

**KANSAS DEPARTMENT OF TRANSPORTATION  
SPECIAL PROVISION TO THE  
STANDARD SPECIFICATIONS, EDITION 2007**

Delete SECTION 401 and replace with the following:

**SECTION 401**

**CONCRETE**

**401.1 DESCRIPTION**

Provide the grades of concrete specified in the Contract Documents.

**401.2 MATERIALS**

Provide materials that comply with the applicable requirements.

Coarse, Fine and Mixed Aggregate .....	<b>DIVISION 1100</b>
Admixtures, Plasticizers, and Silica Fume .....	<b>DIVISION 1400</b>
Cement, Fly Ash, and Ground Granulated Furnace Slag .....	<b>DIVISION 2000</b>
Water .....	<b>DIVISION 2400</b>

**401.3 CONCRETE MIX DESIGN**

**a. General.** Design the concrete mixes specified in the Contract Documents.

Provide aggregate gradations that comply with **SECTION 1102** and Contract Documents.

If desired, contact the DME for available information to help determine approximate proportions to produce concrete having the required characteristics on the project.

Take full responsibility for the actual proportions of the concrete mix, even if the Engineer assists in the design of the concrete mix.

Submit all concrete mix designs to the Engineer for review and approval. Submit completed volumetric mix designs on KDOT Form No. 694 (or other forms approved by the DME).

Do not place any concrete on the project until the Engineer approves the concrete mix designs. Once the Engineer approves the concrete mix design, do not make changes without the Engineer's approval.

Submit test data from KT-73, KT-79 or AASHTO T-277 for all bridge overlays and any project with over 250 cubic yards of concrete (this includes concrete for structures, pavement, etc). Provide the test data for each mix, tested at the highest water-cement ratio. The mix design and test data must be submitted to KDOT at least 60 days prior to placement of concrete on the project. Two options are available for mix design procedures. Use the procedures outlined in **subsection 401.3b.** or Appendix A to design concrete mixes.

**b. Concrete Mix Design Based On Previous Data.** Provide concrete mix designs based on previous 28-day compressive strength test data from similar concrete mixtures. Similar mixtures are within 1000 psi of the specified 28-day compressive strength, and are produced with the same type and sources of cementitious materials, admixtures and aggregates. Consider sand sources the same, provided they are not more than 25 miles apart on the same river and no tributaries enter the river between the 2 points. Consider crushed locations similar if they are mined in one continuous operation, and there is no significant change in geology. Mixes that have changes of more than 10% in proportions of cementitious materials, aggregates or water content are not considered similar. Air entrained mixes are not considered similar to non-air entrained mixes. Test data should represent at least 30 separate batches of the mix. One set of data is the average of at least 2 cylinders from the batch. The data shall represent a minimum of 45 days of production within the past 12 months. Do not include data over 1 year old. When fewer than 30 data sets are available, the standard deviation of the data must be corrected to compensate for the fewer data points.

Provide a concrete mix design that will permit no more than 5% of the 28-day compressive strength tests to fall below the specified 28-day compressive strength ( $f'c$ ) based on equation A, and no more than 1% of the 28-day

compressive strength tests to fall below the specified 28-day compressive strength ( $f'c$ ) by more than 500 psi based on equation B.

Equation A:  $f'cr = f'c + 1.62 * k * s$

Equation B:  $f'cr = (f'c - 500) + 2.24 * k * s$

Where:  $f'cr$  = average 28-day compressive strength required to meet the above criteria.  
 $f'c$  = specified 28-day compressive strength  
 $s$  = standard deviation of test data  
 $k$  = constant based on number of data points  
 $n$  = number of data points  
 $k = 1.3 - n / 100$ , where  $15 < n < 30$   
 $k = 1$ , where  $n > 30$

Provide a concrete mix design that has an average compressive strength that is equal to the larger of Equation A or Equation B. Submit all supporting test data with the mix design.

**All other concrete mix designs.**

For concrete mixes that have fewer than 15 data points, or if no statistical data is available, use Equations A and B to calculate  $f'cr$  using the following values.

$s = 20\%$  of the specified 28-day compressive strength ( $f'c$ )  
 $k = 1$

Provide 28-day compressive strength test data at 3 different water–cementitious ratios showing compliance with required  $f'cr$ . Each set of test data shall be the average of a minimum of 3 cylinders. These mixes shall utilize materials that will be used on the project.

**c. Air-Entrained Concrete for Pavement.** Design air-entrained concrete for pavement according to **TABLE 401-1.**

TABLE 401-1: AIR-ENTRAINED CONCRETE FOR PAVEMENT							
Type of Agg (SEC 1100)	lb. of Cementitious per yd <sup>3</sup> of Concrete, minimum <sup>1</sup>	lb. of Water per lb. of Cementitious, maximum <sup>2</sup>	Percent of Air by Volume <sup>3</sup>	28-Day Comp Strength psi minimum	Volume of Permeable Voids <sup>4,5</sup> , maximum	Surface Resistivity <sup>4,5</sup> , minimum	Rapid Chloride Permeability <sup>4,5</sup> , maximum
Coarse and Fine	564	0.47	See <b>subsecti on 401.3h.</b>	4000	12.00%	9.0 kΩ-cm	3000 Coulombs
MA-2							
MA-3	517						
MA-4							

<sup>1</sup>The amount of cementitious listed is the designated minimum for concrete pavement. It may be necessary to add additional cementitious or otherwise adjust the mix proportions as permitted by the specifications to provide a mix design that complies with the compressive strength requirement.

