optimum gradation line originates at the bottom left corner and extends upward to the nominal maximum size. If the plotted line is located to the left of the theoretical optimum gradation line, this indicates a finer gradation. If the plotted line is located to the right of the theoretical optimum gradation line, this indicates a coarser gradation.

![0.45 Power Chart](image)

Figure 1.2.2 Gap Graded Aggregate Mix Design (Table 1.2.1) and Blended Aggregate Mix Design (Table 1.2.2) Example on 0.45 Power Curve
### 1.3 Aggregate Blending Worksheet

**Aggregate Blend**

<table>
<thead>
<tr>
<th>Coarse Aggregate</th>
<th>Fine Aggregate</th>
<th>Intermediate Aggregate</th>
<th>% of Total</th>
<th>% Pass, A</th>
<th>% Pass, B</th>
<th>% Ret., B</th>
<th>% Pass, A</th>
<th>% Pass, B</th>
<th>% Ret., B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td>Ret.</td>
<td>A</td>
<td>B</td>
<td>Ret.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Sieves

**Metric**

- 63 mm
- 45 mm
- 37.5 mm
- 25 mm
- 19 mm
- 16 mm
- 12.5 mm
- 9.5 mm
- 6.3 mm
- 4.75 mm
- 3.36 mm
- 2.36 mm
- 1.18 mm
- 0.60 mm
- 0.30 mm
- 0.18 mm
- 0.15 mm
- 0.075 mm

**English**

- 2 1/2 in.
- 2 in.
- 1 3/4 in.
- 1 1/2 in.
- 1 in.
- 3/4 in.
- 5/8 in.
- 1/2 in.
- 1/4 in.
- No. 4
- No. 8
- No. 16
- No. 30
- No. 40
- No. 50
- No. 100
- No. 200

\[ TB = \left( \frac{A^2}{100} \times B \right) + \left( \frac{B^2}{100} \times C \right) + \ldots \]
1.4 “8-18” Rule Worksheet

[Diagram showing a scale for percent retained with corresponding sieve sizes for both metric and English systems.]
1.5 0.45 Power Curve Worksheet
APPENDIX F

CEMENT AGGREGATE MIXTURE (CAM) II

1.0 CEMENT AGGREGATE MIXTURE (CAM) II MIX DESIGN DEVELOPMENT

The development of a CAM II mix design is similar to that of the Department’s conventional concrete mix design. However, a fine aggregate water requirement, a coarse aggregate water requirement, and a mortar factor are not used.

Per Article 312.26, the Engineer will determine the proportions of materials for the mixture; however, the Contractor may substitute their own mix design. The Department recommends developing three mix designs for a cement-only mixture, or three mix designs for a cement and fly ash mixture, as follows:

<table>
<thead>
<tr>
<th>Mixture Type</th>
<th>Mix Design Option</th>
<th>English Units, lb./yd³</th>
<th>Metric Units, kg/m³</th>
<th>W/C Ratio</th>
<th>CA 6, 9, 10</th>
<th>CA 7, 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Only Mixture</td>
<td>1</td>
<td>200</td>
<td>120</td>
<td>1.2</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>250</td>
<td>150</td>
<td>1.1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>300</td>
<td>180</td>
<td>1.0</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Cement and Fly Ash Mixture</td>
<td>1</td>
<td>170, 60</td>
<td>101, 36</td>
<td>1.2</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>205, 70</td>
<td>122, 42</td>
<td>1.1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>245, 85</td>
<td>145, 50</td>
<td>1.0</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

The procedure for developing a CAM II mix design is as follows:

1. Calculate the absolute volume of the cement and fly ash ($V_{\text{Cement}}$ and $V_{\text{Ash}}$). The mixture shall have a portland cement content minimum of 200 lb./yd³ (120 kg/m³), except a maximum 25 percent Class F ash or 30 percent Class C ash may replace the portland cement. However, per Article 312.26, the replacement shall not result in a mixture with a cement content less than 170 lb./yd³ (101 kg/m³). Furthermore, based on laboratory experience, the Department recommends a maximum cement content of 300 lb./yd³ (136 kg/m³), or maximum 330 lb./yd³ (195 kg/m³) of cement and fly ash combined.

2. Calculate the absolute volume of water ($V_{\text{Water}}$). The water/cement ratio indicated in the table in step 1 is only a starting point. Department experience has shown the water/cement ratio to range from 0.60 to 1.60. No matter what water/cement ratio is selected, a water-reducing admixture shall be used.

3. Calculate the absolute volume of air ($V_{\text{Air}}$). An air-entraining admixture shall be used to produce an air content of 7.0 to 10.0 percent. Design using the midpoint of this range, i.e. 8.5 percent.

4. Calculate the absolute volume of combined aggregate ($V_{\text{Agg}}$). The specifications (Article 312.26) indicate the volume of fine aggregate shall not exceed the volume of coarse aggregate.

$$V_{\text{Agg}} = 1 - [V_{\text{Cement}} + V_{\text{Ash}} + V_{\text{Water}} + V_{\text{Air}}]$$
5. **Calculate the absolute volume of the constituent aggregates** ($V_{CA}$ and $V_{FA}$). The **absolute volume of combined aggregate** is multiplied by the percentage of each aggregate to obtain their respective absolute volumes.

Absolute volume of coarse aggregate: \[ V_{CA} = V_{Agg} \times \frac{\%CA}{100} \]

Absolute volume of fine aggregate: \[ V_{FA} = V_{Agg} \times \frac{\%FA}{100} \]

Department lab experience has shown a 50-50 percent blend of coarse aggregate to fine aggregate is a reasonable starting point when the coarse aggregate is CA 7, CA 9, or CA 11. For CA 6, the Department recommends 75 percent coarse aggregate and 25 percent fine aggregate. For CA 10, the Department recommends starting with 100 percent coarse aggregate and no fine aggregate. As an alternative to these starting points, refer to Appendix E for developing a uniformly graded mixture.

As a word of caution, the coarse aggregate may be Class D quality or better. The risk is more clay material in Class B, C, or D quality aggregate as compared to Class A quality aggregate. Clay can make it more difficult to entrain air, which is why Class A quality aggregate is normally specified for concrete.

6. Convert the absolute volumes of fine aggregate and coarse aggregate to pounds (kilograms).

\[ \text{Weight of Aggregate (lb./yd}^3\) = } V \times G_{SSD} \times 1,683.99 \quad \text{(English)} \]

\[ \text{Mass of Aggregate (kg/m}^3\) = } V \times G_{SSD} \times 1,000.00 \quad \text{(Metric)} \]

Where \( V \) = Absolute volume of coarse aggregate ($V_{CA}$) or fine aggregate ($V_{FA}$)
\( G_{SSD} \) = Specific gravity of coarse aggregate or fine aggregate

7. A trial batch should be performed for each mix design. The slump shall range from 1 in. (25 mm) to 3 in. (75 mm), and the air content shall range from 7.0 to 10.0 percent. If the slump and air content cannot be batched within the specified range, revise the mix design. It should also be noted that CAM II has no strength requirements. However, it is recommended to make three 4 in. x 8 in. (102 mm x 203 mm) cylinders for strength testing at 14 days. A value from 750-1500 psi (5,170-10,340 kPa) is desired, but a mix outside this range is perfectly acceptable.

8. Submit the mix design to the Department for freeze/thaw testing according to AASHTO T 161, Procedure B.

### 1.1 EXAMPLE PROBLEM FOR CEMENT AGGREGATE MIXTURE (CAM) II MIX DESIGN

**Given:**
- Type I portland cement with $> 0.60$ alkalies will be used.
- Class C fly ash with calcium oxide of 26.0 percent and specific gravity of 2.70 will be used.
- A fine aggregate (FA 1) with a saturated surface-dry specific gravity of 2.65 will be used. The alkali-silica reaction expansion for the fine aggregate is in the $>0.16\% – 0.27\%$ range.
- A crushed stone coarse aggregate (CA 6) with a saturated surface-dry specific gravity of 2.69 will be used. The alkali-silica reaction expansion for the coarse aggregate limestone is an assigned value of 0.05 percent per Article 1004.02(g)(1).
1.1.1 Example for English Units

Step 1 Determine the absolute volume of cement.

- The minimum required cement is 170 lb./yd$^3$ if the portland cement is replaced with fly ash.
- The Class C fly ash can replace up to 30 percent of the cement.
- From 2.4.3 “Mitigation of Alkali-Silica Reaction with Finely Divided Minerals”, it is determined that the aggregate is in Group II. Thus, a minimum 25.0 percent Class C fly ash is required to reduce the risk of a deleterious alkali-silica reaction.

Thus, the Department’s default cement and fly ash mix design option 1 is selected. This mix design has 170 lb./yd$^3$ of cement and 60 lb./yd$^3$ of fly ash, and satisfies the minimum fly ash needed for the reactive aggregate without exceeding the maximum replacement.

The calculation to determine the percent replacement

$$\text{percent replacement} = \frac{60 \text{ lb./yd}^3}{(170 \text{ lb./yd}^3 + 60 \text{ lb./yd}^3)} = 26\% \text{ Class C fly ash.}$$

The absolute volume of cement per cubic yard

$$= \frac{170 \text{ lb./yd}^3}{(3.15 \times 1,683.99 \text{ lb./yd}^3)} = 0.032$$

Step 2 Determine the absolute volume of fly ash.

The Department’s cement and fly ash mix design option 1 specifies 60 lb./yd$^3$ of fly ash.

The absolute volume of fly ash per cubic yard

$$= \frac{60 \text{ lb./yd}^3}{(2.70 \times 1,683.99 \text{ lb./yd}^3)} = 0.013$$

Step 3 Determine the absolute volume of water.

Assume a water/cement ratio of 1.10 which takes into account that a water-reducing admixture will be used.

The calculation is $1.10 \times (170 \text{ lb./yd}^3 + 60 \text{ lb./yd}^3) = 253 \text{ lb./yd}^3$

The absolute volume of water per cubic yard

$$= \frac{253 \text{ lb./yd}^3}{(1.0 \times 1,683.99 \text{ lb./yd}^3)} = 0.150$$

Step 4 Determine the absolute volume of air.

The midpoint of the air content range for CAM II is 8.5 percent.

The absolute volume of air per cubic yard

$$= 8.5\% \div 100 = 0.085$$

Step 5 Determine the absolute volume of the combined fine and coarse aggregates.

The absolute volume of combined fine and coarse aggregates per cubic yard

$$= 1 - (0.032 + 0.013 + 0.150 + 0.085) = 0.720$$

For a CA 6, use the Department’s recommendation of a 75-25 percent blend of coarse aggregate to fine aggregate.

The absolute volume of coarse aggregate per cubic yard

$$= 0.720 \times (75 \text{ percent} \div 100) = 0.540$$

The absolute volume of fine aggregate per cubic yard

$$= 0.720 \times (25 \text{ percent} \div 100) = 0.180$$
Step 6 Convert the absolute volumes of the coarse and fine aggregate to pounds.

   Coarse aggregate = 0.540 yd³ × 2.69 × 1,683.99 lb./yd³ = 2,446 lb./yd³
   Fine aggregate = 0.180 yd³ × 2.65 × 1,683.99 lb./yd³ = 803 lb./yd³

Step 7 Summarize the mix design.

   Cement (3.15*) = 170 lb./yd³
   Fly Ash (2.70*) = 60 lb./yd³
   Water = 253 lb./yd³
   or
   = 253 lb./yd³ ÷ 8.33 lb./gallon = 30 gallons/yd³
   Air Content (Target) = 8.5 percent
   Coarse Aggregate (2.69*) = 2,446 lb./yd³
   Fine Aggregate (2.65*) = 803 lb./yd³
   Admixture = water-reducing admixture
   Slump (Target) = 2 inches
   Water/Cement Ratio = 1.10

*Specific Gravity

1.1.2 Example for Metric Units

Step 1 Determine the absolute volume of cement.

   - The minimum required cement is 101 kg/m³ if the portland cement is replaced with fly ash.
   - The Class C fly ash can replace up to 30 percent of the cement.
   - From 2.4.3 "Mitigation of Alkali-Silica Reaction with Finely Divided Minerals", it is determined that the aggregate is in Group II. Thus, a minimum 25.0 percent Class C fly ash is required to reduce the risk of a deleterious alkali-silica reaction.

   Thus, the Department’s default cement and fly ash mix design option 1 is selected. This mix design has 101 kg/m³ of cement and 36 kg/m³ of fly ash, and satisfies the minimum fly ash needed for the reactive aggregate without exceeding the maximum replacement.

   The calculation to determine the percent replacement
   = 36 kg/m³ ÷ (101 kg/m³ + 36 kg/m³) = 26% Class C fly ash.

   The absolute volume of cement per cubic meter
   = 101 kg/m³ ÷ (3.15 × 1000.00 kg/m³) = 0.032

Step 2 Determine the absolute volume of fly ash.

   The Department’s cement and fly ash mix design option 1 specifies 36 kg/m³ of fly ash.

   The absolute volume of fly ash per cubic meter
   = 36 kg/m³ ÷ (2.70 × 1000.00 kg/m³) = 0.013

Step 3 Determine the absolute volume of water.

   Assume a water/cement ratio of 1.10, which takes into account that a water-reducing admixture will be used.

   The calculation is 1.10 × (101 kg/m³ + 36 kg/m³) = 151 kg/m³

   The absolute volume of water per cubic meter
   = 151 kg/m³ ÷ (1.00 × 1,000.00 kg/m³) = 0.151
Step 4 Determine the absolute volume of air.

The midpoint of the air content range for CAM II is 8.5 percent.

The absolute volume of air per cubic meter = $8.5\% \div 100 = 0.085$.

Step 5 Determine the absolute volume of the combined fine and coarse aggregates.

The absolute volume of combined fine and coarse aggregates per cubic meter

$= 1 - (0.032 + 0.013 + 0.151 + 0.085) = 0.719$

For a CA 6, use the Department’s recommendation of a 75-25 percent blend of coarse aggregate to fine aggregate.

The absolute volume of coarse aggregate per cubic meter

$= 0.719 \times (75\% \div 100) = 0.539$

The absolute volume of fine aggregate per cubic yard

$= 0.719 \times (25\% \div 100) = 0.180$

Step 6 Convert the absolute volumes of the fine and coarse aggregates to kilograms.

Coarse aggregate $= 0.539 \text{ m}^3 \times 2.69 \times 1000.00 \text{ kg/m}^3 = 1450 \text{ kg/m}^3$

Fine aggregate $= 0.180 \text{ m}^3 \times 2.65 \times 1000.00 \text{ kg/m}^3 = 477 \text{ kg/m}^3$

Step 7 Summarize the mix design.

Cement (3.15*) = 101 kg/m$^3$

Fly Ash (2.70*) = 36 kg/m$^3$

Water = 151 kg/m$^3$

or

$= 151 \text{ kg/m}^3 \div 1 \text{ liter/m}^3 = 151 \text{ liters/m}^3$

Air Content (Target) = 8.5 percent

Coarse Aggregate (2.69*) = 1450 kg/m$^3$

Fine Aggregate (2.65*) = 477 kg/m$^3$

Admixture = water-reducing admixture

Slump (Target) = 50 mm

Water/Cement Ratio = 1.10

*Specific Gravity

2.0 DEPARTMENT CEMENT AGGREGATE MIXTURE (CAM) II MIX DESIGN VERIFICATION

2.1 Verification by the Engineer

A new cement aggregate mixture (CAM) II mix design will be verified by the Engineer from test information provided by the Contractor (optional), testing performed by the Engineer, applicable Department historical test data, and previous Department experience.

For a CAM II mix design previously developed by the Engineer or Contractor, the Engineer will verify the mix design if the Department’s historical test data shows compliance with specification requirements.

2.2 Testing Performed by the Engineer

Per Article 312.26, constituent materials for CAM II mixtures are submitted to the Department for testing. The Department will verify all materials meet specification requirements.
Additionally, because CA 6, CA 9, and CA 10 gravel aggregates are not normally screened by the Department for alkali reaction per Article 1004.02(g), CA 6, CA 9, and CA 10 gravel aggregates submitted will need to be tested according to ASTM C 1260, and the mixture will be evaluated to meet the requirements of Article 1020.05(d).

The CAM II mixture shall meet the test requirements in Article 312.26 for relative durability (freeze/thaw resistance), air-entrainment, and slump. The mix design with the lowest cement content or cement and fly ash contents that meets the requirements will be reported to the District. Once one mix design is approved for a contract, no additional mixtures will be tested for that contract.

2.2.1 Testing Proportions Determined by the Engineer
The Engineer will test either a cement only mixture or a cement and fly ash mixture. For the selected mixture type, the Engineer will develop proportions for three mix design options. Refer to 1.0 “Cement Aggregate Mixture (CAM) II Mix Design Development”. In the event all three mix designs fail to meet specification requirements, one additional round of testing may be performed by the Engineer.

2.2.2 Testing Proportions Determined by the Contractor
The Engineer will test either a cement only mixture or a cement and fly ash mixture. For the selected mixture type, the Contractor can develop the proportions for up to three mix design options. The mix designs may be different from those suggested in 1.0 “Cement Aggregate Mixture (CAM) II Mix Design Development”. In the event all three mix designs fail to meet specification requirements, one additional round of testing (comprised of three mix design options) may be performed by the Engineer using proportions determined by the Engineer.

2.2.3 Unacceptable Materials
In some cases, all three mix design options fail due to material deficiencies that can be identified after the first round of testing. For example, high fines in an aggregate can make it impossible to properly entrain air, or very poor freeze/thaw durable aggregate can make it impossible to meet relative durability requirements. The Engineer may discontinue further testing of some or all materials determined to be of questionable quality after evaluating a minimum of three mix design options (one round of testing).
APPENDIX G

CONTROLLED LOW-STRENGTH MATERIAL (CLSM)

1.0 CONTROLLED LOW-STRENGTH MATERIAL (CLSM) MIX DESIGN DEVELOPMENT

For CLSM, there is no formal mix design procedure. However, the principle of volumetric mix design, designing in terms of a standard unit volume, still applies. The absolute volumes of cement, fly ash, water, air, and aggregate shall equal one. In addition, the mix shall comply with the mix design criteria. For more details concerning the mix design criteria and submittal of the mix design, refer to Section 1019 of the Standard Specifications.

The Contractor is advised that CLSM does not normally pump well.

2.0 DEPARTMENT CONTROLLED LOW-STRENGTH MATERIAL (CLSM) MIX DESIGN VERIFICATION

2.1 Verification by the Engineer

A new controlled low-strength material (CLSM) mix design will be verified by the Engineer according to Article 1019.06 of the Standard Specifications.

For a CLSM mix design previously developed by the Engineer or Contractor, the Engineer will verify the mix design if the Department’s historical test data shows compliance with specification requirements.
APPENDIX H

STAMPED OR INTEGRALLY COLORED CONCRETE

Stamped or integrally colored concrete shall be done according to contract specifications. The following information is for information purposes when stamped or integrally colored concrete is used.

Stamped Concrete

A minimum cement factor of 6.05 cwt/yd³ (360 kg/m³) for central-mixed, truck-mixed or shrink-mixed concrete is recommended.

A slump range of 3 in. (75 mm) to 5 in. (125 mm) is recommended.

A coarse aggregate gradation of CA 11, CA 13, CA 14, or CA 16 is recommended.

A mortar factor of 0.88 to 0.90 is recommended.

Integrally Colored Concrete

The pigment for colored concrete has no influence on the mix design.

The following guidance will prevent color variations.

- A water/cement ratio range of ± 0.02 is recommended.
- A calcium chloride accelerating admixture shall not be used.
This Page Reserved
Appendix I

CONCRETE REVETMENT MATS

1.0 CONCRETE REVETMENT MAT MIX DESIGN DEVELOPMENT

For concrete revetment mats, there is no formal mix design procedure, and Section 285 of the Standard Specifications provides very few mix design parameters. However, the principle of volumetric mix design, designing in terms of a standard unit volume, still applies. The absolute volumes of cement, fly ash, water, air, and fine aggregate (there is no coarse aggregate) shall equal one.

For an air content of not less than 6.0 percent nor more than 9.0 percent, the following mix design parameters should be used to meet the required 28 day compressive strength of 2500 psi (17,000 kPa).

Cement Only Mix Design
- Cement: 650 – 800 lb/yd³ (385 – 475 kg/m³)
- Water/Cement Ratio: Maximum 0.60
- Fine Aggregate (saturated surface dry condition): Adjust for cement, water, and air
- Air Content (Target): 7.5 percent
- Water-Reducing or High Range Water-Reducing Admixture: Optional

Cement and Fly Ash Mix Design
- Cement: 470 – 610 lb/yd³ (279 – 362 kg/m³)
- Total Cement Plus Fly Ash*: 725 – 825 lb/yd³ (430 – 489 kg/m³)
- Water/Cement Ratio: Maximum 0.60
- Fine Aggregate (saturated surface dry condition): Adjust for cement, fly ash, water, and air
- Air Content (Target): 7.5 percent
- Water-Reducing or High Range Water-Reducing Admixture: Optional

*It is recommended to keep the fly ash at a maximum of 35 percent of the total cement plus fly ash.