<sup>2</sup>Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

<sup>3</sup>The maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

<sup>4</sup>Provide concrete for pavement with either a maximum 28-day Volume of Permeable Voids of 12.0% as per KT-73, a minimum 28-day Surface Resistivity of 9.0 kΩ-cm as per KT-79, or a maximum 56-day Rapid Chloride Permeability of 3000 Coulombs as per AASHTO T-277 when required. Submit accelerated cure procedures for the Engineer's approval.

<sup>5</sup>**Exclude these requirements for concrete patching material used in SECTION 833 when the existing pavement to be patched is more than 10 years old.**

Improvements in concrete strength, workability and durability are possible if the combined aggregate grading is optimized. Procedures found in ACI 302.1 or other mix design techniques are acceptable in optimizing the mix design.

Use either Air-Entrained Concrete for Pavement or Optimized, Air-Entrained Concrete for Pavement. Provide the Engineer written notification of the selection prior to the pre-construction conference.

Submit the concrete mix design, and supply the Engineer with the necessary materials to enable the Engineer to test the mix properties at least 60 days before the anticipated date of using the design on the project and include the following information:

(1) A single point grading for the combined aggregates along with a plus/minus tolerance for each sieve to the Engineer. Use plus/minus tolerances to perform quality control checks and by the Engineer to perform aggregate grading verification testing. The tests may be performed on the combined materials or on individual aggregates, and then theoretically combined to determine compliance.

(2) Laboratory 28-day compressive strength test results on a minimum of 1 set of 3 cylinders produced from the proposed mix design, utilizing the actual materials proposed for use on the project. Design compressive strength should be a minimum of 2 of the Contractor's normal standard deviations for this type of mix above 4000 psi (cylinders) or meet the requirements of **subsection 401.3b**.

(3) Use historical mix production data for the plant used on the project to substantiate the standard deviation selected. If such historical data is not available or is unacceptable to the Engineer, use 5300 psi for design strength.

The Engineer will provide an initial review of the design within 5 business days following submittal. After initial review, the Engineer will perform any testing necessary to verify the design.

To verify the mix design in the field, perform compressive strength tests on cylinders made from samples taken from concrete produced at the project site before or during the first day that concrete pavement is placed on the project. If the compressive strength tests indicate noncompliance with minimum design values, add additional cement to the mix or make other appropriate mix design changes at no additional cost to KDOT.

**d. Air-Entrained Concrete for Shoulders.** Design air-entrained concrete for shoulders according to **TABLE 401-2**.

<b>TABLE 401-2: AIR-ENTRAINED CONCRETE FOR SHOULDERS</b>						
<b>Type of Aggregate (SECTION 1100)</b>	<b>lb. of Cementitious per yd<sup>3</sup> of Concrete, minimum</b>	<b>lb. of Water per lb. of Cementitious, maximum<sup>1</sup></b>	<b>Percent of Air by Volume<sup>2</sup></b>	<b>Volume of Permeable Voids<sup>3,4</sup>, maximum</b>	<b>Surface Resistivity<sup>3,4</sup>, minimum</b>	<b>Rapid Chloride Permeability<sup>3,4</sup>, maximum</b>
Coarse and Fine	520	0.49	See <b>subsection 401.3h</b> .	12.00%	9.0 kΩ-cm	3000 Coulombs
MA-2						
MA-3	480					
MA-4						

<sup>1</sup>Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

<sup>2</sup>The maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

<sup>3</sup>Concrete for shoulders using the same aggregates and gradations as the mainline pavement concrete on the same project will be approved without testing for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability.

<sup>4</sup>Exclude these requirements for concrete patching material used in SECTION 833 when the existing pavement to be patched is more than 10 years old.

**e. Concrete for Structures.** Design concrete for structures as outlined in **subsection 401.3b**, with a maximum water to cementitious ratio of 0.50 and a minimum cementitious content of 480 lbs per cubic yard according to **TABLE 401-3a and 401-3b**.

<b>TABLE 401-3a: CONCRETE</b>		
<b>Specified 28 Day Compressive Strengths, minimum, psi <i>f</i>'<sub>c</sub></b>		
<b>Grade of Concrete:</b>	<b>Non Air Entrained Concrete</b>	<b>Air Entrained Concrete</b>
Grade 6.0	6,000	6,000
Grade 5.0	5,000	5,000
Grade 4.5	4,500	4,500
Grade 4.0	4,000	4,000
Grade 3.5	3,500	3,500
Grade 3.0	3,000	3,000
Grade 2.5	2,500	2,500

- (1) Provide air entrained concrete for structures with a target air content of 6.5 ± 1.5 percent.
- (2) Maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.
- (3) Determine air content by KT-19 (Rollometer). A regularly calibrated air meter may be used for production with random verification by the rollometer. See KT-19 for special requirements when using the rollometer with high cementitious concretes or mixtures with midrange water reducers or plasticizers.

<b>TABLE 401-3b: PERMEABILITY REQUIREMENTS FOR CONCRETE FOR STRUCTURES</b>				
	<b>Volume of Permeable Voids<sup>1</sup>, maximum</b>	<b>Surface Resistivity<sup>1</sup>, minimum</b>	<b>Rapid Chloride Permeability<sup>1</sup>, maximum</b>	<b>ASTM C-1567<sup>2</sup> Accelerated Mortar Bar Expansion</b>
Use Low Permeability Concrete (LPC) for Bridge Overlays	9.5%	27.0 kΩ-cm	1000 Coulombs	0.10% @ 16 days
Use Moderate Permeability Concrete (MPC) for specified Full Depth Bridge Decks	11.0%	13.0 kΩ-cm	2000 Coulombs	0.10% @ 16 days
Use Standard Permeability Concrete (SPC) for all other structure concrete not specified as Low Permeability or Moderate Permeability	12.0%	9.0 kΩ-cm	3000 Coulombs	0.10% @ 16 days

<sup>1</sup> Perform 28-day Volume of Permeable Voids as per KT-73, 28-day Surface Resistivity as per KT-79, or 56-day Rapid Chloride Permeability as per AASHTO T-277 when required. Submit accelerated cure procedures for the Engineer's approval.

<sup>2</sup> ASTM C-1567 only required if supplementary cementitious materials (SCMs) are utilized in the concrete.

- (4) Use Quality Requirements for Structural Aggregates as listed in Special Provision to the Standard Specification 07-11009 (latest revision) Aggregates For Concrete Not Placed on Grade.
- (5) Use gradation requirements for aggregates as listed in Special Provision to the Standard Specification 07-11009 Aggregates For Concrete Not Place on Grade.
- (6) Use MA-6 optimized gradation for Low Permeability Concrete for Bridge Overlays.
- (7) Improvements in concrete strength, workability, durability and permeability are possible if the combined aggregate grading is optimized. Procedures found in ACI 302.1 or other mix design techniques are acceptable in optimizing the mix design. See Appendix B for suggested guidelines for meeting permeability requirements.
- (8) A water-reducing admixture for improving workability may be required. Adjust the designated slump accordingly.
- (9) Adjust the yield cement factor (ycf) for higher air within specification limits, as allowed in the Contract Documents.
- (10) When opted for, use Silica Fume for Bridge Overlays either singly or in combination with SCM's as allowed in **TABLE 401-5** and **TABLE 401-8**.

(11) When used, add silica fume with other cementitious materials during batching procedures. If the silica fume cannot be added to the cementitious materials it must be added loose to the bottom of the drum previous to the dry materials. The drum shall be wet with no standing water and not turning. The Engineer may approve shreddable bags on a performance basis, only when a central batch mixing process is used. If so, then add the bags to half of the mixing water and mix before adding cementitious materials, aggregate and remainder of water.

(12) When used, mix silica fume modified concrete for a minimum of 100 mixing revolutions.

(13) Delay the commencement of tests from 4 to 4½ minutes after the sample has been taken from a continuous mixer. If a batch type mixer is used, take the tests at the point of placement and begin testing immediately.

**f. Portland Cement and Blended Hydraulic Cement.** Unless specified otherwise in the Contract Documents, select the type of portland cement or blended hydraulic cement according to **TABLE 401-5**.

<b>TABLE 401-5: PORTLAND CEMENT &amp; BLENDED HYDRAULIC CEMENT</b>	
<b>Concrete for:</b>	<b>Type of Cement Allowed</b>
Bridge Overlays and Concrete Pavement	Type IP(x) Portland-Pozzolan Cement Type IS(x) Portland-Blast Furnace Slag Cement Type IT(Ax)(By) Ternary Blended Cement Type II Portland Cement
All Structures other than Bridge Overlays and Concrete Pavement	Type I Portland Cement Type IP(x) Portland-Pozzolan Cement Type IS(x) Portland-Blast Furnace Slag Cement Type IT(Ax)(By) Ternary Blended Cement Type II Portland Cement
High Early Strength Concrete	Type III Portland Cement Type I, IP(x), IS(x), IT(Ax)(By), or II Cement may be used if strength and time requirements are met.

**g. Design Air Content.** With the exception of concrete for PCCP, use the middle of the specified air content range for the design of air-entrained concrete.

For PCCP concrete, provide a minimum air content that complies with these 2 criteria:

- a minimum by volume of 5.0% behind the paver, and
- a maximum air void spacing factor of 0.01 inch behind the paver<sup>1</sup>.

For a typical PCCP, design the mix at the target air content plus 0.5% air content.

The target air content is the air content that meets both criteria above.

If the air void spacing factor exceeds 0.01 inch, use the following formula as a guide to determine the target air content<sup>1</sup>:

$$\text{Target \% air content at 0.01 inch} = \% \text{ air measured} + (\text{measured spacing factor} - 0.01)/0.001$$

Mixes with Laboratory or Field Prequalification spacing factors greater than 0.01 inch will not be approved.

Take immediate steps to reduce the spacing factor whenever the spacing factor exceeds 0.01 inch. Suspend paving operations when the spacing factor exceeds 0.015 inches and remove and replace the represented concrete<sup>1</sup>.

Take immediate steps to increase the air content whenever the air content behind the paver falls below 5.0%. Suspend paving operations when 2 consecutive air contents behind the paver fall below 4.0% and remove and replace the represented concrete.

<sup>1</sup>Does not apply to concrete used in **SECTION 833** when existing pavement to be patched is more than 10 years old.

**h. Admixtures for Acceleration, Air-Entraining, Plasticizing, Set Retardation and Water Reduction.** Verify that the admixtures used are compatible and will work as intended without detrimental effects. Use the dosages recommended by the admixture manufacturers. Incorporate and mix the admixtures into the concrete mixtures according to the manufacturer's recommendations. Determine the quantity of each admixture for the concrete mix design.

Redosing is permitted to accomplish slump control or air content in the field, when approved by the Engineer, time and temperature limits are not exceeded, and at least 30 mixing revolutions remain before redosing. Redose with up to 50% of the original dose.

If another admixture is added to an air-entrained concrete mixture, determine if it is necessary to adjust the air-entraining admixture dosage to maintain the specified air content.

(1) Accelerating Admixture. When specified in the Contract Documents, or in situations that involve contact with reinforcing steel and require early strength development to expedite opening to traffic, a non-chloride accelerator may be approved. The Engineer may approve the use of a Type C or E accelerating admixture. A Grade 2 calcium chloride accelerator may be used when patching an existing pavement more than 10 years old.