Section 285 states the mixture shall be proportioned to provide a pumpable slurry. A flow cone test according to ASTM D 6449 is a good method to determine pumpability. It is recommended the efflux time range from 9 to 12 seconds.

2.0 DEPARTMENT CONCRETE REVETMENT MAT MIX DESIGN VERIFICATION

2.1 Verification by the Engineer

A new concrete revetment mat mix design will be verified by the Engineer from test information provided by the Contractor (optional), testing performed by the Engineer, applicable Department historical test data, target strength calculations, and previous Department experience.

For a concrete revetment mat mix design previously developed by the Engineer or Contractor, the Engineer will verify the mix design if the Department’s historical test data shows compliance with specification requirements.
2.2 Testing Performed by the Engineer
The Engineer may require the Contractor to provide a batch of concrete revetment mat mixture at no cost to the Department.

2.2.1 Procedure for Trial Batch
The procedure that follows shall be used to perform a trial batch unless specified otherwise in the contract plans.

The trial batch shall be performed in the presence of the Engineer, and the Engineer will perform all tests. The Contractor has the option to perform their own tests. The volume of the trial batch shall be a minimum of 2.0 yd$^3$ (1.5 m$^3$), but 4.0 yd$^3$ (3.0 m$^3$) is strongly recommended to more accurately evaluate the influence of mixing. For the trial batch, batch at or near the maximum water/cement ratio as requested by the Engineer. The air content should be within 0.5 percent of the maximum allowable specification value or as requested by the Engineer. Strength will be determined for the test of record, or at other times as determined by the Engineer. The test of record shall be the day indicated in Section 285. In all cases, strength will be based on the average of a minimum of two breaks. In addition to air and strength testing, concrete temperature will be determined by the Engineer. Testing will be performed according to Illinois Modified AASHTO T 23, T 141, T 152 or T 196, T 22, and T 309. As an option for additional information, Illinois Modified AASHTO T 121 and ASTM D 6449 may be performed.

2.2.2.1 Verification of Trial Batch
The trial batch will be verified by the Engineer if Department test results meet specification requirements and the mixture is pumpable.
APPENDIX J

INSERTION LINING OF PIPE CULVERTS (GROUT)

1.0 GROUT MIXTURE MIX DESIGN DEVELOPMENT FOR INSERTION LINING OF PIPE CULVERTS

For the grout mixture used in insertion lining of pipe culverts, there is no formal mix design procedure. However, the principle of volumetric mix design, designing in terms of a standard unit volume, still applies. The absolute volumes of cement, fly ash, water, air, and fine aggregate (there is no coarse aggregate) shall equal one. According to Section 543 of the Standard Specifications, the mix design parameters are as follows:

The grout mixture shall be 6.50 cwt/yd$^3$ (385 kg/m$^3$) of portland cement plus fine aggregate and water. Fly ash may replace a maximum of 5.25 cwt/yd$^3$ (310 kg/m$^3$) of the portland cement. The water/cement ratio, according to Article 1020.06, shall not exceed 0.60. An air-entraining admixture shall be used to produce an air content, according to Article 1020.08, of not less than 6.0 percent nor more than 9.0 percent of the volume of the grout. The Contractor shall have the option to use a water-reducing or high range water-reducing admixture.

As indicated by the mix design parameters, there are few variables for developing the mix design. The Contractor shall use a target air content of 7.5 percent, and vary the cement, fly ash, and water proportions to obtain a flowable mix. In addition, the grout mixture shall have a minimum 28 day compressive strength of 150 psi (1035 kPa).

2.0 DEPARTMENT GROUT MIXTURE FOR INSERTION LINING OF PIPE CULVERTS MIX DESIGN VERIFICATION

2.1 Verification by the Engineer

A new insertion lining of pipe culverts mix design will be verified by the Engineer from test information provided by the Contractor (optional), testing performed by the Engineer, applicable Department historical test data, target strength calculations, and previous Department experience.

For an insertion lining of pipe culverts mix design previously developed by the Engineer or Contractor, the Engineer will verify the mix design if the Department's historical test data shows compliance with specification requirements.

2.2 Testing Performed by the Engineer

The Engineer may require the Contractor to provide a batch of insertion lining of pipe culverts mixture at no cost to the Department.

2.2.1 Procedure for Trial Batch

The procedure that follows shall be used to perform a trial batch unless specified otherwise in the contract plans.

The trial batch shall be performed in the presence of the Engineer, and the Engineer will perform all tests. The Contractor has the option to perform their own tests. The volume of the
trial batch shall be a minimum of 2.0 yd$^3$ (1.5 m$^3$), but 4.0 yd$^3$ (3.0 m$^3$) is strongly recommended to more accurately evaluate the influence of mixing. For the trial batch, batch at or near the maximum water/cement ratio as requested by the Engineer. The air content should be within 0.5 percent of the maximum allowable specification value or as requested by the Engineer. Strength will be determined for the test of record, or at other times as determined by the Engineer. The test of record shall be the day indicated in Section 543. In all cases, strength will be based on the average of a minimum of two breaks. In addition to air and strength testing, concrete temperature will be determined by the Engineer. Air and concrete temperature testing will be performed according to Illinois Modified AASHTO T 141, T 152 or T 196, and T 309. Strength testing will be performed according to ASTM C 1107 and C 109. As an option for additional information, Illinois Modified AASHTO T 121 may be performed.

2.2.2.1 Verification of Trial Batch
The trial batch will be verified by the Engineer if Department test results meet specification requirements and the mixture is flowable.

Comment: The grout mixture for insertion lining of pipe culverts is not included in the Special Provision for Quality Control/Quality Assurance of Concrete Mixtures (BDE) as provided in Appendix Q. The mix design would normally be done by the Department, but the Contractor has the option to submit a mix design for a Quality Control/Quality Assurance project.
Appendix K

INSERTION LINING OF PIPE CULVERTS (CELLULAR CONCRETE)

1.0 CELLULAR CONCRETE MIX DESIGN DEVELOPMENT FOR INSERTION LINING OF PIPE CULVERTS

Cellular concrete (or sometimes called engineered fill) is a special mix which relies on foam to make the concrete low strength or light weight.

The mix designs are proprietary in nature, and therefore, their development will not be discussed within this manual. However, the principle of volumetric design, designing in terms of a standard unit volume, still applies. The absolute volume of materials shall equal one.

**Cement Only Mix Design for Strength Range of 30 – 350 psi (207 – 2,413 kPa)**

- Cement 400 – 650 lb/yd$^3$ (237 – 386 kg/m$^3$)
- Water/Cement Ratio 0.50 – 0.60
- Foam Admixture Consult Manufacturer for Dosage
- Homogenous Void or Air Cell Structure 20 – 70 percent

**Comments:**
- Cement replacement with fly ash may reach as high as 65 percent.
- The use of fine aggregate is optional, but is not normally utilized when low strength or light weight is desired.

2.0 DEPARTMENT CELLULAR CONCRETE FOR INSERTION LINING OF PIPE CULVERTS MIX DESIGN VERIFICATION

2.1 Verification by the Engineer
The mix design will be verified by the Engineer from test information provided by the Contractor showing that the mix is flowable and meets compressive strength requirements.
This Page Reserved
APPENDIX L

CLASS SI CONCRETE BETWEEN PRECAST CONCRETE BOX CULVERTS

1.0 CLASS SI CONCRETE MIX DESIGN DEVELOPMENT (WHEN MIXTURE IS USED BETWEEN PRECAST CONCRETE BOX CULVERT SECTIONS)

For the Class SI concrete used between precast concrete box culvert sections, Article 540.06 states “The Class SI concrete shall be according to Section 1020, except the maximum size coarse aggregate shall be ⅜ in. (10 mm).” This requirement is also in the Bridge Guide Special Provision “Three Sided Precast Concrete Structure”. Thus, the principle of volumetric mix design discussed in this manual applies. The key point is that the specification essentially states to replace the coarse aggregate with a fine aggregate. According to Article 1003.01, fine aggregate has a maximum size of ⅜ in. (10 mm). To develop the mix design, the absolute volumes of cement, finely divided minerals, water, and air are calculated and added together. The resultant value is subtracted from one to get the volume of aggregate. Since the coarse aggregate has been replaced with a fine aggregate, the water demand will be higher. It is suggested to use a coarse aggregate basic water requirement of 0.4 gal/cwt (0.33 L/kg) as a starting point in developing the mix design.

2.0 DEPARTMENT CLASS SI CONCRETE MIX DESIGN VERIFICATION (WHEN MIXTURE IS USED BETWEEN PRECAST CONCRETE BOX CULVERT SECTIONS)

2.1 Verification by the Engineer

A new Class SI concrete (used between precast concrete sections) mix design will be verified by the Engineer from test information provided by the Contractor (optional), testing performed by the Engineer, applicable Department historical test data, target strength calculations, and previous Department experience.

For a Class SI concrete (used between precast concrete sections) mix design previously developed by the Engineer or Contractor, the Engineer will verify the mix design if the Department’s historical test data shows compliance with specification requirements.

2.2 Testing Performed by the Engineer

The Engineer may require the Contractor to provide a batch of Class SI concrete (used between precast concrete sections) mixture at no cost to the Department.

2.2.1 Procedure for Trial Batch

The procedure that follows shall be used to perform a trial batch unless specified otherwise in the contract plans.

The trial batch shall be performed in the presence of the Engineer, and the Engineer will perform all tests. The Contractor has the option to perform their own tests. The volume of the trial batch shall be a minimum of 2 yd³ (1.5 m³), but 4 yd³ (3.0 m³) is strongly recommended to more accurately evaluate the influence of mixing. For the trial batch, batch at or near the maximum water/cement ratio or as requested by the Engineer. The air content should be within 0.5 percent of the maximum allowable specification value or as requested by the Engineer. The slump should be within the allowable specification range. Strength will be determined for the test of record, or at other times determined by the Engineer. The test of record shall be the day indicated in Article 1020.04 or as specified. In all cases, strength will be based on the average
of a minimum of two breaks. In addition to slump, air, and strength testing, concrete temperature will be determined by the Engineer. Testing will be performed according to Illinois Modified AASHTO T 23, T 119, T 141, T 152 or T 196, T 22 or T 177, and T 309. As an option for additional information, Illinois Modified AASHTO T 121 may be performed.

2.2.1.1 Verification of Trial Batch, Voids Test, and Durability Test Data

The trial batch will be verified by the Engineer if Department test results meet specification requirements.
APPENDIX M

PERVIOUS CONCRETE

Pervious concrete shall be done according to contract specifications, and there is no formal mix design procedure. However, the principle of volumetric mix design, designing in terms of a standard unit volume, still applies. The absolute volumes of cement, finely divided minerals, water, air, and aggregate shall equal one.

When the contract specifications specify freeze/thaw durability, improved durability may be achieved by entraining air in the cement paste.
This Page Reserved
APPENDIX N

AVERAGE AND STANDARD DEVIATION

1.0 AVERAGE STRENGTH

"Average" strength implies that half of the samples tested are stronger than average and half are weaker than average. Thus, the average strength of a concrete mix must be greater than the minimum required strength. The concrete mix should be designed to have an average, or target strength.

The quantitative difference between the average, or mix design target strength and the minimum required strength, depends on the accuracy and precision of the test results. The accuracy and precision of the test results must be calculated before the mix design target strength can be determined.

1.1 Accuracy and Precision

Accuracy refers to the average of the performance with reference to the target. Precision refers to the consistency of the performance itself. Though the results may not be near the target, amongst themselves they are tightly grouped.

**ACCURACY:**

**PRECISION:**

**ACCURATE & PRECISE:**

Accuracy is typically measured by the mean, or average, of the test results, defined as follows:

\[
\text{Average}, \quad \bar{X} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}
\]

Where \( x_i \) is an individual test result, and \( n \) is the total number of test results.

Precision, or "measure of dispersion," is measured by the standard deviation, which indicates width, spread, clustering, and consistency, and is defined as follows:

\[
\text{Standard Deviation}, \quad S = \sqrt{\frac{\sum (X - x_i)^2}{n-1}}
\]
### Example Using English Units:

<table>
<thead>
<tr>
<th>Test Record (psi)</th>
<th>Deviation $\overline{X} - x_i$</th>
<th>Square of Deviation $(\overline{X} - x_i)^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 3000</td>
<td>$4058 - 3000 = 1058$</td>
<td>$1,119,364$</td>
</tr>
<tr>
<td>2 3450</td>
<td>$4058 - 3450 = 608$</td>
<td>$369,664$</td>
</tr>
<tr>
<td>3 3600</td>
<td>$4058 - 3600 = 458$</td>
<td>$209,764$</td>
</tr>
<tr>
<td>4 4650</td>
<td>$4058 - 4650 = -592$</td>
<td>$350,464$</td>
</tr>
<tr>
<td>5 4750</td>
<td>$4058 - 4750 = -692$</td>
<td>$478,864$</td>
</tr>
<tr>
<td>6 4900</td>
<td>$4058 - 4900 = -842$</td>
<td>$708,964$</td>
</tr>
</tbody>
</table>

$\text{sum} = \sum_{i=1}^{n} x_i = 24,350$

$\text{average, } \overline{X} = \frac{\text{sum}}{n} = 4058 \text{ psi}$

$\text{standard deviation, } S = \sqrt{\frac{\text{sum}}{(n-1)}} = 805 \text{ psi}$

### Example Using Metric Units:

<table>
<thead>
<tr>
<th>Test Record (kPa)</th>
<th>Deviation $\overline{X} - x_i$</th>
<th>Square of Deviation $(\overline{X} - x_i)^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 20,690</td>
<td>$27,980 - 20,690 = 7290$</td>
<td>$53,144,100$</td>
</tr>
<tr>
<td>2 23,790</td>
<td>$27,980 - 23,790 = 4190$</td>
<td>$17,556,100$</td>
</tr>
<tr>
<td>3 24,820</td>
<td>$27,980 - 24,820 = 3160$</td>
<td>$9,985,600$</td>
</tr>
<tr>
<td>4 32,060</td>
<td>$27,980 - 32,060 = -4080$</td>
<td>$16,646,400$</td>
</tr>
<tr>
<td>5 32,750</td>
<td>$27,980 - 32,750 = -4770$</td>
<td>$22,752,900$</td>
</tr>
<tr>
<td>6 33,790</td>
<td>$27,980 - 33,790 = -5810$</td>
<td>$33,756,100$</td>
</tr>
</tbody>
</table>

$\text{sum} = \sum_{i=1}^{n} x_i = 167,900$

$\text{average, } \overline{X} = \frac{\text{sum}}{n} = 27,980 \text{ kPa}$

$\text{standard deviation, } S = \sqrt{\frac{\text{sum}}{(n-1)}} = 5547 \text{ kPa}$
2.0 THE NORMAL DISTRIBUTION—The Bell Curve

Characteristics in any statistical sample population, such as compressive strength test results, can be grouped around some central tendency, or average, as illustrated in Figure 2.0.

Figure 2.0 is an example of a histogram, a graph of the frequency of occurrences per subdivision of the complete range of test results. For example, there were 50 occurrences of test results within 5000 and 5250 psi (34.5 and 36.2 MPa).

Now, a smooth bell-shaped curve can be drawn through the histogram. This “Bell Curve” is known as the Normal Distribution, characterized by a distinct central tendency toward the center, which is the average. The Bell Curve quantitatively illustrates how test results have an equal chance to be above or below the average.

The characteristics of the Normal Distribution are as follows:

- 68 percent of all results fall within 1 standard deviation from either side of the average
- 95 percent of all results fall within 2 standard deviations from either side of the average
- 99.7 percent of all results fall within 3 standard deviations from either side of the average
- 99 percent of all results fall above the value that is 2.33 standard deviations below the average
APPENDIX O

PORTLAND CEMENT CONCRETE (BDE)

Effective: January 1, 2012
Revised: January 1, 2013

Revise Notes 1 and 2 of Article 312.24 of the Standard Specifications to read:

“Note 1. Coarse aggregate shall be gradation CA 6, CA 7, CA 9, CA 10, or CA 11, Class D quality or better. Article 1020.05(d) shall apply.

Note 2. Fine aggregate shall be FA 1 or FA 2. Article 1020.05(d) shall apply.”

Revise the first paragraph of Article 312.26 of the Standard Specifications to read:

“312.26 Proportioning and Mix Design. At least 60 days prior to start of placing CAM II, the Contractor shall submit samples of materials for proportioning and testing. The mixture shall contain a minimum of 200 lb (90 kg) of cement per cubic yard (cubic meter). Portland cement may be replaced with fly ash according to Article 1020.05(c)(1), however the minimum portland cement content in the mixture shall be 170 lbs/cu yd (101 kg/cu m). Blends of coarse and fine aggregates will be permitted, provided the volume of fine aggregate does not exceed the volume of coarse aggregate. The Engineer will determine the proportions of materials for the mixture. However, the Contractor may substitute their own mix design. Article 1020.05(a) shall apply and a Level III PCC Technician shall develop the mix design.”

Revise the second paragraph of Article 503.22 of the Standard Specifications to read:

“Other cast-in-place concrete for structures will be paid for at the contract unit price per cubic yard (cubic meter) for CONCRETE HANDRAIL, CONCRETE ENCASEMENT, and SEAL COAT CONCRETE.”

Add the following to Article 1003.02 of the Standard Specifications:

(e) Alkali Reaction.

(1) ASTM C 1260. Each fine aggregate will be tested by the Department for alkali reaction according to ASTM C 1260. The test will be performed with Type I or II portland cement having a total equivalent alkali content (Na₂O + 0.658K₂O) of 0.90 percent or greater. The Engineer will determine the assigned expansion value for each aggregate, and these values will be made available on the Department’s Alkali-Silica Potential Reactivity Rating List. The Engineer may differentiate aggregate based on ledge, production method, gradation number, or other factors. An expansion value of 0.03 percent will be assigned to limestone or dolomite fine aggregates (manufactured stone sand). However, the Department reserves the right to perform the ASTM C 1260 test.

(2) ASTM C 1293 by Department. In some instances, such as chert natural sand or other fine aggregates, testing according to ASTM C 1260 may not provide accurate test results. In this case, the Department may only test according to ASTM C 1293.
(3) ASTM C 1293 by Contractor. If an individual aggregate has an ASTM C 1260 expansion value that is unacceptable to the Contractor, an ASTM C 1293 test may be performed by the Contractor to evaluate the Department’s ASTM C 1260 test result. The laboratory performing the ASTM C 1293 test shall be approved by the Department according to the current Bureau of Materials and Physical Research Policy Memorandum “Minimum Laboratory Requirements for Alkali-Silica Reactivity (ASR) Testing”.

The ASTM C 1293 test shall be performed with Type I or II portland cement having a total equivalent alkali content (Na₂O + 0.658K₂O) of 0.80 percent or greater. The interior vertical wall of the ASTM C 1293 recommended container (pail) shall be half covered with a wick of absorbent material consisting of blotting paper. If the testing laboratory desires to use an alternate container, wick of absorbent material, or amount of coverage inside the container with blotting paper, ASTM C 1293 test results with an alkali-reactive aggregate of known expansion characteristics shall be provided to the Engineer for review and approval. If the expansion is less than 0.040 percent after one year, the aggregate will be assigned an ASTM C 1260 expansion value of 0.08 percent that will be valid for two years, unless the Engineer determines the aggregate has changed significantly. If the aggregate is manufactured into multiple gradation numbers, and the other gradation numbers have the same or lower ASTM C 1260 value, the ASTM C 1293 test result may apply to multiple gradation numbers.

The Engineer reserves the right to verify a Contractor’s ASTM C 1293 test result. When the Contractor performs the test, a split sample shall be provided to the Engineer. The Engineer may also independently obtain a sample at any time. The aggregate will be considered reactive if the Contractor or Engineer obtains an expansion value of 0.040 percent or greater.

Revise the first paragraph of Article 1004.01(e)(5) of the Standard Specifications to read:

“Crushed concrete, crushed slag, or lightweight aggregate for portland cement concrete shall be stockpiled in a moist condition (saturated surface dry or greater) and the moisture content shall be maintained uniformly throughout the stockpile by periodic sprinkling.”

Revise Article 1004.02(d) of the Standard Specifications to read:

“(d)Combining Sizes. Each size shall be stored separately and care shall be taken to prevent them from being mixed until they are ready to be proportioned. Separate compartments shall be provided to proportion each size.