Add the calcium chloride by solution (the solution is considered part of the mixing water).

- For a minimum cure of 4 hours at 60°F or above, use 2% (by dry weight of cement) calcium chloride.
- For a minimum cure of 6 hours at 60°F or above, use 1% (by dry weight of cement) calcium chloride.

(2) Air-Entraining Admixture. When specified, use an air-entrainer in the concrete mixture.

(3) Water-Reducers and Set-Retarders. If unfavorable weather or other conditions adversely affect the placing and finishing properties of the concrete mix, the Engineer may allow the use of water-reducers and set-retarders. If the Engineer approves the use of water-reducers and set-retarders, their continued use depends on their performance. Verify that the admixtures will work as intended without detrimental effects. If at any point, a water-reducer is used to produce a slump equal to or greater than 7 ½ inches, comply with **subsection 401.3i.(4)**.

(4) Plasticizer Admixture. A plasticizer is defined as an admixture that produces flowing concrete, without further addition of water, and/or retards the setting of concrete. Flowing concrete is defined as having a slump equal to or greater than 7 ½ inches.

Include a batching sequence in the concrete mix design. Consider the location of the concrete plant in relation to the job site, and identify when and at what location the plasticizer is added to the concrete mixture. Do not add water after the plasticizer is added to the concrete mixture.

Manufacturers of plasticizers may recommend mixing revolutions beyond the limits specified in **subsection 401.8**. If necessary, address the additional mixing revolutions in the concrete mix design. The Engineer may allow up to 60 additional revolutions when plasticizers are designated in the mix design.

Before the concrete mixture with a slump equal to or greater than 7 ½ inches is used on the project, conduct tests on at least 1 full trial batch of the concrete mix design to determine the adequacy of the dosage and the batching sequence of the plasticizer to obtain the desired properties. Determine the air content of the trial batch both before and after the addition of the plasticizer. Monitor the slump, air content, temperature and workability at regular intervals of the time period from when the plasticizer is added until the estimated time of completed placement. At the discretion of the Engineer, if all the properties of the trial batch remain within the specified limits, the trial batch may be used in the project.

The Engineer will allow minor adjustments to the dose rate to compensate for environmental changes during placement without a new concrete mix design or trial batch.

**i. Slump.** Designate a slump for each concrete mix design that is within the limits in **TABLE 401-6**.

<b>TABLE 401-6: ALLOWABLE CONCRETE SLUMP</b>	
<b>Concrete Use</b>	<b>Maximum Allowable Slump (inches)</b>
Concrete Pavement	2 ½ <sup>(1)(2)</sup>
Concrete for Structures & Air-Entrained Concrete for Structures	That required for satisfactory placement of the respective parts of the structure. <sup>(2)</sup>
Bridge Subdecks or Decks without Plasticizing Admixtures	3 <sup>(2)</sup>
Concrete with Plasticizing Admixture for Structures, Bridge Subdecks or Decks, Air-Entrained Concrete with Plasticizing Admixture for Structures, & Concrete with Plasticizing Admixture for Prestressed Beams	7 <sup>(3)</sup>
Concrete with Plasticizers for Drilled Shafts	(4)

<sup>(1)</sup>If the Engineer approves, slumps in excess of 2 ½ inches are allowed for areas that are hand finished.

<sup>(2)</sup>If the designated slump is 3 inches or less, the tolerance is  $\pm\frac{3}{4}$  inch, or limited by the maximum allowable slump for the individual type of construction. If the designated slump is greater than 3 inches (without plasticizing admixture), the tolerance is  $\pm 25\%$  of the designated slump.

<sup>(3)</sup>If the Engineer approves the use of plasticizing admixture in the concrete, the tolerance from the designated slump is  $\pm 25\%$  or  $\frac{3}{4}$  inch, whichever is larger, limited by the maximum allowable slump for the individual type of construction. Maintain the required geometry.

<sup>(4)</sup>The target slump just prior to being pumped into the drilled shaft is 9 inches. If the slump is less than 8 inches, then redose the concrete as permitted in **subsection 401.3i**.

**j. Field Blended Cement Concrete.** When approved by the Engineer, the concrete mix design may include supplementary cementitious materials (SCM) such as fly ash or ground granulated blast furnace slag (GGBFS) from an approved source as a partial replacement for portland cement or blended hydraulic cement. Obtain the Engineer's approval before substituting SCMs for Type III cement. The approved source of SCM may not be changed during the project.

Supplementary materials may be inter-ground, plant blended or field blended. Supplementary materials can be combined with cement to create binary or ternary concrete mixes. Do not exceed allowable substitution rates noted in **TABLE 401-8**. Substitute 1 pound of SCM for 1 pound of cement.

<b>TABLE 401-8: ALLOWABLE SUBSTITUTION RATE FOR SUPPLEMENTARY CEMENTITIOUS MATERIAL.</b>	
Material	Substitution Rate*
Slag Modified	40% Maximum
C Fly Ash Modified	25% Maximum
F Ash Modified	25% Maximum
Silica Fume Modified	5% Max
Total Combined	50%

\* Total Substitution Rate includes material in pre-blended cements.

Design field blended cement concrete meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability using the parameters described in **subsection 401.3b**.

Submit complete mix design data including proportions and sources of all mix ingredients, and the results of strength tests representing the mixes proposed for use. The strength data may come from previous KDOT project records or from a laboratory regularly inspected by Cement and Concrete Reference Laboratory (CCRL), and shall equal or exceed the strength requirements for the Grade specified in the Contract Documents. Perform compressive strength tests according to AASHTO T-22.

Provide the results of mortar expansion tests of ASTM C 1567 using the project's mix design concrete materials at their designated percentages. Provide a mix with a maximum expansion of 0.10 % at 16 days after casting.

Waive ASTM C 1567 testing when Silica Fume is used singly.

Provide the results to the Engineer at least 60 days before placement of concrete on the project.

**k. High Early Strength Concrete.** Design the high early strength concrete mix to comply with strength and time requirements specified in the Contract Documents. Unless otherwise specified, design high early strength concrete for pavement at a minimum of 1 of the Contractor's standard deviations above 2400 psi (cylinders) at 24 hours.

Submit complete mix design data including proportions and sources of all mix ingredients, and the results of time and strength tests representing the mixes proposed for use. The strength and time data may come from previous KDOT project records or from an independent laboratory, and shall equal or exceed the strength and time requirements listed in the Contract Documents.

#### **401.4 MORTAR AND GROUT**

**a. General.** Follow the proportioning requirements in **subsection 401.4b**. and **c**. for mortar and grout unless otherwise specified in the Contract Documents, including altering the proportions when a minimum strength is specified.

**b. Mortar.** Mortar is defined as a mixture of cementitious materials, fine aggregate and water, which may contain admixtures, and is typically used to minimize erosion between large stones or to bond masonry units.

Proportion mortar for laying stone for stone rip-rap, slope protection, stone ditch lining or pavement patching at 1 part of portland cement and 3 parts of fine aggregate by volume with sufficient water to make a workable and plastic mix.

Proportion mortar for laying brick, concrete blocks or stone masonry at ½ part masonry cement, ½ part portland cement and 3 parts fine aggregate, either commercially produced masonry sand or FA-M, by volume with sufficient water to make a workable and plastic mix.

Do not use air-entraining agents in mortar for masonry work.

The Engineer may visually accept the sand used for mortar. The Engineer may visually accept any recognized brand of portland cement or masonry cement that is free of lumps.

**c. Grout.** Grout is defined as a mixture of cementitious materials with or without aggregate or admixtures to which sufficient water is added to produce a pouring or pumping consistency without segregation of the constituent materials and meeting the applicable specifications.

#### **401.5 COMMERCIAL GRADE CONCRETE**

If the Contract Documents allow the use of commercial grade concrete for designated items, then use a commercial grade mixture from a ready-mix plant approved by the Engineer.

The Engineer must approve the commercial grade concrete mixture. Approval of the commercial grade mixture is based on these conditions:

- All materials are those normally used for the production and sale of concrete in the vicinity of the project.
- The mixture produced is that normally used for the production and sale of concrete in the vicinity of the project.
- The mixture produced contains a minimum cementitious content of 6 sacks, 564 lbs, of cementitious per cubic yard of concrete.
- The water-cementitious ratio is as designated by the Engineer. The maximum water-cementitious ratio permitted may not exceed 0.55 pounds of water per pound of cementitious including free water in the aggregate.
- Type I, II, III, IP, IS, or IT cement may be used unless otherwise designated. Fly ash or GGBFS may be substituted for the required minimum cement content as specified in **subsection 401.3**. No additives other than air entraining agent will be allowed. The Contractor will not be required to furnish the results of strength tests when submitting mix design data to the Engineer.
- In lieu of the above, approved mix designs (including optimized) for all other grades of concrete, Grade 3.0 or above, are allowable for use as commercial grade concrete, at no additional cost to KDOT.

Exercise good engineering judgement in determining what equipment is used in proportioning, mixing, transporting, placing, consolidating and finishing the concrete.

Construct the items with the best current industry practices and techniques.

Before unloading at the site, provide a delivery ticket for each load of concrete containing the following information:

- Name and location of the plant.
- Time of batching concrete.
- Mix proportions of concrete (or a mix designation approved by the Engineer).
- Number of cubic yards of concrete batched.

Cure the various items placed, as shown in **DIVISION 700**.

The Engineer may test commercial grade concrete by molding sets of 3 cylinders. This is for informational purposes only. No slump or unit weight tests are required.

#### **401.6 CERTIFIED CONCRETE**

If KDOT inspection forces are not available on a temporary basis, the Engineer may authorize the use of concrete from approved concrete plants. Approval for this operation is based on certification of the plant and plant personnel, according to KDOT standards. KDOT's approval may be withdrawn any time that certification procedures are not followed.

The Engineer will not authorize the use of certified concrete for major structures such as bridges, RCB box bridges, RCB culverts, permanent main line and ramp pavement or other structurally, critical items.

Each load of certified concrete must be accompanied by a ticket listing mix proportions, time of batching and setting on revolution counter, total mixing revolutions and must be signed by certified plant personnel.

#### **401.7 REQUIREMENTS FOR COMBINED MATERIALS**

##### **a. Measurements for Proportioning Materials.**

(1) Cement. Measure cement as packed by the manufacturer. A sack of cement is considered as 0.04 cubic yards weighing 94 pounds net. Measure bulk cement by weight. In either case, the measurement must be accurate to within 0.5% throughout the range of use.

(2) Fly Ash. Fly ash proportioning and batching equipment is subject to the same controls as required for cement. Provide positive cut off with no leakage from the fly ash cut off valve. Fly ash may be weighed accumulatively with the cement or separately. If weighed accumulatively, weigh the cement first.

(3) Water. Measure the mixing water by weight or by volume. In either case, the measurement must be accurate to within 1% throughout the range of use.

(4) Aggregates. Measure the aggregates by weight. The measurement must be accurate to within 0.5% throughout the range of use.