(1) When Class BS concrete is to be pumped, the coarse aggregate gradation shall have a minimum of 45 percent passing the 1/2 in. (12.5 mm) sieve. The Contractor may combine two or more coarse aggregate sizes, consisting of CA 7, CA 11, CA 13, CA 14, and CA 16, provided a CA 7 or CA 11 is included in the blend.
(2) If the coarse aggregate is furnished in separate sizes, they shall be combined in proportions to provide a uniformly graded coarse aggregate grading within the following limits.

<table>
<thead>
<tr>
<th>Class of Concrete ¹/</th>
<th>Combined Sizes</th>
<th>Sieve Size and Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 1/2 in.</td>
</tr>
<tr>
<td>PV ²/</td>
<td>CA 5 &amp; CA 7</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>CA 5 &amp; CA 11</td>
<td>---</td>
</tr>
<tr>
<td>SI and SC ²/</td>
<td>CA 3 &amp; CA 7</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>CA 3 &amp; CA 11</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>CA 5 &amp; CA 7</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>CA 5 &amp; CA 11</td>
<td>---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class of Concrete ¹/</th>
<th>Combined Sizes</th>
<th>Sieve Size (metric) and Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>63 mm</td>
</tr>
<tr>
<td>PV ²/</td>
<td>CA 5 &amp; CA 7</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>CA 5 &amp; CA 11</td>
<td>---</td>
</tr>
<tr>
<td>SI and SC ²/</td>
<td>CA 3 &amp; CA 7</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>CA 3 &amp; CA 11</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>CA 5 &amp; CA 7</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>CA 5 &amp; CA 11</td>
<td>---</td>
</tr>
</tbody>
</table>

1/ See Table 1 of Article 1020.04.

2/ Any of the listed combination of sizes may be used.

Add the following to Article 1004.02 of the Standard Specifications:

(g) Alkali Reaction.

(1) ASTM C 1260. Each coarse aggregate will be tested by the Department for alkali reaction according to ASTM C 1260. The test will be performed with Type I or II portland cement having a total equivalent alkali content (Na₂O + 0.658K₂O) of 0.90 percent or greater. The Engineer will determine the assigned expansion value for each aggregate, and these values will be made available on the Department’s Alkali-Silica Potential Reactivity Rating List. The Engineer may differentiate aggregate based on ledge, production method, gradation number, or other factors. An expansion value of 0.05 percent will be assigned to limestone or dolomite coarse aggregates. However, the Department reserves the right to perform the ASTM C 1260 test.

(2) ASTM C 1293 by Department. In some instances testing a coarse aggregate according to ASTM C 1260 may not provide accurate test results. In this case, the Department may only test according to ASTM C 1293.
(3) ASTM C 1293 by Contractor. If an individual aggregate has an ASTM C 1260 expansion value that is unacceptable to the Contractor, an ASTM C 1293 test may be performed by the Contractor according to Article 1003.02(e)(3).

Revise the first paragraph of Article 1019.06 of the Standard Specifications to read:

"1019.06 Contractor Mix Design. A Contractor may submit their own mix design and may propose alternate fine aggregate materials, fine aggregate gradations, or material proportions. Article 1020.05(a) shall apply and a Level III PCC Technician shall develop the mix design."

Revise Section 1020 of the Standard Specifications to read:

"SECTION 1020. PORTLAND CEMENT CONCRETE

1020.01 Description. This item shall consist of the materials, mix design, production, testing, curing, low air temperature protection, and temperature control of concrete.

1020.02 Materials. Materials shall be according to the following.

<table>
<thead>
<tr>
<th>Item</th>
<th>Article/Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Cement</td>
<td>1001</td>
</tr>
<tr>
<td>(b) Water</td>
<td>1002</td>
</tr>
<tr>
<td>(c) Fine Aggregate</td>
<td>1003</td>
</tr>
<tr>
<td>(d) Coarse Aggregate</td>
<td>1004</td>
</tr>
<tr>
<td>(e) Concrete Admixtures</td>
<td>1021</td>
</tr>
<tr>
<td>(f) Finely Divided Minerals</td>
<td>1010</td>
</tr>
<tr>
<td>(g) Concrete Curing Materials</td>
<td>1022</td>
</tr>
<tr>
<td>(h) Straw</td>
<td>1081.06(a)(1)</td>
</tr>
<tr>
<td>(i) Calcium Chloride</td>
<td>1013.01</td>
</tr>
</tbody>
</table>

1020.03 Equipment. Equipment shall be according to the following.

<table>
<thead>
<tr>
<th>Item</th>
<th>Article/Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Concrete Mixers and Trucks</td>
<td>1103.01</td>
</tr>
<tr>
<td>(b) Batching and Weighing Equipment</td>
<td>1103.02</td>
</tr>
<tr>
<td>(c) Automatic and Semi-Automatic Batching Equipment</td>
<td>1103.03</td>
</tr>
<tr>
<td>(d) Water Supply Equipment</td>
<td>1103.04</td>
</tr>
<tr>
<td>(e) Membrane Curing Equipment</td>
<td>1101.09</td>
</tr>
<tr>
<td>(f) Mobile Portland Cement Concrete Plants</td>
<td>1103.04</td>
</tr>
</tbody>
</table>

1020.04 Concrete Classes and General Mix Design Criteria. The classes of concrete shown in Table 1 identify the various mixtures by the general uses and mix design criteria. If the class of concrete for a specific item of construction is not specified, Class SI concrete shall be used.

For the minimum cement factor in Table 1, it shall apply to portland cement, portland-pozzolan cement, and portland blast-furnace slag except when a particular cement is specified in the Table.

The Contractor shall not assume that the minimum cement factor indicated in Table 1 will produce a mixture that will meet the specified strength. In addition, the Contractor shall not
assume that the maximum finely divided mineral allowed in a mix design according to Article 1020.05(c) will produce a mixture that will meet the specified strength. The Contractor shall select a cement factor within the allowable range that will obtain the specified strength. The Contractor shall take into consideration materials selected, seasonal temperatures, and other factors which may require the Contractor to submit multiple mix designs.

For a portland-pozzolan cement, portland blast-furnace slag cement, or when replacing portland cement with finely divided minerals per Articles 1020.05(c) and 1020.05(d), the portland cement content in the mixture shall be a minimum of 375 lbs/cu yd (222 kg/cu m). When the total of organic processing additions, inorganic processing additions, and limestone exceed 5.0 percent in the cement, the minimum portland cement content in the mixture shall be 400 lbs/cu yd (237 kg/cu m). When calculating the portland cement portion in the portland-pozzolan or portland blast-furnace slag cement, the AASHTO M 240 tolerance may be ignored.

Special classifications may be made for the purpose of including the concrete for a particular use or location as a separate pay item in the contract. The concrete used in such cases shall conform to this section.
### TABLE 1. CLASSES OF CONCRETE AND MIX DESIGN CRITERIA

<table>
<thead>
<tr>
<th>Class of Conc.</th>
<th>Use</th>
<th>Specification Section Reference</th>
<th>Cement Factor</th>
<th>Water / Cement Ratio</th>
<th>Slump</th>
<th>Mix Design Compressive Strength (Flexural Strength)</th>
<th>Air Content</th>
<th>Coarse Aggregate Gradations</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>Pavement Base Course</td>
<td>420 or 421</td>
<td>353</td>
<td>107</td>
<td>0.32 - 0.42</td>
<td>2 - 4</td>
<td>3500 (650)</td>
<td>5.0 - 8.0</td>
</tr>
<tr>
<td></td>
<td>Base Course Widening</td>
<td>354</td>
<td>423</td>
<td>483</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>5.65 (1)</td>
<td>6.05</td>
</tr>
<tr>
<td></td>
<td>Driveway Pavement</td>
<td>420</td>
<td>353</td>
<td>423</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>5.65 (1)</td>
<td>6.05</td>
</tr>
<tr>
<td></td>
<td>Shoulders</td>
<td>483</td>
<td>483</td>
<td>483</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>5.65 (1)</td>
<td>6.05</td>
</tr>
<tr>
<td></td>
<td>Shoulder Curb</td>
<td>662</td>
<td>662</td>
<td>662</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>5.65 (1)</td>
<td>6.05</td>
</tr>
<tr>
<td>PP</td>
<td>Pavement Patching</td>
<td>442</td>
<td>442</td>
<td>442</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>5.65 (1)</td>
<td>6.05</td>
</tr>
<tr>
<td></td>
<td>Bridge Deck Patching (10)</td>
<td>442</td>
<td>442</td>
<td>442</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>5.65 (1)</td>
<td>6.05</td>
</tr>
<tr>
<td></td>
<td>PP-1</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
<td>Ty III 3500 (650)</td>
<td>5.0 - 8.0</td>
<td>CA 7, CA 11, CA 13, CA 14, or CA 16</td>
</tr>
<tr>
<td></td>
<td>PP-2</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
<td>Ty III 3500 (650)</td>
<td>5.0 - 8.0</td>
<td>CA 7, CA 11, CA 13, CA 14, or CA 16</td>
</tr>
<tr>
<td></td>
<td>PP-3</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
<td>Ty III 3500 (650)</td>
<td>5.0 - 8.0</td>
<td>CA 7, CA 11, CA 13, CA 14, or CA 16</td>
</tr>
<tr>
<td></td>
<td>PP-4</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
<td>Ty III 3500 (650)</td>
<td>5.0 - 8.0</td>
<td>CA 7, CA 11, CA 13, CA 14, or CA 16</td>
</tr>
<tr>
<td></td>
<td>PP-5</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
<td>Ty III 3500 (650)</td>
<td>5.0 - 8.0</td>
<td>CA 7, CA 11, CA 13, CA 14, or CA 16</td>
</tr>
<tr>
<td>RR</td>
<td>Railroad Crossing</td>
<td>422</td>
<td>422</td>
<td>422</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
</tr>
<tr>
<td>BS</td>
<td>Bridge Superstructure</td>
<td>503</td>
<td>503</td>
<td>503</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
</tr>
<tr>
<td></td>
<td>Bridge Approach Slab</td>
<td>503</td>
<td>503</td>
<td>503</td>
<td>6.50</td>
<td>7.50</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
</tr>
<tr>
<td>PC</td>
<td>Various Precast Concrete Items</td>
<td>1042</td>
<td>1042</td>
<td>1042</td>
<td>5.65</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
</tr>
<tr>
<td></td>
<td>Wet Cast</td>
<td>5.65</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
<td>4000 (675)</td>
<td>5.0 - 8.0</td>
<td>CA 7, CA 11, CA 13, or CA 14</td>
</tr>
<tr>
<td></td>
<td>Dry Cast</td>
<td>5.65</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
<td>4000 (675)</td>
<td>5.0 - 8.0</td>
<td>CA 7, CA 11, CA 13, or CA 14</td>
</tr>
<tr>
<td>PS</td>
<td>Precast Prestressed Members</td>
<td>504</td>
<td>504</td>
<td>504</td>
<td>5.65</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
</tr>
<tr>
<td></td>
<td>Precast Prestressed Piles and Extensions</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>5.65</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
</tr>
<tr>
<td></td>
<td>Precast Prestressed Sight Screen</td>
<td>639</td>
<td>639</td>
<td>639</td>
<td>5.65</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Class of Conc.</td>
<td>Use</td>
<td>Specification Section Reference</td>
<td>Cement Factor cwt/cu yd (3)</td>
<td>Water / Cement Ratio lb/lb</td>
<td>Slump in. (4)</td>
<td>Mix Design Compressive Strength (psi, minimum)</td>
<td>Air Content %</td>
<td>Coarse Aggregate Gradations (14)</td>
</tr>
<tr>
<td>---------------</td>
<td>-----</td>
<td>---------------------------------</td>
<td>-----------------------------</td>
<td>---------------------------</td>
<td>-----------</td>
<td>--------------------------------------------</td>
<td>--------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>DS</td>
<td>Drilled Shaft (12)</td>
<td>516</td>
<td>6.65</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>6 - 8 (6)</td>
<td>4000 (675)</td>
<td>5.0 - 8.0</td>
</tr>
<tr>
<td></td>
<td>Metal Shell Piles (12)</td>
<td>512</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sign Structures Drilled Shaft (12)</td>
<td>734</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Light Tower Foundation (12)</td>
<td>837</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>Seal Coat</td>
<td>503</td>
<td>5.65 (1)</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>3 - 5</td>
<td>3500 (650)</td>
</tr>
<tr>
<td>SI</td>
<td>Structures (except Superstructure) Sidewalk</td>
<td>503</td>
<td>5.65 (1)</td>
<td>6.05 (2)</td>
<td>7.05</td>
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<td>2 - 4 (5)</td>
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<td>5.65 (1)</td>
<td>6.05 (2)</td>
<td>7.05</td>
<td>0.32 - 0.44</td>
<td>2 - 4 (5)</td>
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<td>Sign Structures Spread Footing Concrete Foundation</td>
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<td>Pole Foundation (12)</td>
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<td>Traffic Signal Foundation Drilled Shaft (12) Square or Rectangular</td>
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Notes:

1. Central-mixed.
2. Truck-mixed or shrink-mixed.
3. For Class SC concrete and for any other class of concrete that is to be placed underwater, except Class DS concrete, the cement factor shall be increased by ten percent.
4. The maximum slump may be increased to 7 in. when a high range water-reducing admixture is used for all classes of concrete, except Class PV, SC, and PP. For Class SC, the maximum slump may be increased to 8 in. For Class PP-1, the maximum slump may be increased to 6 in. For Class PS, the 7 in. maximum slump may be increased to 8 1/2 in. if the high range water-reducing admixture is the polycarboxylate type.
5. The slump range for slipform construction shall be 1/2 to 2 1/2 in. and the air content range shall be 5.5 to 8.0 percent.
6. If concrete is placed to displace drilling fluid, or against temporary casing, the slump shall be 8 - 10 in. at the point of placement. If a water-reducing admixture is used in lieu of a high range water-reducing admixture according to Article 1020.05(b)(7), the slump shall be 2 - 4 in.
7. For Class BS concrete used in bridge deck patching, the coarse aggregate gradation shall be CA 13, CA 14, or CA 16, except CA 11 may be used for full-depth patching.
8. In addition to the Type III portland cement, 100 lb/cu yd of ground granulated blast-furnace slag and 50 lb/cu yd of microsilica (silica fume) shall be used. For an air temperature greater than 85 ºF, the Type III portland cement may be replaced with Type I or II portland cement.
9. The cement shall be a rapid hardening cement from the Department’s “Approved List of Packaged, Dry, Rapid Hardening Cementitious Materials for Concrete Repairs” for PP-4 and calcium aluminate cement for PP-5.
10. For Class PP concrete used in bridge deck patching, the coarse aggregate gradation shall be CA 13, CA 14, or CA 16, except CA 11 may be used for full-depth patching. In addition, the mix design shall have 72 hours to obtain a 4,000 psi compressive or 675 psi flexural strength for all PP mix designs.
11. The nominal maximum size permitted is 3/4 in. Nominal maximum size is defined as the largest sieve which retains any of the aggregate sample particles.
12. The concrete mix shall be designed to remain fluid throughout the anticipated duration of the pour plus one hour. At the Engineer’s discretion, the Contractor may be required to conduct a minimum 2 cu yd trial batch to verify the mix design.
13. CA 3 or CA 5 may be used when the nominal maximum size does not exceed two-thirds the clear distance between parallel reinforcement bars, or between the reinforcement bar and the form. Nominal maximum size is defined in Note 11.
14. Alternate combinations of gradation sizes may be used with the approval of the Engineer. Refer also to Article 1004.02(d) for additional information on combining sizes.
### TABLE 1. CLASSES OF CONCRETE AND MIX DESIGN CRITERIA (metric)

<table>
<thead>
<tr>
<th>Class of Conc.</th>
<th>Use</th>
<th>Specification Section Reference</th>
<th>Cement Factor kg/cu m (3)</th>
<th>Water / Cement Ratio kg/kg</th>
<th>Slump mm (4)</th>
<th>Mix Design Compressive Strength (Flexural Strength) kPa, minimum</th>
<th>Air Content %</th>
<th>Coarse Aggregate Gradations (14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Pavement</td>
<td>Base Course</td>
<td>420 or 421 353</td>
<td>335 (1) 360 (2)</td>
<td>418</td>
<td>0.32 - 0.42 50 - 100 (5)</td>
<td>Ty III 24,000 (4500)</td>
<td>5.0 - 8.0 (5)</td>
<td>CA 5 &amp; CA 7, CA 5 &amp; CA 11, CA 7, CA 11, or CA 14</td>
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<td>PV Pavement</td>
<td>Base Course Widening</td>
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<td>PV Pavement</td>
<td>Driveway Pavement</td>
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<td>PV Pavement</td>
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<td>PV Pavement</td>
<td>Shoulder Curb</td>
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<td>PP Pavement Patching</td>
<td>Bridge Deck Patching (10)</td>
<td>442</td>
<td>385 365 (Ty III) 445 425 (Ty III)</td>
<td>0.32 - 0.44 50 - 100</td>
<td>at 48 hours</td>
<td>22,100 (4150) Article 701.17(e)(3)b.</td>
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<td>PP Pavement Patching</td>
<td>PP-1</td>
<td>385 365 (Ty III) 445 425 (Ty III)</td>
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<td>at 48 hours</td>
<td>4.0 - 7.0</td>
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<tr>
<td>PP Pavement Patching</td>
<td>PP-2</td>
<td>435 485</td>
<td>0.32 - 0.38 50 - 150</td>
<td>at 24 hours</td>
<td>4.0 - 6.0</td>
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<td>PP Pavement Patching</td>
<td>PP-3</td>
<td>435 (Ty III) (8) 435 (Ty III) (8)</td>
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<td>at 16 hours</td>
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<td>PP Pavement Patching</td>
<td>PP-4</td>
<td>355 (9) 370 (9)</td>
<td>0.32 - 0.50 50 - 150</td>
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<td>PP Pavement Patching</td>
<td>PP-5</td>
<td>400 (9) 400 (9)</td>
<td>0.32 – 0.40 50 - 200</td>
<td>at 4 hours</td>
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<td>RR Railroad Crossing</td>
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<td>385 365 (Ty III) 445 425 (Ty III)</td>
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<td>24,000 (4500) at 48 hours</td>
<td>4.0 - 7.0</td>
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<td>BS Bridge Superstructure Bridge Approach Slab</td>
<td>503</td>
<td>360 418</td>
<td>0.32 - 0.44 50 - 100 (5)</td>
<td>27,500 (4650)</td>
<td>5.0 - 8.0 (5)</td>
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<td>CA 7, CA 11, or CA 14 (7)</td>
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<td>PC Various Precast Concrete Items Wet Cast Dry Cast</td>
<td>1042</td>
<td>335 335 (TY III) 418 418 (TY III)</td>
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<td>See Section 1042</td>
<td>5.0 - 8.0 N/A</td>
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<td>CA 7, CA11, CA13, CA 14, CA 16, or CA 7 &amp; CA 16</td>
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<td>PC Precast Prestressed Members</td>
<td>504</td>
<td>335 335 (TY III) 418 418 (TY III)</td>
<td>0.32 - 0.44 25 - 100</td>
<td>34,500 Plans</td>
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<td>CA 11 (11), CA 13, CA 14 (11), or CA 16</td>
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<td>PC Precast Prestressed Sight Screen</td>
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<td>Class of Conc.</td>
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<td>Water / Cement Ratio kg/kg</td>
<td>Slump mm (4)</td>
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<td>Air Content %</td>
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<td>Drilled Shaft (12)</td>
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<td>50 - 100 (5)</td>
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<td>5.0 - 8.0</td>
<td>CA 3 &amp; CA 7, CA 5 &amp; CA 11, CA 7, or CA 11.</td>
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<td>CA 3 &amp; CA 7, CA 5 &amp; CA 11, CA 7, or CA 11.</td>
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<td>Traffic Signal Foundation</td>
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<td>Square or Rectangular</td>
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<td>CA 3 &amp; CA 7, CA 5 &amp; CA 11, CA 7, or CA 11.</td>
</tr>
</tbody>
</table>
Notes:  
(1) Central-mixed.  
(2) Truck-mixed or shrink-mixed.  
(3) For Class SC concrete and for any other class of concrete that is to be placed underwater, except Class DS concrete, the cement factor shall be increased by ten percent.  
(4) The maximum slump may be increased to 175 mm when a high range water-reducing admixture is used for all classes of concrete except Class PV, SC, and PP. For Class SC, the maximum slump may be increased to 200 mm. For Class PP-1, the maximum slump may be increased to 150 mm. For Class PS, the 175 mm maximum slump may be increased to 215 mm if the high range water-reducing admixture is the polycarboxylate type.  
(5) The slump range for slipform construction shall be 13 to 64 mm and the air content range shall be 5.5 to 8.0 percent.  
(6) If concrete is placed to displace drilling fluid, or against temporary casing, the slump shall be 200 - 250 mm at the point of placement. If a water-reducing admixture is used in lieu of a high range water-reducing admixture according to Article 1020.05(b)(7), the slump shall be 50 – 100 mm.  
(7) For Class BS concrete used in bridge deck patching, the coarse aggregate gradation shall be CA 13, CA 14, or CA 16, except CA 11 may be used for full-depth patching.  
(8) In addition to the Type III portland cement, 60 kg/cu m of ground granulated blast-furnace slag and 30 kg/cu m of microsilica (silica fume) shall be used. For an air temperature greater than 30 °C, the Type III portland cement may be replaced with Type I or II portland cement.  
(9) The cement shall be a rapid hardening cement from the Department's "Approved List of Packaged, Dry, Rapid Hardening Cementitious Materials for Concrete Repairs" for PP-4 and calcium aluminate cement for PP-5.  
(10) For Class PP concrete used in bridge deck patching, the coarse aggregate gradation shall be CA 13, CA 14, or CA 16, except CA 11 may be used for full-depth patching. In addition, the mix design shall have 72 hours to obtain a 27,500 kPa compressive or 4,650 kPa flexural.  
(11) The nominal maximum size permitted is 19 mm. Nominal maximum size is defined as the largest sieve which retains any of the aggregate sample particles.  
(12) The concrete mix shall be designed to remain fluid throughout the anticipated duration of the pour plus one hour. At the Engineer's discretion, the Contractor may be required to conduct a minimum 1.5 cu m trial batch to verify the mix design.  
(13) CA 3 or CA 5 may be used when the nominal maximum size does not exceed two-thirds the clear distance between parallel reinforcement bars, or between the reinforcement bar and the form. Nominal maximum size is defined in Note 11.  
(14) Alternate combinations of gradation sizes may be used with the approval of the Engineer. Refer also to Article 1004.02(d) for additional information on combining sizes.
Self-consolidating concrete is a flowable mixture that does not require mechanical vibration for consolidation. Self-consolidating concrete mix designs may be developed for Class BS, PC, PS, DS, and SI concrete. Self-consolidating concrete mix designs may also be developed for precast concrete products that are not subjected to Class PC concrete requirements according to Section 1042. The mix design criteria for the concrete mixture shall be according to Article 1020.04 with the following exceptions.