(5) Admixtures. Measure liquid admixtures by weight or volume. If liquid admixtures are used in small quantities in proportion to the cement as in the case of air-entraining agents, use readily adjustable mechanical dispensing equipment capable of being set to deliver the required quantity and to cut off the flow automatically when this quantity is discharged. The measurement must be accurate to within 3% of the quantity required.

##### **b. Testing of Aggregates.**

(1) Production of On Grade Concrete Aggregate (OGCA). If OGCA is required, notify the Engineer in writing at least 2 weeks in advance of producing the aggregate. Include the source of the aggregate and the date production will begin. Failure to notify the Engineer, as required, may result in rejection of the aggregate for use as OGCA. Maintain separate stockpiles for OGCA at the quarry and at the batch site and identify them accordingly.

(2) Testing Aggregates at the Batch Site. Provide the Engineer with reasonable facilities at the batch site for obtaining samples of the aggregates. Provide adequate and safe laboratory facilities at the batch site allowing the Engineer to test the aggregates for compliance with the specified requirements.

KDOT will sample and test aggregates from each source to determine their compliance with specifications. Do not batch the concrete mixture until the Engineer has determined that the aggregates comply with the specifications. KDOT will conduct sampling at the batching site, and test samples according to the Sampling and Testing Frequency Chart in Part V. For QC/QA Contracts, establish testing intervals within the specified minimum frequency.

After initial testing is complete and the Engineer has determined that the aggregate process control is satisfactory, use the aggregates concurrently with sampling and testing as long as tests indicate compliance with specifications. When batching, sample the aggregates as near the point of batching as feasible. Sample from the stream as the storage bins or weigh hoppers are loaded. If samples can not be taken from the stream, take them from approved stockpiles, or use a template and sample from the conveyor belt. If test results indicate an aggregate does not comply with specifications, cease concrete production using that aggregate. Unless a tested and approved stockpile for that aggregate is available at the batch plant, do not use any additional aggregate from that source and specified grading until subsequent testing of that aggregate indicate compliance with specifications. When tests are completed and the Engineer is satisfied that process control is satisfactory, production of concrete using aggregates tested concurrently with production may resume.

##### **c. Handling of Materials.**

(1) Approved stockpiles are permitted only at the batch plant and only for small concrete placements or for maintaining concrete production. Mark the approved stockpile with an "Approved Materials" sign. Provide a suitable stockpile area at the batch plant so that aggregates are stored without detrimental segregation or

contamination. At the plant, limit stockpiles of tested and approved coarse aggregate and fine aggregate to 250 tons each, unless approved for more by the Engineer. If mixed aggregate is used, limit the approved stockpile to 500 tons, the size of each being proportional to the amount of each aggregate to be used in the mix.

Load aggregates into the mixer such that no material foreign to the concrete or material capable of changing the desired proportions is included. When 2 or more sizes or types of coarse or fine aggregates are used on the same project, only 1 size or type of each aggregate may be used for any one continuous concrete placement.

(2) Segregation. Do not use segregated aggregates. Previously segregated materials may be thoroughly re-mixed and used when representative samples taken anywhere in the stockpile indicated a uniform gradation exists.

(3) Cement, Fly Ash and GGBFS. Protect cement, fly ash and GGBFS in storage or stockpiled on the site from any damage by climatic conditions which would change the characteristics or usability of the material.

(4) Moisture. Provide aggregate with a moisture content of  $\pm 0.5\%$  from the average of that day. If the moisture content in the aggregate varies by more than the above tolerance, take whatever corrective measures are necessary to bring the moisture to a constant and uniform consistency before placing concrete. This may be accomplished by handling or manipulating the stockpiles to reduce the moisture content, or by adding moisture to the stockpiles in a manner producing uniform moisture content through all portions of the stockpile.

For plants equipped with an approved accurate moisture-determining device capable of determining the free moisture in the aggregates, and provisions made for batch to batch correction of the amount of water and the weight of aggregates added, the requirements relative to manipulating the stockpiles for moisture control will be waived. Any procedure used will not relieve the producer of the responsibility for delivering concrete of uniform slump within the limits specified.

(5) Separation of Materials in Tested and Approved Stockpiles. Only use KDOT Approved Materials. Provide separate means for storing materials approved by KDOT. If the producer elects to use KDOT Approved Materials for non-KDOT work, during the progress of a project requiring KDOT Approved Materials, inform the Engineer and agree to pay all costs for additional materials testing.

Clean all conveyors, bins and hoppers of any unapproved materials before beginning the manufacture of concrete for KDOT work.

#### **401.8 MIXING, DELIVERY AND PLACEMENT LIMITATIONS**

**a. Concrete Batching, Mixing and Delivery.** Batch and mix the concrete in a central mix plant, in a truck mixer or in a drum mixer at the work site. Provide plant capacity and delivery capacity sufficient to maintain continuous delivery at the rate required. The delivery rate of concrete during concreting operations must provide for the proper handling, placing and finishing of the concrete.

Seek the Engineer's approval of the concrete plant/batch site by the Engineer before any concrete is produced for the project. The Engineer will inspect the equipment, the method of storing and handling of materials, the production procedures and the transportation and rate of delivery of concrete from the plant to the point of use. The Engineer will grant approval of the concrete plant/batch site based on compliance with the specified requirements. The Engineer may, at any time, rescind permission to use concrete from a previously approved concrete plant/batch site upon failure to comply with the specified requirements.

Clean the mixing drum before it is charged with the concrete mixture. Charge the batch into the mixing drum such that a portion of the water is in the drum before the aggregates and cementitious. Uniformly flow materials into the drum throughout the batching operation. All mixing water must be in the drum by the end of the first 15 seconds of the mixing cycle. Keep the throat of the drum free of accumulations restricting the flow of materials into the drum.

Do not exceed the rated capacity (cubic yards shown on the manufacturer's plate on the mixer) of the mixer when batching the concrete. The Engineer may allow an overload of up to 10% above the rated capacity for central mix plants and drum mixers at the work site, provided the concrete test data for strength, segregation and uniform consistency are satisfactory, and no concrete is spilled during the mixing cycle.

Operate the mixing drum at the speed specified by the mixer's manufacturer (shown on the manufacturer's plate on the mixer).

Mixing time is measured from the time all materials, except water, are in the drum. If it is necessary to increase the mixing time to obtain the specified percent of air in air-entrained concrete, the Engineer will determine the mixing time.

If the concrete is mixed in a central mix plant or a drum mixer at the work site, mix the batch between 1 to 5 minutes at mixing speed. Do not exceed the maximum total 60 mixing revolutions. Mixing time begins after all materials, except water, are in the drum, and ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. Mix time may be reduced for plants utilizing high performance mixing drums

provided thoroughly mixed and uniform concrete is being produced with the proposed mix time. Performance of the plant must conform with Table A1.1 of ASTM C 94, Standard Specification for Ready Mixed Concrete. Five of the 6 tests listed in Table A1.1 must be within the limits of the specification to indicate that uniform concrete is being produced.

If the concrete is mixed in a truck mixer, mix the batch between 70 and 100 revolutions of the drum or blades at mixing speed. After the mixing is completed, set the truck mixer drum at agitating speed. Unless the mixing unit is equipped with an accurate device indicating and controlling the number of revolutions at mixing speed, perform the mixing at the batch plant and operate the mixing unit at agitating speed while travelling from the plant to the work site. Do not exceed 300 total revolutions (mixing and agitating).

If a truck mixer or truck agitator is used to transport concrete that was completely mixed in a stationary central mixer, agitate the concrete while transporting at the agitating speed specified by the manufacturer of the equipment (shown on the manufacturer's plate on the equipment). Do not exceed 200 total revolutions (additional re-mixing and agitating).

Provide a batch slip including batch weights of every constituent of the concrete and time for each batch of concrete delivered at the work site, issued at the batching plant that bears the time of charging of the mixer drum with cementitious and aggregates. Include quantities, type, product name and manufacturer of all admixtures on the batch ticket.

On paving projects and other high volume work, the Engineer will determine the haul time, and whether tickets will be required for every load. Thereafter, random checks of the loads will be made.

When non-agitating equipment is used for transportation of concrete, provide approved covers for protection against the weather when required by the Engineer.

Place non-agitated concrete within 30 minutes of adding the cement to the water.

Place concrete within the time and temperature conditions shown in **TABLE 401-9**.

<b>TABLE 401-9: AMBIENT AIR TEMPERATURE AND AGITATED CONCRETE PLACEMENT TIME</b>		
<b>T = Ambient Air Temperature at Time of Batching (°F)</b>	<b>Specimen Age Time limit agitated concrete must be placed within, after the addition of cement to water (hours)</b>	<b>Admixtures</b>
T < 75	1 ½	None
75 ≤ T	1	None
75 ≤ T < 90	1 ½	Set Retarder

In all cases, if the concrete temperature at time of placement is 90°F or above, or under conditions contributing to quick stiffening of the concrete, place the concrete within 45 minutes of adding the cement to the water. Do not use concrete that has developed its initial set. Regardless of the speed of delivery and placement, the Engineer will suspend the concreting operations until corrective measures are taken, if there is evidence that the concrete can not be adequately consolidated.

Weather conditions and the use of admixtures can effect the set times for the concrete. Do not use the time limits and total revolutions as the sole criterion for rejection of concrete. Exceed the time limits and total revolutions only after demonstrating that the properties of the concrete can be improved. Evaluation of the consistency and workability should be taken into consideration. However, concrete that cannot be adequately consolidated should be rejected.

Adding water to concrete after the initial mixing is prohibited, with this exception:

If the concrete is delivered to the work site in a truck mixer, the Engineer will allow water (up to 2 gallons per cubic yard) be withheld from the mixture at the batch site, and if needed, added at the work site to adjust the slump to the specified requirements. Determine the need for additional water as soon as the load arrives at the construction site. Use a calibrated water-measuring device to add the water, and add the water to the entire load. Do not add more water than was withheld at the batch site. After the additional water is added, turn the drum or blades an additional 20 to 30 revolutions at mixing speed. The Engineer will supervise the adding of water to the load, and will allow this procedure only once per load.

**b. Placement Limitations.**

(1) Placing Concrete at Night. Do not mix, place or finish concrete without sufficient natural light, unless an adequate, artificial lighting system approved by the Engineer is provided.

(2) Placing Concrete in Cold Weather. Unless authorized by the Engineer, discontinue mixing and concreting operations when the descending ambient air temperature reaches 40°F. Do not begin concreting operations until an ascending ambient air temperature reaches 35°F and is expected to exceed 40°F.

If the Engineer permits placing concrete during cold weather, aggregates may be heated by either steam or dry heat system before placing them in the mixer. Use an apparatus that heats the mass uniformly and is so arranged as to preclude the possible occurrence of overheated areas which might injure the materials. Do not heat aggregates directly by gas or oil flame or on sheet metal over fire. Aggregates that are heated in bins, by steam-coil or water-coil heating, or by other methods not detrimental to the aggregates may be used. The use of live steam on or through binned aggregates is prohibited. Unless otherwise authorized, maintain the temperature of the mixed concrete between 50 to 90°F at the time of placing. Do not, under any circumstances, continue concrete operations if the ambient air temperature is less than 20°F.