(a) The slump requirements shall not apply.

(b) The concrete mixture should be uniformly graded, and information in the “Portland Cement Concrete Level III Technician Course – Manual of Instructions for Design of Concrete Mixtures” may be used to develop the uniformly graded mix design. The coarse aggregate gradations shall be CA 11, CA 13, CA 14, CA 16, or a blend of these gradations. However, the final gradation when using a single coarse aggregate or combination of coarse aggregates shall have 100 percent pass the 1 in. (25 mm) sieve, and minimum 95 percent pass the 3/4 in. (19 mm) sieve. The fine aggregate proportion shall be a maximum 50 percent by weight (mass) of the total aggregate used.

(c) The slump flow range shall be 22 in. (560 mm) minimum to 28 in. (710 mm) maximum and tested according to Illinois Test Procedure SCC-2.

(d) The visual stability index shall be a maximum of 1 and tested according to Illinois Test Procedure SCC-2.

(e) The J-Ring value shall be a maximum of 2 in. (50 mm) and tested according to Illinois Test Procedure SCC-3. The L-Box blocking ratio shall be a minimum of 80 percent and tested according to Illinois Test Procedure SCC-3. The Contractor has the option to select either test.

(f) The hardened visual stability index shall be a maximum of 1 and tested according to Illinois Test Procedure SCC-6.

(g) If Class PC concrete requirements do not apply to the precast concrete product according to Section 1042, the maximum cement factor shall be 7.05 cwt/cu yd (418 kg/cu m) and the maximum allowable water/cement ratio shall be 0.44.

(h) If the measured slump flow, visual stability index, J-Ring value, or L-Box blocking ratio fall outside the limits specified, a check test will be made. In the event of a second failure, the Engineer may refuse to permit the use of the batch of concrete represented.

The Contractor may use water or self-consolidating admixtures at the jobsite to obtain the specified slump flow, visual stability index, J-ring value, or L-box blocking ratio. The maximum design water/cement ratio shall not be exceeded.

1020.05 Other Concrete Criteria. The concrete shall be according to the following.

(a) Proportioning and Mix Design. For all Classes of concrete, it shall be the Contractor's responsibility to determine mix design material proportions and to proportion each batch of concrete. A Level III PCC Technician shall develop the mix design for all Classes of concrete, except Classes PC and PS. The mix design, submittal information, trial batch, and Engineer verification shall be according to the “Portland Cement Concrete Level III Technician” course material.
The Contractor shall provide the mix designs a minimum of 45 calendar days prior to production. More than one mix design may be submitted for each class of concrete.

The Engineer will verify the mix design submitted by the Contractor. Verification of a mix design shall in no manner be construed as acceptance of any mixture produced. Once a mix design has been verified, the Engineer shall be notified of any proposed changes.

Tests performed at the jobsite will determine if a mix design can meet specifications. If the tests indicate it cannot, the Contractor shall make adjustments to a mix design, or submit a new mix design if necessary, to comply with the specifications.

(b) Admixtures. The Contractor shall be responsible for using admixtures and determining dosages for all Classes of concrete, cement aggregate mixture II, and controlled low-strength material that will produce a mixture with suitable workability, consistency, and plasticity. In addition, admixture dosages shall result in the mixture meeting the specified plastic and hardened properties. The Contractor shall obtain approval from the Engineer to use an accelerator when the concrete temperature is greater than 60 °F (16 °C). However, this accelerator approval by the Engineer will not be required for Class PP, RR, PC, and PS concrete. The accelerator shall be the non-chloride type unless otherwise specified in the contract plans.

The Department will maintain an Approved List of Corrosion Inhibitors. Corrosion inhibitor dosage rates shall be according to Article 1020.05(b)(10). For information on approved controlled low-strength material air-entraining admixtures, refer to Article 1019.02. The Department will also maintain an Approved List of Concrete Admixtures, and an admixture technical representative shall be consulted by the Contractor prior to the pour when determining an admixture dosage from this list or when making minor admixture dosage adjustments at the jobsite. The dosage shall be within the range indicated on the approved list unless the influence by other admixtures, jobsite conditions (such as a very short haul time), or other circumstances warrant a dosage outside the range. The Engineer shall be notified when a dosage is proposed outside the range. To determine an admixture dosage, air temperature, concrete temperature, cement source and quantity, finely divided mineral sources and quantity, influence of other admixtures, haul time, placement conditions, and other factors as appropriate shall be considered. The Engineer may request the Contractor to have a batch of concrete mixed in the lab or field to verify the admixture dosage is correct. An admixture dosage or combination of admixture dosages shall not delay the initial set of concrete by more than one hour. When a retarding admixture is required or appropriate for a bridge deck or bridge deck overlay pour, the initial set time shall be delayed until the deflections due to the concrete dead load are no longer a concern for inducing cracks in the completed work. However, a retarding admixture shall not be used to further extend the pour time and justify the alteration of a bridge deck pour sequence.

When determining water in admixtures for water/cement ratio, the Contractor shall calculate 70 percent of the admixture dosage as water, except a value of 50 percent shall be used for a latex admixture used in bridge deck latex concrete overlays.

The sequence, method, and equipment for adding the admixtures shall be approved by the Engineer. Admixtures shall be added to the concrete separately. An accelerator shall always be added prior to a high range water-reducing admixture, if both are used.

Admixture use shall be according to the following.
(1) When the atmosphere or concrete temperature is 65 °F (18 °C) or higher, a retarding admixture shall be used in the Class BS concrete and concrete bridge deck overlays. The proportions of the ingredients of the concrete shall be the same as without the retarding admixture, except that the amount of mixing water shall be reduced, as may be necessary, in order to maintain the consistency of the concrete as required. In addition, a high range water-reducing admixture shall be used in bridge deck concrete. At the option of the Contractor, a water-reducing admixture may be used with the high range water-reducing admixture in Class BS concrete.

(2) At the Contractor's option, admixtures in addition to an air-entraining admixture may be used for Class PP-1 or RR concrete. When the air temperature is less than 55 °F (13 °C) and an accelerator is used, the non-chloride accelerator shall be calcium nitrite.

(3) When Class C fly ash or ground granulated blast-furnace slag is used in Class PP-1 or RR concrete, a water-reducing or high range water-reducing admixture shall be used.

(4) For Class PP-2 or PP-3 concrete, a non-chloride accelerator followed by a high range water-reducing admixture shall be used, in addition to the air-entraining admixture. The Contractor has the option to use a water-reducing admixture with the high range water-reducing admixture. For Class PP-3 concrete, the non-chloride accelerator shall be calcium nitrite. For Class PP-2 concrete, the non-chloride accelerator shall be calcium nitrite when the air temperature is less than 55 °F (13 °C).

(5) For Class PP-4 concrete, a high range water-reducing admixture shall be used in addition to the air-entraining admixture. The Contractor has the option to use a water-reducing admixture with the high range water-reducing admixture. An accelerator shall not be used. For stationary or truck-mixed concrete, a retarding admixture shall be used to allow for haul time. The Contractor has the option to use a mobile portland cement concrete plant, but a retarding admixture shall not be used unless approved by the Engineer.

For PP-5 concrete, a non-chloride accelerator, high range water-reducing admixture, and air-entraining admixture shall be used. The accelerator, high range water-reducing admixture, and air-entraining admixture shall be per the Contractor's recommendation and dosage. The approved list of concrete admixtures shall not apply. A mobile portland cement concrete plant shall be used to produce the patching mixture.

(6) When a calcium chloride accelerator is specified in the contract, the maximum chloride dosage shall be 1.0 quart (1.0 L) of solution per 100 lb (45 kg) of cement. The dosage may be increased to a maximum 2.0 quarts (2.0 L) per 100 lb (45 kg) of cement if approved by the Engineer. When a calcium chloride accelerator for Class PP-2 concrete is specified in the contract, the maximum chloride dosage shall be 1.3 quarts (1.3 L) of solution per 100 lb (45 kg) of cement. The dosage may be increased to a maximum 2.6 quarts (2.6 L) per 100 lb (45 kg) of cement if approved by the Engineer.

(7) For Class DS concrete a retarding admixture and a high range water-reducing admixture shall be used. For dry excavations that are 10 ft (3 m) or less, the high range water-reducing admixture may be replaced with a water-reducing admixture if
the concrete is vibrated. The use of admixtures shall take into consideration the slump loss limits specified in Article 516.12 and the fluidity requirement in Article 1020.04 (Note 12).

(8) At the Contractor's option, when a water-reducing admixture or a high range water-reducing admixture is used for Class PV, PP-1, RR, SC, and SI concrete, the cement factor may be reduced a maximum 0.30 hundredweight/cu yd (18 kg/cu m). However, a cement factor reduction will not be allowed for concrete placed underwater.

(9) When Type F or Type G high range water-reducing admixtures are used, the initial slump shall be a minimum of 1 1/2 in. (40 mm) prior to addition of the Type F or Type G admixture, except as approved by the Engineer.

(10) When specified, a corrosion inhibitor shall be added to the concrete mixture utilized in the manufacture of precast, prestressed concrete members and/or other applications. It shall be added, at the same rate, to all grout around post-tensioning steel when specified.

When calcium nitrite is used, it shall be added at the rate of 4 gal/cu yd (20 L/cu m), and shall be added to the mix immediately after all compatible admixtures have been introduced to the batch.

When Rheocrete 222+ is used, it shall be added at the rate of 1.0 gal/cu yd (5.0 L/cu m), and the batching sequence shall be according to the manufacturer's instructions.

(c) Finely Divided Minerals. Use of finely divided minerals shall be according to the following.

(1) Fly Ash. At the Contractor's option, fly ash from approved sources may partially replace portland cement in cement aggregate mixture II, Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete.

The use of fly ash shall be according to the following.

a. Measurements of fly ash and portland cement shall be rounded up to the nearest 5 lb (2.5 kg).

b. When Class F fly ash is used in cement aggregate mixture II, Class PV, BS, PC, PS, DS, SC, and SI concrete, the amount of portland cement replaced shall not exceed 25 percent by weight (mass).

c. When Class C fly ash is used in cement aggregate mixture II, Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete, the amount of portland cement replaced shall not exceed 30 percent by weight (mass).

d. Fly ash may be used in concrete mixtures when the air temperature is below 40 °F (4 °C), but the Engineer may request a trial batch of the concrete mixture to show the mix design strength requirement will be met.

(2) Ground Granulated Blast-Furnace (GGBF) Slag. At the Contractor's option, GGBF slag may partially replace portland cement in Class PV, PP-1, PP-2, RR, BS, PC,
PS, DS, SC, and SI concrete. For Class PP-3 concrete, GGBF slag shall be used according to Article 1020.04.

The use of GGBF slag shall be according to the following.

a. Measurements of GGBF slag and portland cement shall be rounded up to the nearest 5 lb (2.5 kg).

b. When GGBF slag is used in Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC and SI concrete, the amount of portland cement replaced shall not exceed 35 percent by weight (mass).

c. GGBF slag may be used in concrete mixtures when the air temperature is below 40 °F (4 °C), but the Engineer may request a trial batch of the concrete mixture to show the mix design strength requirement will be met.

(3) Microsilica. At the Contractor’s option, microsilica may be added at a maximum of 5.0 percent by weight (mass) of the cement and finely divided minerals summed together.

Microsilica shall be used in Class PP-3 concrete according to Article 1020.04.

(4) High Reactivity Metakaolin (HRM). At the Contractor’s option, HRM may be added at a maximum of 5.0 percent by weight (mass) of the cement and finely divided minerals summed together.

(5) Mixtures with Multiple Finely Divided Minerals. Except as specified for Class PP-3 concrete, the Contractor has the option to use more than one finely divided mineral in Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete as follows.

a. The mixture shall contain a maximum of two finely divided minerals. The finely divided mineral in portland-pozzolan cement or portland blast-furnace slag cement shall count toward the total number of finely divided minerals allowed. The finely divided minerals shall constitute a maximum of 35.0 percent of the total cement plus finely divided minerals. The fly ash portion shall not exceed 30.0 percent for Class C fly ash or 25.0 percent for Class F fly ash. The Class C and F fly ash combination shall not exceed 30.0 percent. The ground granulated blast-furnace slag portion shall not exceed 35.0 percent. The microsilica or high-reactivity metakaolin portion used together or separately shall not exceed ten percent. The finely divided mineral in the portland-pozzolan cement or portland blast-furnace slag blended cement shall apply to the maximum 35.0 percent.

b. Central Mixed. For Class PV, SC, and SI concrete, the mixture shall contain a minimum of 565 lbs/cu yd (335 kg/cu m) of cement and finely divided minerals summed together. If a water-reducing or high-range water-reducing admixture is used, the Contractor has the option to use a minimum of 535 lbs/cu yd (320 kg/cu m).

c. Truck-Mixed or Shrink-Mixed. For Class PV, SC, and SI concrete, the mixture shall contain a minimum of 605 lbs/cu yd (360 kg/cu m) of cement and finely divided minerals summed together. If a water-reducing or high-range water-
reducing admixture is used, the Contractor has the option to use a minimum of 575 lbs/cu yd (345 kg/cu m).

d. Central-Mixed, Truck-Mixed or Shrink-Mixed. For Class PP-1 and RR concrete, the mixture shall contain a minimum of 650 lbs/cu yd (385 kg/cu m) of cement and finely divided minerals summed together. For Class PP-1 and RR concrete using Type III portland cement, the mixture shall contain a minimum of 620 lbs/cu yd (365 kg/cu m).

For Class PP-2 concrete, the mixture shall contain a minimum of 735 lbs/cu yd (435 kg/cu m) of cement and finely divided minerals summed together. For Class BS concrete, the mixture shall contain a minimum of 605 lbs/cu yd (360 kg/cu m). For Class DS concrete, the mixture shall contain a minimum of 665 lbs/cu yd (395 kg/cu m).

If a water-reducing or high range water-reducing admixture is used in Class PP-1 and RR concrete, the Contractor has the option to use a minimum of 620 lbs/cu yd (365 kg/cu m) of cement and finely divided minerals summed together. If a water-reducing or high-range water-reducing admixture is used with Type III portland cement in Class PP-1 and RR concrete, the Contractor has the option to use a minimum of 590 lbs/cu yd (350 kg/cu m).

e. Central-Mixed or Truck-Mixed. For Class PC and PS concrete, the mixture shall contain a minimum of 565 lbs/cu yd (335 kg/cu m) of cement and finely divided minerals summed together.

f. The mixture shall contain a maximum of 705 lbs/cu yd (418 kg/cu m) of cement and finely divided mineral(s) summed together for Class PV, BS, PC, PS, DS, SC, and SI concrete. For Class PP-1 and RR concrete, the mixture shall contain a maximum of 750 lbs/cu yd (445 kg/cu m). For Class PP-1 and RR concrete using Type III portland cement, the mixture shall contain a maximum of 720 lbs/cu yd (425 kg/cu m). For Class PP-2 concrete, the mixture shall contain a maximum of 820 lbs/cu yd (485 kg/cu m).

g. For Class SC concrete and for any other class of concrete that is to be placed underwater, except Class DS concrete, the allowable cement and finely divided minerals summed together shall be increased by ten percent.

h. The combination of cement and finely divided minerals shall comply with Article 1020.05(d).

(d) Alkali-Silica Reaction. For cast-in-place (includes cement aggregate mixture II and latex mixtures), precast, and precast prestressed concrete, one of the mixture options provided in Article 1020.05(d)(2) shall be used to reduce the risk of a deleterious alkali-silica reaction in concrete exposed to humid or wet conditions. The mixture options are not intended or adequate for concrete exposed to potassium acetate, potassium formate, sodium acetate, or sodium formate. The mixture options will not be required for the dry environment (humidity less than 60 percent) found inside buildings for residential or commercial occupancy.

The mixture options shall not apply to concrete revetment mats, insertion lining of pipe culverts, portland cement mortar fairing course, controlled low-strength material,
miscellaneous grouts that are not prepackaged, Class PP-3 concrete, Class PP-4 concrete, and Class PP-5 concrete.

(1) Aggregate Groups. Each combination of aggregates used in a mixture will be assigned to an aggregate group. The point at which the coarse aggregate and fine aggregate expansion values intersect in the following table will determine the group.

<table>
<thead>
<tr>
<th>Aggregate Groups</th>
<th>Coarse Aggregate or Coarse Aggregate Blend</th>
<th>Fine Aggregate Or Fine Aggregate Blend</th>
<th>ASTM C 1260 Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤0.16%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;0.16% - 0.27%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;0.27%</td>
</tr>
<tr>
<td>Group I</td>
<td></td>
<td></td>
<td>Group I</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
<td>Group II</td>
</tr>
<tr>
<td>Group III</td>
<td></td>
<td></td>
<td>Group III</td>
</tr>
<tr>
<td>Group IV</td>
<td></td>
<td></td>
<td>Group IV</td>
</tr>
</tbody>
</table>

(2) Mixture Options. Based upon the aggregate group, the following mixture options shall be used. However, the Department may prohibit a mixture option if field performance shows a deleterious alkali-silica reaction or Department testing indicates the mixture may experience a deleterious alkali-silica reaction.

<table>
<thead>
<tr>
<th>Reduction of Risk for Deleterious Alkali-Silica Reaction</th>
<th>Aggregate Groups</th>
<th>Mixture Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group I</td>
<td>Option 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Option 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Option 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Option 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Option 5</td>
</tr>
<tr>
<td>Mixture options are not applicable. Use any cement or finely divided mineral.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Combine Option 2 with Option 3</td>
<td></td>
<td>Combine Option 2 with Option 3</td>
</tr>
<tr>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Combine Option 2 with Option 3</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Combine Option 2 with Option 4</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Combine Option 2 with Option 4</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

“X” denotes valid mixture option for aggregate group.

a. Mixture Option 1. The coarse or fine aggregates shall be blended to place the material in a group that will allow the selected cement or finely divided mineral to be used. Coarse aggregate may only be blended with another coarse aggregate. Fine aggregate may only be blended with another fine aggregate. Blending of coarse with fine aggregate to place the material in another group will not be permitted.
When a coarse or fine aggregate is blended, the weighted expansion value shall be calculated separately for the coarse and fine aggregate as follows:

Weighted Expansion Value = (a/100 x A) + (b/100 x B) + (c/100 x C) + …

Where:  a, b, c... = percentage of aggregate in the blend;
A, B, C... = expansion value for that aggregate.

b. Mixture Option 2. A finely divided mineral shall be used as described in 1), 2), 3), or 4) that follow. In addition, a blended cement with a finely divided mineral may be added to a separate finely divided mineral to meet the following requirements, provided the finely divided minerals are the same material. However, adding together two different finely divided minerals to obtain the specified minimum percentage of one material will not be permitted for 1), 2), 3), and 4). Refer to Mixture Option 5 to address this situation.

1. Class F Fly Ash. For cement aggregate mixture II, Class PV, BS, PC, PS, MS, DS, SC and SI concrete, the Class F fly ash shall be a minimum 25.0 percent by weight (mass) of the cement and finely divided minerals summed together.

If the maximum total equivalent available alkali content (Na₂O + 0.658K₂O) exceeds 4.50 percent for the Class F fly ash, it may be used only if it complies with Mixture Option 5.

2. Class C Fly Ash. For cement aggregate mixture II, Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete, Class C fly ash shall be a minimum of 25.0 percent by weight (mass) of the cement and finely divided minerals summed together.

If the maximum total equivalent available alkali content (Na₂O + 0.658K₂O) exceeds 4.50 percent or the calcium oxide exceeds 26.50 percent for the Class C fly ash, it may be used only per Mixture Option 5.

3. Ground Granulated Blast-Furnace Slag. For Class PV, PP-1, PP-2, RR, BS, PC, PS, DS, SC, and SI concrete, ground granulated blast-furnace slag shall be a minimum of 25.0 percent by weight (mass) of the cement and finely divided minerals summed together.

If the maximum total equivalent available alkali content (Na₂O + 0.658K₂O) exceeds 1.00 percent for the ground granulated blast-furnace slag, it may be used only per Mixture Option 5.

4. Microsilica or High Reactivity Metakaolin. Microsilica solids or high reactivity metakaolin shall be a minimum 5.0 percent by weight (mass) of the cement and finely divided minerals summed together.

If the maximum total equivalent available alkali content (Na₂O + 0.658K₂O) exceeds 1.00 percent for the Microsilica or High Reactivity Metakaolin, it may be used only if it complies with Mixture Option 5.
c. Mixture Option 3. The cement used shall have a maximum total equivalent alkali content \((\text{Na}_2\text{O} + 0.658\text{K}_2\text{O})\) of 0.60 percent. When aggregate in Group II is involved and the Contractor desires to use a finely divided mineral, any finely divided mineral may be used with the cement unless the maximum total equivalent available alkali content \((\text{Na}_2\text{O} + 0.658\text{K}_2\text{O})\) exceeds 4.50 percent for the fly ash; or 1.00 percent for the ground granulated blast-furnace slag, microsilica or high reactivity metakaolin. If the alkali content is exceeded, the finely divided mineral may be used only per Mixture Option 5.

d. Mixture Option 4. The cement used shall have a maximum total equivalent alkali content \((\text{Na}_2\text{O} + 0.658\text{K}_2\text{O})\) of 0.45 percent. When aggregate in Group II or III is involved and the Contractor desires to use a finely divided mineral, any finely divided mineral may be used with the cement unless the maximum total equivalent available alkali content \((\text{Na}_2\text{O} + 0.658\text{K}_2\text{O})\) exceeds 4.50 percent for the fly ash; or 1.00 percent for the ground granulated blast-furnace slag, microsilica, or high reactivity metakaolin. If the alkali content is exceeded, the finely divided mineral may be used only per Mixture Option 5.

e. Mixture Option 5. The proposed cement or finely divided mineral may be used if the ASTM C 1567 expansion value is \(\leq 0.16\) percent when performed on the aggregate in the concrete mixture with the highest ASTM C 1260 test result. The laboratory performing the ASTM C1567 test shall be approved by the Department according to the current Bureau of Materials and Physical Research Policy Memorandum “Minimum Laboratory Requirements for Alkali-Silica Reactivity (ASR) Testing”. The ASTM C 1567 test will be valid for two years, unless the Engineer determines the materials have changed significantly.

For latex concrete, the ASTM C 1567 test shall be performed without the latex.

The 0.20 percent autoclave expansion limit in ASTM C 1567 shall not apply.

If during the two year time period the Contractor needs to replace the cement, and the replacement cement has an equal or lower total equivalent alkali content \((\text{Na}_2\text{O} + 0.658\text{K}_2\text{O})\), a new ASTM C 1567 test will not be required.

The Engineer reserved the right to verify a Contractor's ASTM C 1567 test result. When the Contractor performs the test, a split sample may be requested by the Engineer. The Engineer may also independently obtain a sample at any time. The proposed cement or finely divided mineral will not be allowed for use if the Contractor or Engineer obtains an expansion value greater than 0.16 percent.

**1020.06 Water/Cement Ratio.** The water/cement ratio shall be determined on a weight (mass) basis. When a maximum water/cement ratio is specified, the water shall include mixing water, water in admixtures, free moisture on the aggregates, and water added at the jobsite. The quantity of water may be adjusted within the limit specified to meet slump requirements.

When fly ash, ground granulated blast-furnace slag, high-reactivity metakaolin, or microsilica (silica fume) are used in a concrete mix, the water/cement ratio will be based on the total cement and finely divided minerals contained in the mixture.

**1020.07 Slump.** The slump shall be determined according to Illinois Modified AASHTO T 119.
If the measured slump falls outside the limits specified, a check test will be made. In the event of a second failure, the Engineer may refuse to permit the use of the batch of concrete represented.

If the Contractor is unable to add water to prepare concrete of the specified slump without exceeding the maximum design water/cement ratio, a water-reducing admixture shall be added.

1020.08 Air Content. The air content shall be determined according to Illinois Modified AASHTO T 152 or Illinois Modified AASHTO T 196. The air-entrainment shall be obtained by the use of cement with an approved air-entraining admixture added during the mixing of the concrete or the use of air-entraining cement.

If the air-entraining cement furnished is found to produce concrete having air content outside the limits specified, its use shall be discontinued immediately and the Contractor shall provide other air-entraining cement which will produce air contents within the specified limits.

If the air content obtained is above the specified maximum limit at the jobsite, the Contractor may have the concrete further mixed, within the limits of time and revolutions specified, to reduce the air content. If the air content obtained is below the specified minimum limit, the Contractor may add to the concrete a sufficient quantity of an approved air-entraining admixture at the jobsite to bring the air content within the specified limits.

1020.09 Strength Tests. The specimens shall be molded and cured according to Illinois Modified AASHTO T 23. Specimens shall be field cured with the construction item as specified in Illinois Modified AASHTO T 23. The compressive strength shall be determined according to Illinois Modified AASHTO T 22. The flexural strength shall be determined according to Illinois Modified AASHTO T 177.

Except for Class PC and PS concrete, the Contractor shall transport the strength specimens from the site of the work to the field laboratory or other location as instructed by the Engineer. During transportation in a suitable light truck, the specimens shall be embedded in straw, burlap, or other acceptable material in a manner meeting with the approval of the Engineer to protect them from damage; care shall be taken to avoid impacts during hauling and handling. For strength specimens, the Contractor shall provide a field curing box for initial curing and a water storage tank for final curing. The field curing box will be required when an air temperature below 60 °F (16 °C) is expected during the initial curing period. The device shall maintain the initial curing temperature range specified in Illinois Modified AASHTO T 23, and may be insulated or power operated as appropriate.

1020.10 Handling, Measuring, and Batching Materials. Aggregates shall be handled in a manner to prevent mixing with soil and other foreign material.

Aggregates shall be handled in a manner which produces a uniform gradation, before placement in the plant bins. Aggregates delivered to the plant in a nonuniform gradation condition shall be stockpiled. The stockpiled aggregate shall be mixed uniformly before placement in the plant bins.

Aggregates shall have a uniform moisture content before placement in the plant bins. This may require aggregates to be stockpiled for 12 hours or more to allow drainage, or water added to the stockpile, or other methods approved by the Engineer. Moisture content requirements for crushed concrete, crushed slag or lightweight aggregate shall be according to Article 1004.01(e)(5).
Aggregates, cement, and finely divided minerals shall be measured by weight (mass). Water and admixtures shall be measured by volume or weight (mass).

The Engineer may permit aggregates, cement, and finely divided minerals to be measured by volume for small isolated structures and for miscellaneous items. Aggregates, cement, and finely divided minerals shall be measured individually. The volume shall be based upon dry, loose materials.

1020.11 Mixing Portland Cement Concrete. The mixing of concrete shall be according to the following.

(a) Ready-Mixed Concrete. Ready-mixed concrete is central-mixed, truck-mixed, or shrink-mixed concrete transported and delivered in a plastic state ready for placement in the work and shall be according to the following.

(1) Central-Mixed Concrete. Central-mixed concrete is concrete which has been completely mixed in a stationary mixer and delivered in a truck agitator, a truck mixer operating at agitating speed, or a nonagitator truck.

The stationary mixer shall operate at the drum speed for which it was designed. The batch shall be charged into the drum so that some of the water shall enter in advance of the cement, finely divided minerals, and aggregates. The flow of the water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing period. Water shall begin to enter the drum from zero to two seconds in advance of solid material and shall stop flowing within two seconds of the beginning of mixing time.

Some coarse aggregate shall enter in advance of other solid materials. For the balance of the charging time for solid materials, the aggregates, finely divided minerals, and cement (to assure thorough blending) shall each flow at acceptably uniform rates, as determined by visual observation. Coarse aggregate shall enter two seconds in advance of other solid materials and a uniform rate of flow shall continue to within two seconds of the completion of charging time.

The entire contents of the drum, or of each single compartment of a multiple-drum mixer, shall be discharged before the succeeding batch is introduced.

The volume of concrete mixed per batch shall not exceed the mixer's rated capacity as shown on the standard rating plate on the mixer by more than ten percent.

The minimum mixing time shall be 75 seconds for a stationary mixer having a capacity greater than 2 cu yd (1.5 cu m). For a mixer with a capacity equal to or less than 2 cu yd (1.5 cu m) the mixing time shall be 60 seconds. Transfer time in multiple drum mixers is included in the mixing time. Mixing time shall begin when all materials are in the mixing compartment and shall end when the discharge of any part of the batch is started. The required mixing times will be established by the Engineer for all types of stationary mixers.

When central-mixed concrete is to be transported in a truck agitator or a truck mixer, the stationary-mixed batch shall be transferred to the agitating unit without delay and without loss of any portion of the batch. Agitating shall start immediately thereafter and shall continue without interruption until the batch is discharged from the agitator. The ingredients of the batch shall be completely discharged from the agitator before
the succeeding batch is introduced. Drums and auxiliary parts of the equipment shall be kept free from accumulations of materials.

The vehicles used for transporting the mixed concrete shall be of such capacity, or the batches shall be so proportioned, that the entire contents of the mixer drum can be discharged into each vehicle load.

(2) Truck-Mixed Concrete. Truck-mixed concrete is completely mixed and delivered in a truck mixer. When the mixer is charged with fine and coarse aggregates simultaneously, not less than 60 nor more than 100 revolutions of the drum or blades at mixing speed shall be required, after all of the ingredients including water are in the drum. When fine and coarse aggregates are charged separately, not less than 70 revolutions will be required. For self-consolidating concrete, a minimum of 100 revolutions is required in all cases. Additional mixing beyond 100 revolutions shall be at agitating speed unless additions of water, admixtures, or other materials are made at the jobsite. The mixing operation shall begin immediately after the cement and water, or the cement and wet aggregates, come in contact. The ingredients of the batch shall be completely discharged from the drum before the succeeding batch is introduced. The drum and auxiliary parts of the equipment shall be kept free from accumulations of materials. If additional water or an admixture is added at the jobsite, the concrete batch shall be mixed a minimum of 40 additional revolutions after each addition.

(3) Shrink-Mixed Concrete. Shrink-mixed concrete is mixed partially in a stationary mixer and completed in a truck mixer for delivery. The mixing time of the stationary mixer may be reduced to a minimum of 30 seconds to intermingle the ingredients, before transferring to the truck mixer. All ingredients for the batch shall be in the stationary mixer and partially mixed before any of the mixture is discharged into the truck mixer. The partially mixed batch shall be transferred to the truck mixer without delay and without loss of any portion of the batch, and mixing in the truck mixer shall start immediately. The mixing time in the truck mixer shall be not less than 50 nor more than 100 revolutions of the drum or blades at mixing speed. For self-consolidating concrete, a minimum of 100 revolutions is required in the truck mixer. Additional mixing beyond 100 revolutions shall be at agitating speed, unless additions of water, admixtures, or other materials are made at the jobsite. Units designed as agitators shall not be used for shrink mixing. The ingredients of the batch shall be completely discharged from the drum before the succeeding batch is introduced. The drum and auxiliary parts of the equipment shall be kept free from accumulations of materials. If additional water or an admixture is added at the jobsite, the concrete batch shall be mixed a minimum of 40 additional revolutions after each addition.

(4) Mixing Water. Wash water shall be completely discharged from the drum or container before a batch is introduced. All mixing water shall be added at the plant and any adjustment of water at the jobsite by the Contractor shall not exceed the specified maximum water/cement ratio or slump. If strength specimens have been made for a batch of concrete, and subsequently during discharge there is more water added, additional strength specimens shall be made for the batch of concrete. No additional water may be added at the jobsite to central-mixed concrete if the mix design has less than 565 lbs/cu yd (335 kg/cu m) of cement and finely divided minerals summed together.
(5) Mixing and Agitating Speeds. The mixing or agitating speeds used for truck mixers or truck agitators shall be per the manufacturer’s rating plate.

(6) Capacities. The volume of plastic concrete in a given batch will be determined according to AASHTO T 121, based on the total weight (mass) of the batch, determined either from the weight (masses) of all materials, including water, entering the batch or directly from the net weight (mass) of the concrete in the batch as delivered.

The volume of mixed concrete in truck mixers or truck agitators shall in no case be greater than the rated capacity determined according to the Truck Mixer, Agitator, and Front Discharge Concrete Carrier Standards of the Truck Mixer Manufacturer’s Bureau, as shown by the rating plate attached to the truck. If the truck mixer does not have a rating plate, the volume of mixed concrete shall not exceed 63 percent of the gross volume of the drum or container, disregarding the blades. For truck agitators, the value is 80 percent.

(7) Time of Haul. Haul time shall begin when the delivery ticket is stamped. The delivery ticket shall be stamped no later than five minutes after the addition of the mixing water to the cement, or after the addition of the cement to the aggregate when the combined aggregates contain free moisture in excess of two percent by weight (mass). If more than one batch is required for charging a truck using a stationary mixer, the time of haul shall start with mixing of the first batch. Haul time shall end when the truck is emptied for incorporation of the concrete into the work.

The time elapsing from when water is added to the mix until it is deposited in place at the site of the work shall not exceed 30 minutes when the concrete is transported in nonagitating trucks.

The maximum haul time for concrete transported in truck mixers or truck agitators shall be according to the following.

<table>
<thead>
<tr>
<th>Concrete Temperature at Point of Discharge °F (°C)</th>
<th>Haul Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
</tr>
<tr>
<td>50-64 (10-17.5)</td>
<td>1</td>
</tr>
<tr>
<td>&gt;64 (&gt;17.5) - without retarder</td>
<td>1</td>
</tr>
<tr>
<td>&gt;64 (&gt;17.5) - with retarder</td>
<td>1</td>
</tr>
</tbody>
</table>

To encourage start-up testing for mix adjustments at the plant, the first two trucks will be allowed an additional 15 minutes haul time whenever such testing is performed.

For a mixture which is not mixed on the jobsite, a delivery ticket shall be required for each load. The following information shall be recorded on each delivery ticket: (1) ticket number; (2) name of producer and plant location; (3) contract number; (4) name of Contractor; (5) stamped date and time batched; (6) truck number; (7) quantity batched; (8) amount of admixture(s) in the batch; (9) amount of water in the batch; and (10) Department mix design number.

For concrete mixed in jobsite stationary mixers, the above delivery ticket may be waived, but a method of verifying the haul time shall be established to the satisfaction of the Engineer.
(8) Production and Delivery. The production of ready-mixed concrete shall be such that the operations of placing and finishing will be continuous insofar as the job operations require. The Contractor shall be responsible for producing concrete that will have the required workability, consistency, and plasticity when delivered to the work. Concrete which is unsuitable for placement as delivered will be rejected. The Contractor shall minimize the need to adjust the mixture at the jobsite, such as adding water and admixtures prior to discharging.

(9) Use of Multiple Plants in the Same Construction Item. The Contractor may simultaneously use central-mixed, truck-mixed, and shrink-mixed concrete from more than one plant, for the same construction item, on the same day, and in the same pour. However, the following criteria shall be met.

a. Each plant shall use the same cement, finely divided minerals, aggregates, admixtures, and fibers.

b. Each plant shall use the same mix design. However, material proportions may be altered slightly in the field to meet slump and air content criteria. Field water adjustments shall not result in a difference that exceeds 0.02 between plants for water/cement ratio. The required cement factor for central-mixed concrete shall be increased to match truck-mixed or shrink-mixed concrete, if the latter two types of mixed concrete are used in the same pour.

c. The maximum slump difference between deliveries of concrete shall be 3/4 in. (19 mm) when tested at the jobsite. If the difference is exceeded, but test results are within specification limits, the concrete may be used. The Contractor shall take immediate corrective action and shall test subsequent deliveries of concrete until the slump difference is corrected. For each day, the first three truck loads of delivered concrete from each plant shall be tested for slump by the Contractor. Thereafter, when a specified test frequency for slump is to be performed, it shall be conducted for each plant at the same time.

d. The maximum air content difference between deliveries of concrete shall be 1.5 percent when tested at the jobsite. If the difference is exceeded, but test results are within specification limits, the concrete may be used. The Contractor shall take immediate corrective action and shall test subsequent deliveries of concrete until the air content difference is corrected. For each day, the first three truck loads of delivered concrete from each plant shall be tested for air content by the Contractor. Thereafter, when a specified test frequency for air content is to be performed, it shall be conducted for each plant at the same time.

e. Strength tests shall be performed and taken at the jobsite for each plant. When a specified strength test is to be performed, it shall be conducted for each plant at the same time. The difference between plants for strength shall not exceed 900 psi (6200 kPa) compressive and 90 psi (620 kPa) flexural. If the strength difference requirements are exceeded, the Contractor shall take corrective action.

f. The maximum haul time difference between deliveries of concrete shall be 15 minutes. If the difference is exceeded, but haul time is within specification limits, the concrete may be used. The Contractor shall take immediate corrective action and check subsequent deliveries of concrete.
(b) Class PC Concrete. The concrete shall be central-mixed or truck-mixed. Variations in plastic concrete properties shall be minimized between batches.

(c) Class PV Concrete. The concrete shall be central-mixed, truck-mixed, or shrink-mixed.

The required mixing time for stationary mixers with a capacity greater than 2 cu yd (1.5 cu m) may be less than 75 seconds upon satisfactory completion of a mixer performance test. Mixer performance tests may be requested by the Contractor when the quantity of concrete to be placed exceeds 50,000 sq yd (42,000 sq m). The testing shall be conducted according to the current Bureau of Materials and Physical Research’s Policy Memorandum, "Field Test Procedures for Mixer Performance and Concrete Uniformity Tests".

The Contractor will be allowed to test two mixing times within a range of 50 to 75 seconds. If satisfactory results are not obtained from the required tests, the mixing time shall continue to be 75 seconds for the remainder of the contract. If satisfactory results are obtained, the mixing time may be reduced. In no event will mixing time be less than 50 seconds.

The Contractor shall furnish the labor, equipment, and material required to perform the testing according to the current Bureau of Materials and Physical Research’s Policy Memorandum, “Field Test Procedures for Mixer Performance and Concrete Uniformity Tests”.

A contract which has 12 ft (3.6 m) wide pavement or base course, and a continuous length of 1/2 mile (0.8 km) or more, shall have the following additional requirements.

(1) The plant and truck delivery operation shall be able to provide a minimum of 50 cu yd (38 cu m) of concrete per hour.

(2) The plant shall have automatic or semi-automatic batching equipment.

(d) All Other Classes of Concrete. The concrete shall be central-mixed, truck-mixed, or shrink-mixed concrete.

1020.12 Mobile Portland Cement Concrete Plants. The use of a mobile portland cement concrete plant may be approved under the provisions of Article 1020.10 for volumetric proportioning in small isolated structures, thin overlays, and for miscellaneous and incidental concrete items.

The first 1 cu ft (0.03 cu m) of concrete produced may not contain sufficient mortar and shall not be incorporated in the work. The side plate on the cement feeder shall be removed periodically (normally the first time the mixer is used each day) to see if cement is building up on the feed drum.

Sufficient mixing capacity of mixers shall be provided to enable continuous placing and finishing insofar as the job operations and the specifications require.

Slump and air tests made immediately after discharge of the mix may be misleading, since the aggregates may absorb a significant amount of water for four or five minutes after mixing.

1020.13 Curing and Protection. The method of curing, curing period, and method of protection for each type of concrete construction is included in the following Index Table.
### INDEX TABLE OF CURING AND PROTECTION OF CONCRETE CONSTRUCTION

<table>
<thead>
<tr>
<th>TYPE OF CONSTRUCTION</th>
<th>CURING METHODS</th>
<th>CURING PERIOD DAYS</th>
<th>LOW AIR TEMPERATURE PROTECTION METHODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-Place Concrete 11/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pavement Shoulder</td>
<td>1020.13(a)(1)(2)(3)(4)(5)</td>
<td>3</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Base Course</td>
<td>1020.13(a)(1)(2)(3)(4)(5)</td>
<td>3</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Driveway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb</td>
<td>1020.13(a)(1)(2)(3)(4)(5)</td>
<td>3</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Gutter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb &amp; Gutter</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sidewalk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope Wall</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Paved Ditch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catch Basin</td>
<td>1020.13(a)(1)(2)(3)(4)(5)</td>
<td>3</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Manhole</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valve Vault</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pavement Patching</td>
<td>1020.13(a)(1)(2)(3)(4)(5)</td>
<td>2</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Bridge Deck Patching</td>
<td>1020.13(a)(3)(5)</td>
<td>3 or 7 12/</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Railroad Crossing</td>
<td>1020.13(a)(3)(5)</td>
<td>1</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Piles and Drilled Shafts</td>
<td>1020.13(a)(3)(5)</td>
<td>7</td>
<td>1020.13(d)(1)(2)(3)</td>
</tr>
<tr>
<td>Foundations &amp; Footings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superstructure (except deck)</td>
<td>1020.13(a)(1)(2)(3)(5)</td>
<td>8</td>
<td>1020.13(d)(1)(2)</td>
</tr>
<tr>
<td>Deck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridge Approach Slab</td>
<td>1020.13(a)(5)</td>
<td>7</td>
<td>1020.13(d)(1)(2)</td>
</tr>
<tr>
<td>Other Incidental Concrete</td>
<td>1020.13(a)(1)(2)(3)(5)</td>
<td>3</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Precast Concrete 11/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridge Slabs</td>
<td>1020.13(a)(3)(5)</td>
<td>9</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>Piles and Pile Caps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Structural Members</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Other Precast Items</td>
<td>1020.13(a)(3)(4)(5)</td>
<td>8</td>
<td>1020.13(c)</td>
</tr>
<tr>
<td>All Items</td>
<td>1020(a)(3)(5)</td>
<td>9</td>
<td>1020.13(c)</td>
</tr>
</tbody>
</table>

Notes-General:

1/ Type I, membrane curing only

2/ Type II, membrane curing only

3/ Type III, membrane curing only
4/ Type I, II and III membrane curing

5/ Membrane Curing will not be permitted between November 1 and April 15.

6/ The use of water to inundate foundations and footings, seal coats or the bottom slab of culverts is permissible when approved by the Engineer, provided the water temperature can be maintained at 45 °F (7 °C) or higher.

7/ Asphalt emulsion for waterproofing may be used in lieu of other curing methods when specified and permitted according to Article 503.18.

8/ On non-traffic surfaces which receive protective coat according to Article 503.19, a linseed oil emulsion curing compound may be used as a substitute for protective coat and other curing methods. The linseed oil emulsion curing compound will be permitted between April 16 and October 31 of the same year, provided it is applied with a mechanical sprayer according to Article 1101.09(b).

9/ Steam, supplemental heat, or insulated blankets (with or without steam-supplemental heat) are acceptable and shall be according to the Bureau of Materials and Physical Research’s Policy Memorandum “Quality Control/Quality Assurance Program for Precast Concrete Products” and the “Manual for Fabrication of Precast, Prestressed Concrete Products”.

10/ A moist room according to AASHTO M 201 is acceptable for curing.

11/ If curing is required and interrupted because of form removal for cast-in-place concrete items, precast concrete products, or precast prestressed concrete products, the curing shall be resumed within two hours from the start of the form removal.

12/ Curing maintained only until opening strength is attained for pavement patching, with a maximum curing period of three days. For bridge deck patching the curing period shall be three days if Class PP concrete is used and 7 days if Class BS concrete is used.

13/ The curing period shall end when the concrete has attained the mix design strength. The producer has the option to discontinue curing when the concrete has attained 80 percent of the mix design strength or after seven days. All strength test specimens shall remain with the units and shall be subjected to the same curing method and environmental condition as the units, until the time of testing.

14/ The producer shall determine the curing period or may elect to not cure the product. All strength test specimens shall remain with the units and shall be subjected to the same curing method and environmental condition as the units, until the time of testing.

15/ The producer has the option to continue curing after strand release.

16/ When structural steel or structural concrete is in place above slope wall, Article 1020.13(c) shall not apply. The protection method shall be according to Article 1020.13(d)(1).
17/ When Article 1020.13(d)(2) is used to protect the deck, the housing may enclose only the bottom and sides. The top surface shall be protected according to Article 1020.13(d)(1).

18/ For culverts having a waterway opening of 10 sq ft (1 sq m) or less, the culverts may be protected according to Article 1020.13(d)(3).

(a) Methods of Curing. Except as provided for in the Index Table of Curing and Protection of Concrete Construction, curing shall be accomplished by one of the following described methods. When water is required to wet the surface, it shall be applied as a fine spray so that it will not mar or pond on the surface. Except where otherwise specified, the curing period shall be at least 72 hours.

(1) Waterproof Paper Method. The surface of the concrete shall be covered with waterproof paper as soon as the concrete has hardened sufficiently to prevent marring the surface. The surface of the concrete shall be wetted immediately before the paper is placed. The blankets shall be lapped at least 12 in. (300 mm) end to end, and these laps shall be securely weighted with a windrow of earth, or other approved method, to form a closed joint. The same requirements shall apply to the longitudinal laps where separate strips are used for curing edges, except the lap shall be at least 9 in. (225 mm). The edges of the blanket shall be weighted securely with a continuous windrow of earth or any other means satisfactory to the Engineer to provide an air-tight cover. Any torn places or holes in the paper shall be repaired immediately by patches cemented over the openings, using a bituminous cement having a melting point of not less than 180 °F (82 °C). The blankets may be reused, provided they are air-tight and kept serviceable by proper repairs. A longitudinal pleat shall be provided in the blanket to permit shrinkage where the width of the blanket is sufficient to cover the entire surface. The pleat will not be required where separate strips are used for the edges. Joints in the blanket shall be sewn or cemented together in such a manner that they will not separate during use.

(2) Polyethylene Sheeting Method. The surface of the concrete shall be covered with white polyethylene sheeting as soon as the concrete has hardened sufficiently to prevent marring the surface. The surface of the concrete shall be wetted immediately before the sheeting is placed. The edges of the sheeting shall be weighted securely with a continuous windrow of earth or any other means satisfactory to the Engineer to provide an air-tight cover. Adjoining sheets shall overlap not less than 12 in. (300 mm) and the laps shall be securely weighted with earth, or any other means satisfactory to the Engineer, to provide an air tight cover. For surface and base course concrete, the polyethylene sheets shall be not less than 100 ft (30 m) in length nor longer than can be conveniently handled, and shall be of such width that, when in place, they will cover the full width of the surface, including the edges, except that separate strips may be used to cover the edges. Any tears or holes in the sheeting shall be repaired. When sheets are no longer serviceable as a single unit, the Contractor may select from such sheets and reuse those which will serve for further applications, provided two sheets are used as a single unit; however, the double sheet units will be rejected when the Engineer deems that they no longer provide an air tight cover.

(3) Wetted Burlap Method. The surface of the concrete shall be covered with wetted burlap blankets as soon as the concrete has hardened sufficiently to prevent marring the surface. The blankets shall overlap 6 in. (150 mm). At least two layers of wetted
burlap shall be placed on the finished surface. The burlap shall be kept saturated by means of a mechanically operated sprinkling system. In place of the sprinkling system, at the Contractor’s option, two layers of burlap covered with impermeable covering shall be used. The burlap shall be kept saturated with water. Plastic coated burlap may be substituted for one layer of burlap and impermeable covering.

The blankets shall be placed so that they are in contact with the edges of the concrete, and that portion of the material in contact with the edges shall be kept saturated with water.

(4) Membrane Curing Method. Membrane curing will not be permitted where a protective coat, concrete sealer, or waterproofing is to be applied, or at areas where rubbing or a normal finish is required, or at construction joints other than those necessary in pavement or base course. Concrete at these locations shall be cured by another method specified in Article 1020.13(a).

After all finishing work to the concrete surface has been completed, it shall be sealed with membrane curing compound of the type specified within ten minutes. The seal shall be maintained for the specified curing period. The edges of the concrete shall, likewise, be sealed within ten minutes after the forms are removed. Two separate applications, applied at least one minute apart, each at the rate of not less than 1 gal/250 sq ft (0.16 L/sq m) will be required upon the surfaces and edges of the concrete. These applications shall be made with the mechanical equipment specified. Type III compound shall be agitated immediately before and during the application.

At locations where the coating is discontinuous or where pin holes show or where the coating is damaged due to any cause and on areas adjacent to sawed joints, immediately after sawing is completed, an additional coating of membrane curing compound shall be applied at the above specified rate. The equipment used may be of the same type as that used for coating variable widths of pavement. Before the additional coating is applied adjacent to sawed joints, the cut faces of the joint shall be protected by inserting a suitable flexible material in the joint, or placing an adhesive width of impermeable material over the joint, or by placing the permanent sealing compound in the joint. Material, other than the permanent sealing compound, used to protect cut faces of the joint, shall remain in place for the duration of the curing period. In lieu of applying the additional coating, the area of the sawed joint may be cured according to any other method permitted.

When rain occurs before an application of membrane curing compound has dried, and the coating is damaged, the Engineer may require another application be made in the same manner and at the same rate as the original coat. The Engineer may order curing by another method specified, if unsatisfactory results are obtained with membrane curing compound.

(5) Wetted Cotton Mat Method. After the surface of concrete has been textured or finished, it shall be covered immediately with dry or damp cotton mats. The cotton mats shall be placed in a manner which will not mar the concrete surface. A texture resulting from the cotton mat material is acceptable. The cotton mats shall then be wetted immediately and thoroughly soaked with a gentle spray of water. For bridge decks, a foot bridge shall be used to place and wet the cotton mats.
The cotton mats shall be maintained in a wetted condition until the concrete has hardened sufficiently to place soaker hoses without marring the concrete surface. The soaker hoses shall be placed on top of the cotton mats at a maximum 4 ft (1.2 m) spacing. The cotton mats shall be kept wet with a continuous supply of water for the remainder of the curing period. Other continuous wetting systems may be used if approved by the Engineer.

After placement of the soaker hoses, the cotton mats shall be covered with white polyethylene sheeting or burlap-polyethylene blankets.

For construction items other than bridge decks, soaker hoses or a continuous wetting system will not be required if the alternative method keeps the cotton mats wet. Periodic wetting of the cotton mats is acceptable.

For areas inaccessible to the cotton mats on bridge decks, curing shall be according to Article 1020.13(a)(3).

(b) Removing and Replacing Curing Covering. When curing methods specified above in Article 1020.13(a), (1), (2), or (3) are used for concrete pavement, the curing covering for each day's paving shall be removed to permit testing of the pavement surface with a profilograph or straightedge, as directed by the Engineer.

Immediately after testing, the surface of the pavement shall be wetted thoroughly and the curing coverings replaced. The top surface and the edges of the concrete shall not be left unprotected for a period of more than 1/2 hour.

(c) Protection of Concrete, Other Than Structures, From Low Air Temperatures. When the official National Weather Service forecast for the construction area predicts a low of 32 °F (0 °C), or lower, or if the actual temperature drops to 32 °F (0 °C), or lower, concrete less than 72 hours old shall be provided at least the following protection.

<table>
<thead>
<tr>
<th>Minimum Temperature</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 – 32 °F (−4 – 0 °C)</td>
<td>Two layers of polyethylene sheeting, one layer of polyethylene and one layer of burlap, or two layers of waterproof paper.</td>
</tr>
<tr>
<td>Below 25 °F (−4 °C)</td>
<td>6 in. (150 mm) of straw covered with one layer of polyethylene sheeting or waterproof paper.</td>
</tr>
</tbody>
</table>

These protective covers shall remain in place until the concrete is at least 96 hours old. When straw is required on pavement cured with membrane curing compound, the compound shall be covered with a layer of burlap, polyethylene sheeting or waterproof paper before the straw is applied.

After September 15, there shall be available to the work within four hours, sufficient clean, dry straw to cover at least two days production. Additional straw shall be provided as needed to afford the protection required. Regardless of the precautions taken, the Contractor shall be responsible for protection of the concrete placed and any concrete damaged by cold temperatures shall be removed and replaced.

(d) Protection of Concrete Structures From Low Air Temperatures. When the official National Weather Service forecast for the construction area predicts a low below 45 °F
(7 °C), or if the actual temperature drops below 45 °F (7 °C), concrete less than 72 hours old shall be provided protection. Concrete shall also be provided protection when placed during the winter period of December 1 through March 15. Concrete shall not be placed until the materials, facilities, and equipment for protection are approved by the Engineer.

When directed by the Engineer, the Contractor may be required to place concrete during the winter period. When winter construction is specified, the Contractor shall proceed with the construction, including excavation, pile driving, concrete, steel erection, and all appurtenant work required for the complete construction of the item, except at times when weather conditions make such operations impracticable.

Regardless of the precautions taken, the Contractor shall be responsible for protection of the concrete placed and any concrete damaged by cold temperatures shall be removed and replaced.

(1) Protection Method I. The concrete shall be completely covered with insulating material such as fiberglass, rock wool, or other approved commercial insulating material having the minimum thermal resistance $R$, as defined in ASTM C 168, for the corresponding minimum dimension of the concrete unit being protected as shown in the following table.

<table>
<thead>
<tr>
<th>Minimum Pour Dimension</th>
<th>Thermal Resistance $R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>in. (mm)</td>
<td></td>
</tr>
<tr>
<td>6 or less (150 or less)</td>
<td>R=16</td>
</tr>
<tr>
<td>&gt; 6 to 12 (&gt;150 to 300)</td>
<td>R=10</td>
</tr>
<tr>
<td>&gt; 12 to 18 (&gt;300 to 450)</td>
<td>R=6</td>
</tr>
<tr>
<td>&gt; 18 (&gt;450)</td>
<td>R=4</td>
</tr>
</tbody>
</table>

The insulating material manufacturer shall clearly mark the insulating material with the thermal resistance $R$ value.

The insulating material shall be completely enclosed on sides and edges with an approved waterproof liner and shall be maintained in a serviceable condition. Any tears in the liner shall be repaired in a manner approved by the Engineer. The Contractor shall provide means for checking the temperature of the surface of the concrete during the protection period.

On formed surfaces, the insulating material shall be attached to the outside of the forms with wood cleats or other suitable means to prevent any circulation of air under the insulation and shall be in place before the concrete is placed. The blanket insulation shall be applied tightly against the forms. The edges and ends shall be attached so as to exclude air and moisture. If the blankets are provided with nailing flanges, the flanges shall be attached to the studs with cleats. Where tie rods or reinforcement bars protrude, the areas adjacent to the rods or bars shall be adequately protected in a manner satisfactory to the Engineer. When practicable, the insulation shall overlap any previously placed concrete by at least 1 ft (300 mm). Insulation on the underside of floors on steel members shall cover the top flanges of supporting members. On horizontal surfaces, the insulating material shall be placed as soon as the concrete has set, so that the surface will not be marred and shall be covered with canvas or other waterproof covering. The insulating material shall remain in place for a period of seven days after the concrete is placed.
The Contractor may remove the forms, providing the temperature is 35 °F (2 °C) and rising and the Contractor is able to wrap the particular section within two hours from the time of the start of the form removal. The insulation shall remain in place for the remainder of the seven days curing period.

(2) Protection Method II. The concrete shall be enclosed in adequate housing and the air surrounding the concrete kept at a temperature of not less than 50 °F (10 °C) nor more than 80 °F (27 °C) for a period of seven days after the concrete is placed. The Contractor shall provide means for checking the temperature of the surface of the concrete or air temperature within the housing during the protection period. All exposed surfaces within the housing shall be cured according to the Index Table. The Contractor shall provide adequate fire protection where heating is in progress and such protection shall be accessible at all times. The Contractor shall maintain labor to keep the heating equipment in continuous operation.

At the close of the heating period, the temperature shall be decreased to the approximate temperature of the outside air at a rate not to exceed 15 °F (8 °C) per 12 hour period, after which the housing maybe removed. The surface of the concrete shall be permitted to dry during the cooling period.

(3) Protection Method III. As soon as the surface is sufficiently set to prevent marring, the concrete shall be covered with 12 in. (300 mm) of loose, dry straw followed by a layer of impermeable covering. The edges of the covering shall be sealed to prevent circulation of air and prevent the cover from flapping or blowing. The protection shall remain in place until the concrete is seven days old. If construction operations require removal, the protection removed shall be replaced immediately after completion or suspension of such operations.

1020.14 Temperature Control for Placement. Temperature control for concrete placement shall be according to the following.

(a) Concrete other than Structures. Concrete may be placed when the air temperature is above 35 °F (2 °C) and rising, and concrete placement shall stop when the falling temperature reaches 40 °F (4 °C) or below, unless otherwise approved by the Engineer.

The temperature of concrete immediately before placement shall be a minimum of 50 °F (10 °C) and a maximum of 90 °F (32 °C). If concrete is pumped, the temperature of the concrete at point of placement shall be a minimum of 50 °F (10 °C) and a maximum of 90 °F (32 °C). A maximum concrete temperature shall not apply to Class PP concrete.

(b) Concrete in Structures. Concrete may be placed when the air temperature is above 40 °F (4 °C) and rising, and concrete placement shall stop when the falling temperature reaches 45 °F (7 °C) or below, unless otherwise approved by the Engineer.

The temperature of the concrete immediately before placement shall be a minimum of 50 °F (10 °C) and a maximum of 90 °F (32 °C). If concrete is pumped, the temperature of the concrete at point of placement shall be a minimum of 50 °F (10 °C) and a maximum of 90 °F (32 °C).

When insulated forms are used according to Article 1020.13(d)(1), the maximum temperature of the concrete mixture immediately before placement shall be 80 °F (25 °C).
When concrete is placed in contact with previously placed concrete, the temperature of the freshly mixed concrete may be increased to 80 °F (25 °C) by the Contractor to offset anticipated heat loss.

(c) All Classes of Concrete. Aggregates and water shall be heated or cooled uniformly and as necessary to produce concrete within the specified temperature limits. No frozen aggregates shall be used in the concrete.

(d) Temperature. The concrete temperature shall be determined according to Illinois Modified AASHTO T 309.

1020.15 Heat of Hydration Control for Concrete Structures. The Contractor shall control the heat of hydration for concrete structures when the least dimension for a drilled shaft, foundation, footing, substructure, or superstructure concrete pour exceeds 5.0 ft (1.5 m). The work shall be according to the following.

(a) Temperature Restrictions. The maximum temperature of the concrete after placement shall not exceed 150 °F (66 °C). The maximum temperature differential between the internal concrete core and concrete 2 to 3 in. (50 to 75 mm) from the exposed surface shall not exceed 35 °F (19 °C). The Contractor shall perform temperature monitoring to ensure compliance with the temperature restrictions.

(b) Thermal Control Plan. The Contractor shall provide a thermal control plan a minimum of 28 calendar days prior to concrete placement for review by the Engineer. Acceptance of the thermal control plan by the Engineer shall not preclude the Contractor from specification compliance, and from preventing cracks in the concrete. At a minimum, the thermal control plan shall provide detailed information on the following requested items and shall comply with the specific specifications indicated for each item.

(1) Concrete mix design(s) to be used. Grout mix design if post-cooling with embedded pipe.

The mix design requirements in Articles 1020.04 and 1020.05 shall be revised to include the following additional requirements to control the heat of hydration.

a. The concrete mixture should be uniformly graded and preference for larger size aggregate should be used in the mix design. Article 1004.02(d)(2) shall apply and information in the “Portland Cement Concrete Level III Technician Course – Manual of Instructions for Design of Concrete Mixtures” may be used to develop the uniformly graded mixture.

b. The following shall apply to all concrete except Class DS concrete or when self-consolidating concrete is desired. For central-mixed concrete, the Contractor shall have the option to develop a mixture with a minimum of 520 lbs/cu yd (309 kg/cu m) of cement and finely divided minerals summed together. For truck-mixed or shrink-mixed concrete, the Contractor shall have the option to develop a mixture with a minimum of 550 lbs/cu yd (326 kg/cu m) of cement and finely divided minerals summed together. A water-reducing or high range water-reducing admixture shall be used in the central mixed, truck-mixed or shrink-mixed concrete mixture. For any mixture to be placed underwater, the minimum cement and finely divided minerals shall be 550 lbs/cu yd (326 kg/cu m) for central-mixed concrete, and 580 lbs/cu yd (344 kg/cu m) for truck-mixed or shrink-mixed concrete.
For Class DS concrete, CA 11 may be used. If CA 11 is used, the Contractor shall have the option to develop a mixture with a minimum cement and finely divided minerals of 605 lbs/cu yd (360 kg/cu m) summed together. If CA 11 is used and either Class DS concrete is placed underwater or a self-consolidating concrete mixture is desired, the Contractor shall have the option to develop a mixture with a minimum cement and finely divided minerals of 635 lbs/cu yd (378 kg/cu m) summed together.

c. The minimum portland cement content in the mixture shall be 375 lbs/cu yd (222 kg/cu m). When the total of organic processing additions, inorganic processing additions, and limestone addition exceed 5.0 percent in the cement, the minimum portland cement content in the mixture shall be 400 lbs/cu yd (237 kg/cu m). For a drilled shaft, foundation, footing, or substructure, the minimum portland cement may be reduced to as low as 330 lbs/cu yd (196 kg/cu m) if the concrete has adequate freeze/thaw durability. The Contractor shall provide freeze/thaw test results according to AASHTO T 161 Procedure A or B, and the relative dynamic modulus of elasticity of the mix design shall be a minimum of 80 percent. Freeze/thaw testing will not be required for concrete that will not be exposed to freezing and thawing conditions as determined by the Engineer.

d. The maximum cement replacement with fly ash shall be 40.0 percent. The maximum cement replacement with ground granulated blast-furnace slag shall be 65.0 percent. When cement replacement with ground granulated blast-furnace slag exceeds 35.0 percent, only Grade 100 shall be used.

e. The mixture may contain a maximum of two finely divided minerals. The finely divided mineral in portland-pozzolan cement or portland blast-furnace slag cement shall count toward the total number of finely divided minerals allowed. The finely divided minerals shall constitute a maximum of 65.0 percent of the total cement plus finely divided minerals. The fly ash portion shall not exceed 40.0 percent. The ground granulated blast-furnace slag portion shall not exceed 65.0 percent. The microsilica or high-reactivity metakaolin portion used together or separately shall not exceed 5.0 percent.

f. The time to obtain the specified strength may be increased to a maximum 56 days, provided the curing period specified in Article 1020.13 is increased to a minimum of 14 days.

The minimum grout strength for filling embedded pipe shall be as specified for the concrete, and testing shall be according to AASHTO T 106.

(2) The selected mathematical method for evaluating heat of hydration thermal effects, which shall include the calculated adiabatic temperature rise, calculated maximum concrete temperature, and calculated maximum temperature differential between the internal concrete core and concrete 2 to 3 in. (50 to 75 mm) from the exposed surface. The time when the maximum concrete temperature and maximum temperature differential will occur is required.

Acceptable mathematical methods include ACI 207.2R “Report on Thermal and Volume Change Effects on Cracking of Mass Concrete” as well as other proprietary methods. The Contractor shall perform heat of hydration testing on the cement and finely divided minerals to be used in the concrete mixture. The test shall be
according to ASTM C 186 or other applicable test methods, and the result for heat shall be used in the equation to calculate adiabatic temperature rise. Other required test parameters for the mathematical model may be assumed if appropriate.

The Contractor has the option to propose a higher maximum temperature differential between the internal concrete core and concrete 2 to 3 in. (50 to 75 mm) from the exposed surface, but the proposed value shall not exceed 50 °F (28 °C). In addition, based on strength gain of the concrete, multiple maximum temperature differentials at different times may be proposed. The proposed value shall be justified through a mathematical method.

(3) Proposed maximum concrete temperature or temperature range prior to placement.

Article 1020.14 shall apply except a minimum 40 °F (4 °C) concrete temperature will be permitted.

(4) Pre-cooling, post-cooling, and surface insulation methods that will be used to ensure the concrete will comply with the specified maximum temperature and specified or proposed temperature differential. For reinforcement that extends beyond the limits of the pour, the Contractor shall indicate if the reinforcement is required to be covered with insulation.

Refer to ACI 207.4R “Cooling and Insulating Systems for Mass Concrete” for acceptable methods that will be permitted. If embedded pipe is used for post-cooling, the material shall be polyvinyl chloride or polyethylene. The embedded pipe system shall be properly supported, and the Contractor shall subsequently inspect glued joints to ensure they are able to withstand free falling concrete. The embedded pipe system shall be leak tested after inspection of the glued joints, and prior to the concrete placement. The leak test shall be performed at maximum service pressure or higher for a minimum of 15 minutes. All leaks shall be repaired. The embedded pipe cooling water may be from natural sources such as streams and rivers, but shall be filtered to prevent system stoppages. When the embedded pipe is no longer needed, the surface connections to the pipe shall be removed to a depth of 4 in. (100 mm) below the surface of the concrete. The remaining pipe shall be completely filled with grout. The 4 in. (100 mm) deep concrete hole shall be filled with nonshrink grout. Form and insulation removal shall be done in a manner to prevent cracking and ensure the maximum temperature differential is maintained. Insulation shall be in good condition as determined by the Engineer and properly attached.

(5) Dimensions of each concrete pour, location of construction joints, placement operations, pour pattern, lift heights, and time delays between lifts.

Refer to ACI 207.1R “Guide to Mass Concrete” for acceptable placement operations that will be permitted.

(6) Type of temperature monitoring system, the number of temperature sensors, and location of sensors.

A minimum of two independent temperature monitoring systems and corresponding sensors shall be used.
The temperature monitoring system shall have a minimum temperature range of 32 °F (0 °C) to 212 °F (100 °C), an accuracy of ± 2 °F (± 1 °C), and be able to automatically record temperatures without external power. Temperature monitoring shall begin once the sensor is encased in concrete, and with a maximum interval of one hour. Temperature monitoring may be discontinued after the maximum concrete temperature has been reached, post-cooling is no longer required, and the maximum temperature differential between the internal concrete core and the ambient air temperature does not exceed 35 °F (19 °C). The Contractor has the option to select a higher maximum temperature differential, but the proposed value shall not exceed 50 °F (28 °C). The proposed value shall be justified through a mathematical method.

At a minimum, a temperature sensor shall be located at the theoretical hottest portion of the concrete, normally the geometric center, and at the exterior face that will provide the maximum temperature differential. At the exterior face, the sensor shall be located 2 to 3 in. (50 to 75 mm) from the surface of the concrete. Sensors shall also be located a minimum of 1 in. (25 mm) away from reinforcement, and equidistant between cooling pipes if either applies. A sensor will also be required to measure ambient air temperature. The entrant/exit cooling water temperature for embedded pipe shall also be monitored.

Temperature monitoring results shall be provided to the Engineer a minimum of once each day and whenever requested by the Engineer. The report may be electronic or hard copy. The report shall indicate the location of each sensor, the temperature recorded, and the time recorded. The report shall be for all sensors and shall include ambient air temperature and entrant/exit cooling water temperatures. The temperature data in the report may be provided in tabular or graphical format, and the report shall indicate any corrective actions during the monitoring period. At the completion of the monitoring period, the Contractor shall provide the Engineer a final report that includes all temperature data and corrective actions.

(7) Indicate contingency operations to be used if the maximum temperature or temperature differential of the concrete is reached after placement.

(c) Temperature Restriction Violations. If the maximum temperature of the concrete after placement exceeds 150 °F (66 °C), but is equal to or less than 158 °F (70 °C), the concrete will be accepted if no cracking or other unacceptable defects are identified. If cracking or unacceptable defects are identified, Article 105.03 shall apply. If the concrete temperature exceeds 158 °F (70 °C), Article 105.03 shall apply.

If a temperature differential between the internal concrete core and concrete 2 to 3 in. (50 to 75 mm) from the exposed surface exceeds the specified or proposed maximum value allowed, the concrete will be accepted if no cracking or other unacceptable defects are identified. If unacceptable defects are identified, Article 105.03 shall apply.

When the maximum 150 °F (66 °C) concrete temperature or the maximum allowed temperature differential is violated, the Contractor shall implement corrective action prior to the next pour. In addition, the Engineer reserves the right to request a new thermal control plan for acceptance before the Contractor is allowed to pour again.

(d) Inspection and Repair of Cracks. The Engineer will inspect the concrete for cracks after the temperature monitoring is discontinued, and the Contractor shall provide access for the Engineer to do the inspection. A crack may require repair by the Contractor as determined by the Engineer. The Contractor shall be responsible for the repair of all cracks. Protective coat or a concrete sealer shall be applied to a crack less than 0.007 in. (0.18 mm) in width. A crack that is 0.007 in. (0.18 mm) or greater shall be pressure injected with epoxy according to Section 590.
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APPENDIX P

ALKALI-SILICA REACTION MITIGATION FLOW CHART

**MIXTURE TYPE**

CAM II, latex, and Classes:

PV, BS, PC, PS, DS, SC, SI,

RR, MS, PP-1, and PP-2

Determine the Aggregate Group for the mixture's aggregates:

* Article 1020.05(d)(1)

**GROUP I**

- Use any Cement or FDM.

**GROUP II**

- MIX OPTION 1
- MIX OPTION 2
- MIX OPTION 3
- MIX OPTION 4
- MIX OPTION 5

**GROUP III**

- MIX OPTION 1
- MIX OPTION 2
- MIX OPTION 3
- MIX OPTION 4
- MIX OPTION 5

**GROUP IV**

- MIX OPTION 1
- MIX OPTION 2
- MIX OPTION 3
- MIX OPTION 4
- MIX OPTION 5

**MIX OPTION 1**

Blend Aggregate

* Article 1020.05(d)(2)a.

**MIX OPTION 2**

Use a FDM as follows:

* Article 1020.05(d)(2)b.

**MIX OPTION 3**

Cement: Na₂O+0.658K₂O ≤0.60%

* Article 1020.05(d)(2)c.

**MIX OPTION 4**

Cement: Na₂O+0.658K₂O ≤0.45%

* Article 1020.05(d)(2)d.

**MIX OPTION 5**

ASTM C1567

* Article 1020.05(d)(2)e.

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**KEY**

CAM: Cement Aggregate Mixture (e.g., CAM II)

CLSM: Controlled Low Strength Material

FDM: Finely Divided Mineral

GGBF: Ground Granulated Blast Furnace (slag)

HRM: High Reactivity Metakaolin

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* Not applicable: concrete revetment mat, insertion lining of pipe culvert, portland cement mortar fairing course, CLSM, miscellaneous grouts that are not prepackaged, and Classes PP-3, PP-4, PP-5.
This Page Reserved
APPENDIX Q

QUALITY CONTROL/QUALITY ASSURANCE OF CONCRETE MIXTURES (BDE)

Effective: January 1, 2012
Revised: January 1, 2013

Add the following to Section 1020 of the Standard Specifications:

"1020.16 Quality Control/Quality Assurance of Concrete Mixtures. This Article specifies the quality control responsibilities of the Contractor for concrete mixtures (except Class PC and PS concrete), cement aggregate mixture II, and controlled low-strength material incorporated in the project, and defines the quality assurance and acceptance responsibilities of the Engineer.

A list of quality control/quality assurance (QC/QA) documents is provided in Article 1020.16(g), Schedule D.

A Level I Portland Cement Concrete (PCC) Technician shall be defined as an individual who has successfully completed the Department’s training for concrete testing.

A Level II Portland Cement Concrete (PCC) Technician shall be defined as an individual who has successfully completed the Department’s training for concrete proportioning.

A Level III Portland Cement Concrete (PCC) Technician shall be defined as an individual who has successfully completed the Department’s training for concrete mix design.

A Concrete Tester shall be defined as an individual who has successfully completed the Department’s training to assist with concrete testing and is monitored on a daily basis.

Aggregate Technician shall be defined as an individual who has successfully completed the Department’s training for gradation testing involving aggregate production and mixtures.

Mixture Aggregate Technician shall be defined as an individual who has successfully completed the Department’s training for gradation testing involving mixtures.

Gradation Technician shall be defined as an individual who has successfully completed the Department’s training to assist with gradation testing and is monitored on a daily basis.

(a) Equipment/Laboratory. The Contractor shall provide a laboratory and test equipment to perform their quality control testing.

The laboratory shall be of sufficient size and be furnished with the necessary equipment, supplies, and current published test methods for adequately and safely performing all required tests. The laboratory will be approved by the Engineer according to the current Bureau of Materials and Physical Research Policy Memorandum “Minimum Private Laboratory Requirements for Construction Materials Testing or Mix Design”. Production of a mixture shall not begin until the Engineer provides written approval of the laboratory. The Contractor shall refer to the Department’s "Required Sampling and Testing Equipment for Concrete" for equipment requirements.

Test equipment shall be maintained and calibrated as required by the appropriate test method, and when required by the Engineer. This information shall be documented on the Department's "Calibration of Concrete Testing Equipment" form.
Test equipment used to determine compressive or flexural strength shall be calibrated each 12 month period by an independent agency, using calibration equipment traceable to the National Institute of Standards and Technology (NIST). The Contractor shall have the calibration documentation available at the test equipment location.

The Engineer will have unrestricted access to the plant and laboratory at any time to inspect measuring and testing equipment, and will notify the Contractor of any deficiencies. Defective equipment shall be immediately repaired or replaced by the Contractor.

(b) Quality Control Plan. The Contractor shall submit, in writing, a proposed Quality Control (QC) Plan to the Engineer. The QC Plan shall be submitted a minimum of 45 calendar days prior to the production of a mixture. The QC Plan shall address the quality control of the concrete, cement aggregate mixture II, and controlled low-strength material incorporated in the project. The Contractor shall refer to the Department's "Model Quality Control Plan for Concrete Production" to prepare a QC Plan. The Engineer will respond in writing to the Contractor’s proposed QC Plan within 15 calendar days of receipt.

Production of a mixture shall not begin until the Engineer provides written approval of the QC Plan. The approved QC Plan shall become a part of the contract between the Department and the Contractor, but shall not be construed as acceptance of any mixture produced.

The QC Plan may be amended during the progress of the work, by either party, subject to mutual agreement. The Engineer will respond in writing to a Contractor’s proposed QC Plan amendment within 15 calendar days of receipt. The response will indicate the approval or denial of the Contractor’s proposed QC Plan amendment.

(c) Quality Control by Contractor. The Contractor shall perform quality control inspection, sampling, testing, and documentation to meet contract requirements. Quality control includes the recognition of obvious defects and their immediate correction. Quality control also includes appropriate action when passing test results are near specification limits, or to resolve test result differences with the Engineer. Quality control may require increased testing, communication of test results to the plant or the jobsite, modification of operations, suspension of mixture production, rejection of material, or other actions as appropriate. The Engineer shall be immediately notified of any failing tests and subsequent remedial action. Passing tests shall be reported no later than the start of the next work day.

When a mixture does not comply with specifications, the Contractor shall reject the material; unless the Engineer accepts the material for incorporation in the work, according to Article 105.03.

(1) Personnel Requirements. The Contractor shall provide a Quality Control (QC) Manager who will have overall responsibility and authority for quality control. The jobsite and plant personnel shall be able to contact the QC Manager by cellular phone, two-way radio or other methods approved by the Engineer.

The QC Manager shall visit the jobsite a minimum of once a week. A visit shall be performed the day of a bridge deck pour, the day a non-routine mixture is placed as determined by the Engineer, or the day a plant is anticipated to produce more than 1000 cu yd (765 cu m). Any of the three required visits may be used to meet the once per week minimum requirement.
The Contractor shall provide personnel to perform the required inspections, sampling, testing and documentation in a timely manner. The Contractor shall refer to the Department’s “Qualifications and Duties of Concrete Quality Control Personnel” document.

A Level I PCC Technician shall be provided at the jobsite during mixture production and placement, and may supervise concurrent pours on the project. For concurrent pours, a minimum of one Concrete Tester shall be required at each pour location. If the Level I PCC Technician is at one of the pour locations, a Concrete Tester is still required at the same location. Each Concrete Tester shall be able to contact the Level I PCC Technician by cellular phone, two-way radio or other methods approved by the Engineer. A single Level I PCC Technician shall not supervise concurrent pours for multiple contracts.

A Level II PCC Technician shall be provided at the plant, or shall be available, during mixture production and placement. A Level II PCC Technician may supervise a maximum of three plants. Whenever the Level II PCC Technician is not at the plant during mixture production and placement, a Concrete Tester or Level I PCC Technician shall be present at the plant to perform any necessary concrete tests. The Concrete Tester, Level I PCC Technician, or other individual shall also be trained to perform any necessary aggregate moisture tests, if the Level II PCC Technician is not at the plant during mixture production and placement. The Concrete Tester, Level I PCC Technician, plant personnel, and jobsite personnel shall have the ability to contact the Level II PCC Technician by cellular phone, two-way radio, or other methods approved by the Engineer.

For a mixture which is produced and placed with a mobile portland cement concrete plant as defined in Article 1103.04, a Level II PCC Technician shall be provided. The Level II PCC Technician shall be present at all times during mixture production and placement. However, the Level II PCC Technician may request to be available if operations are satisfactory. Approval shall be obtained from the Engineer, and jobsite personnel shall have the ability to contact the Level II PCC Technician by cellular phone, two-way radio, or other methods approved by the Engineer.

A Concrete Tester, Mixture Aggregate Technician, and Aggregate Technician may provide assistance with sampling and testing. A Gradation Technician may provide assistance with testing. A Concrete Tester shall be supervised by a Level I or Level II PCC Technician. A Gradation Technician shall be supervised by a Level II PCC Technician, Mixture Aggregate Technician, or Aggregate Technician.

(2) Required Plant Tests. Sampling and testing shall be performed at the plant, or at a location approved by the Engineer, to control the production of a mixture. The required minimum Contractor plant sampling and testing is indicated in Article 1020.16(g) Schedule A.

(3) Required Field Tests. Sampling and testing shall be performed at the jobsite to control the production of a mixture, and to comply with specifications for placement. For standard curing, after initial curing, and for strength testing; the location shall be approved by the Engineer. The required minimum Contractor jobsite sampling and testing is indicated in Article 1020.16(g), Schedule B.

(d) Quality Assurance by Engineer. The Engineer will perform quality assurance tests on independent samples and split samples. An independent sample is a field sample obtained and tested by only one party. A split sample is one of two equal portions of a field sample, where two parties each receive one portion for testing. The Engineer may request the Contractor to obtain a split sample. Aggregate split samples and any failing
strength specimen shall be retained until permission is given by the Engineer for disposal. The results of all quality assurance tests by the Engineer will be made available to the Contractor. However, Contractor split sample test results shall be provided to the Engineer before Department test results are revealed. The Engineer's quality assurance independent sample and split sample testing is indicated in Article 1020.16(g), Schedule C.

(1) Strength Testing. For strength testing, Article 1020.09 shall apply, except the Contractor and Engineer strength specimens may be placed in the same field curing box for initial curing and may be cured in the same water storage tank for final curing.

(2) Comparing Test Results. Differences between the Engineer's and the Contractor's split sample test results will be considered reasonable if within the following limits:

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Acceptable Limits of Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump</td>
<td>0.75 in. (20 mm)</td>
</tr>
<tr>
<td>Air Content</td>
<td>0.9%</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>900 psi (6200 kPa)</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>90 psi (620 kPa)</td>
</tr>
<tr>
<td>Slump Flow (Self-Consolidating Concrete (SCC))</td>
<td>1.5 in. (40 mm)</td>
</tr>
<tr>
<td>Visual Stability Index (SCC)</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>J-Ring (SCC)</td>
<td>1.5 in. (40 mm)</td>
</tr>
<tr>
<td>L-Box (SCC)</td>
<td>10 %</td>
</tr>
<tr>
<td>Hardened Visual Stability Index (SCC)</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Dynamic Segregation Index (SCC)</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Flow (Controlled Low-Strength Material (CLSM))</td>
<td>1.5 in. (40 mm)</td>
</tr>
<tr>
<td>Strength (Controlled Low-Strength Material (CLSM))</td>
<td>40 psi (275 kPa)</td>
</tr>
</tbody>
</table>

When acceptable limits of precision have been met, but only one party is within specification limits, the failing test shall be resolved before the material may be considered for acceptance.

(3) Test Results and Specification Limits.

a. Split Sample Testing. If either the Engineer’s or the Contractor’s split sample test result is not within specification limits, and the other party is within specification limits; immediate retests on a split sample shall be performed for slump, air content, slump flow, visual stability index, J-Ring, L-Box, dynamic segregation index, flow (CLSM), or aggregate gradation. A passing retest result by each party will require no further action. If either the Engineer’s or Contractor’s slump, air content, slump flow, visual stability index, J-Ring, L-Box, dynamic segregation index, flow (CLSM), or aggregate gradation split sample retest result is a failure; or if either the Engineer’s or Contractor’s strength or hardened visual stability index test result is a failure, and the other party is within specification limits; the following actions shall be initiated to investigate the test failure:

1. The Engineer and the Contractor shall investigate the sampling method, test procedure, equipment condition, equipment calibration, and other factors.
2. The Engineer or the Contractor shall replace test equipment, as determined by the Engineer.

3. The Engineer and the Contractor shall perform additional testing on split samples, as determined by the Engineer.

For aggregate gradation, jobsite slump, jobsite air content, jobsite slump flow, jobsite visual stability index, jobsite J-Ring, jobsite L-Box, jobsite dynamic segregation index, and jobsite flow (CLSM); if the failing split sample test result is not resolved according to 1., 2., or 3., and the mixture has not been placed, the Contractor shall reject the material; unless the Engineer accepts the material for incorporation in the work according to Article 105.03. If the mixture has already been placed, or if a failing strength or hardened visual stability index test result is not resolved according to 1., 2., or 3., the material will be considered unacceptable.

If a continued trend of difference exists between the Engineer’s and the Contractor’s split sample test results, or if split sample test results exceed the acceptable limits of precision, the Engineer and the Contractor shall investigate according to items 1., 2., and 3.

b. Independent Sample Testing. For aggregate gradation, jobsite slump, jobsite air content jobsite slump flow, jobsite visual stability index, jobsite J-Ring, jobsite L-Box, jobsite dynamic segregation index, and jobsite flow (CLSM); if the result of a quality assurance test on a sample independently obtained by the Engineer is not within specification limits, and the mixture has not been placed, the Contractor shall reject the material, unless the Engineer accepts the material for incorporation in the work according to Article 105.03. If the mixture has already been placed or the Engineer obtains a failing strength or hardened visual stability index test result, the material will be considered unacceptable.

(e) Acceptance by the Engineer. Final acceptance will be based on the Standard Specifications and the following:

(1) The Contractor's compliance with all contract documents for quality control.

(2) Validation of Contractor quality control test results by comparison with the Engineer's quality assurance test results using split samples. Any quality control or quality assurance test determined to be flawed may be declared invalid only when reviewed and approved by the Engineer. The Engineer will declare a test result invalid only if it is proven that improper sampling or testing occurred. The test result is to be recorded and the reason for declaring the test invalid will be provided by the Engineer.

(3) Comparison of the Engineer's quality assurance test results with specification limits using samples independently obtained by the Engineer.

The Engineer may suspend mixture production, reject materials, or take other appropriate action if the Contractor does not control the quality of concrete, cement aggregate mixture II, or controlled low-strength material for acceptance. The decision will be determined according to (1), (2), or (3).

(f) Documentation.

(1) Records. The Contractor shall be responsible for documenting all observations, inspections, adjustments to the mix design, test results, retest results, and corrective
actions in a bound hardback field book, bound hardback diary, or appropriate Department form, which shall become the property of the Department. The documentation shall include a method to compare the Engineer’s test results with the Contractor’s results. The Contractor shall be responsible for the maintenance of all permanent records whether obtained by the Contractor, the consultants, the subcontractors, or the producer of the mixture. The Contractor shall provide the Engineer full access to all documentation throughout the progress of the work.

The Department’s form MI 504M, form BMPR MI654, and form BMPR MI655 shall be completed by the Contractor, and shall be submitted to the Engineer weekly or as required by the Engineer. A correctly completed form MI 504M, form BMPR MI654, and form BMPR MI655 are required to authorize payment by the Engineer, for applicable pay items.

(2) Delivery Truck Ticket. The following information shall be recorded on each delivery ticket or in a bound hardback field book: initial revolution counter reading (final reading optional) at the jobsite, if the mixture is truck-mixed; time discharged at the jobsite; total amount of each admixture added at the jobsite; and total amount of water added at the jobsite.

(g) Basis of Payment and Schedules. Quality Control/Quality Assurance of portland cement concrete mixtures will not be paid for separately, but shall be considered as included in the cost of the various concrete contract items.

SCHEDULE A

<table>
<thead>
<tr>
<th>CONTRACTOR PLANT SAMPLING AND TESTING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>----------------------------------</td>
</tr>
<tr>
<td>Aggregates (Arriving at Plant)</td>
</tr>
<tr>
<td>Aggregates (Stored at Plant in Stockpiles or Bins)</td>
</tr>
<tr>
<td>Aggregates (Stored at Plant in Stockpiles or Bins)</td>
</tr>
<tr>
<td>Aggregates (Stored at Plant in Stockpiles or Bins)</td>
</tr>
<tr>
<td>Mixture</td>
</tr>
<tr>
<td>Mixture (CLSM)</td>
</tr>
</tbody>
</table>

1/ Refer to the Department’s “Manual of Test Procedures for Materials”.

2/ All gradation tests shall be washed. Testing shall be completed no later than 24 hours after the aggregate has been sampled.
3/ One per week (Sunday through Saturday) minimum unless the stockpile has not received additional aggregate material since the previous test.

One per day minimum for a bridge deck pour unless the stockpile has not received additional aggregate material since the previous test. The sample shall be taken and testing completed prior to the pour. The bridge deck aggregate sample may be taken the day before the pour or as approved by the Engineer.

4/ If the moisture test and moisture sensor disagree by more than 0.5 percent, retest. If the difference remains, adjust the moisture sensor to an average of two or more moisture tests. The Department's "Water/Cement Ratio Worksheet" form shall be completed when applicable.

5/ The Contractor may also perform strength testing according to Illinois Modified AASHTO T 141, T 23, and T 22 or T 177; or water content testing according to Illinois Modified AASHTO T 318; or other tests at the plant to control mixture production.

The Contractor may also perform other available self-consolidating concrete (SCC) tests at the plant to control mixture production.

6/ The Contractor shall select the J-Ring or L-Box test for plant sampling and testing.

7/ The Contractor may also perform strength testing according to Illinois Test Procedure 307.
<table>
<thead>
<tr>
<th>Item</th>
<th>Measured Property</th>
<th>Random Sample Testing Frequency per Mix Design and per Plant 1/</th>
<th>IL Modified AASHTO Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement, Shoulder, Base Course, Base Course Widening, Driveway Pavement, Railroad Crossing, Cement Aggregate Mixture II</td>
<td>Slump 3/4/</td>
<td>1 per 500 cu yd (400 cu m) or minimum 1/day</td>
<td>T 141 and T 119</td>
</tr>
<tr>
<td></td>
<td>Air Content 3/5/</td>
<td>1 per 100 cu yd (80 cu m) or minimum 1/day</td>
<td>T 141</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>And T 152 or T 196</td>
</tr>
<tr>
<td></td>
<td>Compressive</td>
<td>1 per 1250 cu yd (1000 cu m) or minimum 1/day</td>
<td>T 141, T 22 and T 23</td>
</tr>
<tr>
<td></td>
<td>Strength 7/8/ or</td>
<td></td>
<td>Or T 141, T 177 and T 23</td>
</tr>
<tr>
<td></td>
<td>Flexural Strength 7/8/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridge Approach Slab 9/7, Bridge Deck 9/7, Bridge Deck Overlay 9/7, Superstructure 9/7, Substructure, Culvert, Miscellaneous Drainage Structures, Retaining Wall, Building Wall, Drilled Shaft Pile &amp; Encasement Footing, Foundation, Pavement Patching, Structural Repairs</td>
<td>Slump 3/4/</td>
<td>1 per 50 cu yd (40 cu m) or minimum 1/day</td>
<td>T 141 and T 119</td>
</tr>
<tr>
<td></td>
<td>Air Content 3/5/</td>
<td>1 per 50 cu yd (40 cu m) or minimum 1/day</td>
<td>T 141</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>And T 152 or T 196</td>
</tr>
<tr>
<td></td>
<td>Compressive</td>
<td>1 per 250 cu yd (200 cu m) or minimum 1/day</td>
<td>T 141, T 22 and T 23</td>
</tr>
<tr>
<td></td>
<td>Strength 7/8/ or</td>
<td></td>
<td>Or T 141, T 177 and T 23</td>
</tr>
<tr>
<td></td>
<td>Flexural Strength 7/8/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seal Coat</td>
<td>Slump 3/</td>
<td>1 per 250 cu yd (200 cu m) or minimum 1/day</td>
<td>T 141 and T 119</td>
</tr>
<tr>
<td></td>
<td>Air Content 3/4/</td>
<td>1 per 250 cu yd (200 cu m) or minimum 1/day when air is</td>
<td>T 141</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>And T 152 or T 196</td>
</tr>
<tr>
<td></td>
<td>Compressive</td>
<td>1 per 250 cu yd (200 cu m) or minimum 1/day</td>
<td>T 141, T 22 and T 23</td>
</tr>
<tr>
<td></td>
<td>Strength 7/8/ or</td>
<td></td>
<td>Or T 141, T 177 and T 23</td>
</tr>
<tr>
<td></td>
<td>Flexural Strength 7/8/</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### CONTRACTOR JOBSITE SAMPLING & TESTING 1/

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Test Requirement</th>
<th>Frequency</th>
<th>Reference Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curb, Gutter, Median, Barrier, Sidewalk, Slope Wall, Paved Ditch, Fabric Formed Concrete Revetment Mat 10/, Miscellaneous Items, Incidental Items</td>
<td>Slump 3/4/</td>
<td>1 per 100 cu yd (80 cu m) or minimum 1/day</td>
<td>T 141 and T 119</td>
</tr>
<tr>
<td></td>
<td>Air Content 3/5/6/</td>
<td>1 per 50 cu yd (40 cu m) or minimum 1/day</td>
<td>T 141 and T 152 or T 196</td>
</tr>
<tr>
<td></td>
<td>Compressive Strength 7/8/ or Flexural Strength 7/8/</td>
<td>1 per 400 cu yd (300 cu m) or minimum 1/day</td>
<td>T 141, T 22 and T 23 or T 141, T 177 and T 23</td>
</tr>
<tr>
<td>The Item will use a Self-Consolidating Concrete Mixture</td>
<td>Slump Flow 3/ VSI 3/ J-Ring 3/11/ L-Box 3/11/</td>
<td>Perform at same frequency that is specified for the Item's slump</td>
<td>SCC-1 &amp; SCC-2, SCC-1 &amp; SCC-2, SCC-1 &amp; SCC-3, SCC-1 &amp; SCC-4</td>
</tr>
<tr>
<td></td>
<td>HVS 3/</td>
<td>Minimum 1/day at start of production for that day</td>
<td>SCC-1 and SCC-6</td>
</tr>
<tr>
<td>The Item will use a Self-Consolidating Concrete Mixture</td>
<td>Dynamic Segregation Index (DSI)</td>
<td>Minimum 1/week at start of production for that week</td>
<td>SCC-1 and SCC-8 (Option C)</td>
</tr>
<tr>
<td>The Item will use a Self-Consolidating Concrete Mixture</td>
<td>Air Content 3/5/6/</td>
<td>Perform at same frequency that is specified for the Item's air content</td>
<td>SCC-1 and T 152 or T 196</td>
</tr>
<tr>
<td>The Item will use a Self-Consolidating Concrete Mixture</td>
<td>Compressive Strength 7/8/ or Flexural Strength 7/8/</td>
<td>Perform at same frequency that is specified for the Item's strength</td>
<td>SCC-1, T22 and T 23 or SCC-1, T 177 and T 23</td>
</tr>
<tr>
<td>All</td>
<td>Temperature 3/</td>
<td>As needed to control production</td>
<td>T 141 and T 309</td>
</tr>
<tr>
<td>Controlled Low-Strength Material (CLSM)</td>
<td>Flow, Air Content Compressive Strength (28-day) 13/, and Temperature</td>
<td>First truck load delivered and as needed to control production thereafter</td>
<td>Illinois Test Procedure 307</td>
</tr>
</tbody>
</table>

1/ Sampling and testing of small quantities of curb, gutter, median, barrier, sidewalk, slope wall, paved ditch, miscellaneous items, and incidental items may be waived by the Engineer if requested by the Contractor. However, quality control personnel are still required according to Article 1020.16(c)(1) The Contractor shall also provide recent evidence that similar material has been found to be satisfactory under normal sampling and testing procedures. The total quantity that may be waived for testing shall not exceed 100 cu yd (76 cu m) per contract.

If the Contractor’s or Engineer's test result for any jobsite mixture test is not within the specification limits, all subsequent truck loads delivered shall be tested by the Contractor until the problem is corrected.

2/ If one mix design is being used for several construction items during a day's production, one testing frequency may be selected to include all items. The construction items shall have the same slump, air content, and water/cement ratio specifications. For self-consolidating concrete, the construction items shall have the same slump flow, visual stability index, J-Ring, L-Box, air content, and water/cement ratio specifications. The frequency selected shall equal or exceed the testing required for the construction item.

One sufficiently sized sample shall be taken to perform the required test(s). Random numbers shall be determined according to the Department's "Method for Obtaining Random Samples for Concrete". The Engineer will provide random sample locations.
3/ The temperature, slump, and air content tests shall be performed on the first truck load delivered, for each pour. For self-consolidating concrete, the temperature, slump flow, visual stability, index, J-Ring or L-Box, and air content tests shall be performed on the first truck load delivered, for each pour. Unless a random sample is required for the first truck load, testing the first truck load does not satisfy random sampling requirements.

4/ The slump random sample testing frequency shall be a minimum 1/day for a construction item which is slipformed.

5/ If a pump or conveyor is used for placement, a correction factor shall be established to allow for a loss of air content during transport. The first three truck loads delivered shall be tested, before and after transport by the pump or conveyor, to establish the correction factor. Once the correction is determined, it shall be re-checked after an additional 50 cu yd (40 cu m) is pumped, or an additional 100 cu yd (80 cu m) is conveyed. This shall continue throughout the pour. If the re-check indicates the correction factor has changed, a minimum of two truckloads is required to re-establish the correction factor. The correction factor shall also be re-established when significant changes in temperature, distance, pump or conveyor arrangement, and other factors have occurred. If the correction factor is >3.0 percent, the Contractor shall take corrective action to reduce the loss of air content during transport by the pump or conveyor. The Contractor shall record all air content test results, correction factors and corrected air contents. The corrected air content shall be reported on form BMPR MI654.

6/ If the Contractor's or Engineer's air content test result is within the specification limits, and 0.2 percent or closer to either limit, the next truck load delivered shall be tested by the Contractor. For example, if the specified air content range is 5.0 to 8.0 percent and the test result is 5.0, 5.1, 5.2, 7.8, 7.9 or 8.0 percent, the next truck shall be tested by the Contractor.

7/ The test of record for strength shall be the day indicated in Article 1020.04. For cement aggregate mixture II, a strength requirement is not specified and testing is not required. Additional strength testing to determine early falsework and form removal, early pavement or bridge opening to traffic, or to monitor strengths is at the discretion of the Contractor. Strength shall be defined as the average of at least two cylinder or two beam breaks for field tests.

8/ In addition to the strength test, a slump test, air content test, and temperature test shall be performed on the same sample. For self-consolidating concrete, a slump flow test, visual stability index test, J-Ring or L-Box test, air content test, and temperature test shall be performed on the same sample as the strength test. For mixtures pumped or conveyed, the Contractor shall sample according to Illinois Modified AASHTO T 141.

9/ The air content test will be required for each delivered truck load.

10/ For fabric formed concrete revetment mat, the slump test is not required and the flexural strength test is not applicable.

11/ The Contractor shall select the J-Ring or L-Box test for jobsite sampling and testing.

12/ In addition to the hardened visual stability index (HVSI) test, a slump flow test, visual stability index (VSI) test, J-Ring or L-Box test, air content test, and temperature test shall be performed on the same sample. The Contractor shall retain all hardened visual stability index cut cylinder specimens until the Engineer notifies the Contractor that the specimens may be discarded.
13/ The test of record for strength shall be the day indicated in Article 1019.04. In addition to the strength test, a flow test, air content test, and temperature test shall be performed on the same sample. The strength test may be waived by the Engineer if future removal of the material is not a concern.
### SCHEDULE C

#### ENGINEER QUALITY ASSURANCE INDEPENDENT SAMPLE TESTING

<table>
<thead>
<tr>
<th>Location</th>
<th>Measured Property</th>
<th>Testing Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>Gradation of aggregates stored in stockpiles or bins, Slump and Air Content</td>
<td>As determined by the Engineer.</td>
</tr>
<tr>
<td>Jobsite</td>
<td>Slump, Air Content, Slump Flow, Visual Stability Index, J-Ring, L-Box, Hardened Visual Stability Index, Dynamic Segregation Index and Strength</td>
<td>As determined by the Engineer.</td>
</tr>
<tr>
<td></td>
<td>Flow, Air Content, Strength (28-day), and Dynamic Cone Penetration for Controlled Low-Strength Material (CLSM)</td>
<td>As determined by the Engineer.</td>
</tr>
</tbody>
</table>

#### ENGINEER QUALITY ASSURANCE SPLIT SAMPLE TESTING

<table>
<thead>
<tr>
<th>Location</th>
<th>Measured Property</th>
<th>Testing Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>Gradation of aggregates stored in stockpiles or bins</td>
<td>At the beginning of the project, the first test performed by the Contractor. Thereafter, a minimum of 10% of total tests required of the Contractor will be performed per aggregate gradation number and per plant.</td>
</tr>
<tr>
<td></td>
<td>Slump and Air Content</td>
<td>As determined by the Engineer.</td>
</tr>
<tr>
<td>Jobsite</td>
<td>Slump, Air Content, Slump Flow, Visual Stability Index, J-Ring, L-Box</td>
<td>At the beginning of the project, the first three tests performed by the Contractor. Thereafter, a minimum of 20% of total tests required of the Contractor will be performed per plant, which will include a minimum of one test per mix design.</td>
</tr>
<tr>
<td></td>
<td>Hardened Visual Stability Index</td>
<td>As determined by the Engineer.</td>
</tr>
<tr>
<td></td>
<td>Dynamic Segregation Index</td>
<td>As determined by the Engineer.</td>
</tr>
<tr>
<td></td>
<td>Strength</td>
<td>At the beginning of the project, the first test performed by the Contractor. Thereafter, a minimum of 20% of total tests required of the Contractor will be performed per plant, which will include a minimum of one test per mix design.</td>
</tr>
<tr>
<td></td>
<td>Flow, Air Content, and Strength (28-day) for Controlled Low-Strength Material (CLSM)</td>
<td>As determined by the Engineer.</td>
</tr>
</tbody>
</table>

1/ The Engineer will perform the testing throughout the period of quality control testing by the Contractor.

2/ The Engineer will witness and take immediate possession of or otherwise secure the Department’s split sample obtained by the Contractor.

3/ Before transport by pump or conveyor, a minimum of 20 percent of total tests required of the Contractor will be performed per mix design and per plant. After transport by pump or conveyor, a minimum of 20 percent of total tests required of the Contractor will be performed per mix design and per plant.
SCHEDULE D

CONCRETE QUALITY CONTROL AND QUALITY ASSURANCE DOCUMENTS

(a) Model Quality Control Plan for Concrete Production (*)
(b) Qualifications and Duties of Concrete Quality Control Personnel (*)
(c) Development of Gradation Bands on Incoming Aggregate at Mix Plants (*)
(d) Required Sampling and Testing Equipment for Concrete (*)
(e) Method for Obtaining Random Samples for Concrete (*)
(f) Calibration of Concrete Testing Equipment (BMPR PCCQ01 through BMPR PCCQ09) (*)
(g) Water/Cement Ratio Worksheet (BMPR PCCW01) (*)
(h) Field/Lab Gradations (MI 504M) (*)
(i) Concrete Air, Slump and Quantity (BMPR MI654) (*)
(j) P.C. Concrete Strengths (BMPR MI655) (*)
(k) Aggregate Technician Course or Mixture Aggregate Technician Course (*)
(l) Portland Cement Concrete Tester Course (*)
(m) Portland Cement Concrete Level I Technician Course - Manual of Instructions for Concrete Testing (*)
(n) Portland Cement Concrete Level II Technician Course - Manual of Instructions for Concrete Proportioning (*)
(o) Portland Cement Concrete Level III Technician Course - Manual of Instructions for Design of Concrete Mixtures (*)
(p) Manual of Test Procedures for Materials

* Refer to Appendix C of the Manual of Test Procedures for Materials for more information.

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