If the ambient air temperature is 35°F or less at the time the concrete is placed, the Engineer may require that the water and the aggregates be heated to between 70 and 150°F.

Do not place concrete on frozen subgrade or use frozen aggregates in the concrete.

As a general rule, do not use fly ash, GGBFS or blended cement between the dates of October 1 and April 1. However, if weather conditions are unseasonably warm, the Engineer may waive this rule on a day by day basis. The Engineer will consider the nighttime temperatures, the extended weather forecast and the performance and setting of the mix when deciding whether to waive the restrictions.

#### **401.9 INSPECTION AND TESTING**

Unless otherwise designated in the Contract Documents or by the Engineer, obtain samples of fresh concrete for the determination of slump, weight per cubic yard and percent of air from the final point of placement.

The Engineer will cast, store and test strength test specimens in sets of 3.

KDOT will conduct the sampling and test the samples according to **DIVISION 2500** and the Sampling and Testing Frequency Chart in Part V. For QC/QA Contracts, establish testing intervals within the specified minimum frequency.

The Engineer will reject concrete that does not comply with specified requirements.

The Engineer will permit occasional deviations below the specified cementitious content, if it is due to the air content of the concrete exceeding the designated air content, but only up to the maximum tolerance in the air content.

The Contractor has the option to control air content for PCCP by either the Non QC/QA Approach or the QC/QA Approach (see **subsection 401.10** or **401.11**, the Contractor's Quality Control Plan for PCCP shall designate which approach will be used). Continuous operation below the specified cementitious content for any reason is prohibited.

As the work progresses, the Engineer reserves the right to require the Contractor to change the proportions if conditions warrant such changes to produce a satisfactory mix. Any such changes may be made within the limits of the specifications at no additional compensation to the Contractor.

#### **401.10 AIR-ENTRAINED CONCRETE PAVEMENT (NON-QC/QA APPROACH)**

**a. Air Content for PCCP.** Provide an air content that complies with **subsection 401.3 h**.

Using fresh concrete, the Engineer will determine the air void spacing factor using the AVA according to the manufacturer's requirements. Prequalify mixtures by either the laboratory option or the field option. Contact the Engineer to arrange testing by the AVA.

**b. Laboratory Prequalification.** Prepare a trial mix using a drum-type mixer according to AASHTO T 126 using all of the materials in the proportions, except the air entraining agent, contemplated for use in the field. Laboratory mixes require more air entraining agent than is needed in the field. Consolidate a sample in the unit weight bucket by vibration according to KT-20. Obtain 3 samples from the unit weight bucket for testing by the AVA. Valid results must have a minimum of 2 spacing factor readings within a range of 0.0025 inch. Test the third sample if the first two do not meet this criteria. Determine the air content of the trial mix by KT-19 (Roll-a-meter) or KT-18 (pressure meter) calibrated to yield the same result. Calculate a target percent air content at a maximum air void spacing factor of 0.01 inch using the equation in **subsection 401.3h.**, when applicable.

**c. Field Prequalification.** Previous data on air content and air void spacing factors may be submitted as a basis of prequalification for a mixture if the same materials, proportions, equipment and procedures are used. The only exception allowed is a change in coarse aggregate sources if the gradation is similar. The new aggregate source is required to meet the same qualifications as the previous aggregate source. Alternately, produce a trial batch at a minimum air temperature of 60°F using the batch plant and project materials. Test for air content by the procedure specified under laboratory prequalification. Correlate this air content to the average of at least 2 valid AVA test results. Valid AVA results have a maximum range of 0.0025 inch.

When necessary, calculate a target percent air content at a maximum air void spacing factor of 0.01 inch, using the equation in **subsection 401.3h**.

**d. Field Verification.** Coordinate with the Engineer so production samples may be obtained behind the paver to establish the target air content on the first paving day. Produce concrete using the same materials and proportions that were used in the prequalification mixture. Adjustments may be approved in the dosage of air entraining agent and a 5% adjustment may be approved in the water-cementitious ratio. Samples will be taken both in the path of a vibrator and the gap between vibrators. Perform the test for air content at the delivery site of the concrete KT-19 (Roll-a-meter) or KT-18 (pressure meter), calibrated to yield the same result. Make adjustments in the proportions, types of material or the operation to establish a satisfactory, target air content.

**e. Control of the Air Content During Paving Operations.** Maintain an air content behind the paver as determined by KT-19 or KT-18, which meets **subsection 401.3h**. Maintain all production parameters established during field verification. The dosage of air-entraining agent may be varied to control the air content. Five percent adjustments will be permitted to the cementitious content and the water-cementitious ratio. With AVA testing, 5% adjustments will be permitted to the aggregate proportions, as well as any adjustment to the water reducer. Comply with all specifications regarding production of fresh concrete. For all mainline paving, test the concrete at the beginning of the day's operation and approximately every 2 hours thereafter for air content. For all other slipformed pavement, test for air content at the beginning of a day's operation and approximately every 4 hours thereafter. Test hand placements for air content at least once daily.

Determine the air loss due to paving operations once in the AM and once in the PM. Determine the difference between the air content from concrete sampled before the paver, and concrete sampled behind the paver. QC/QA samples may be obtained in front of the paver and then corrected subtracting the difference determined during that ½ days production. Loss of air due to paving operations may adversely affect the spacing factor.

Failure to maintain the minimum required air content will result in suspension of operation. Take immediate steps to increase the air content above the minimum values stated in **subsection 401.3h**.

Other similar designs using higher cementitious contents and the same admixture types and dosage (with the same or lower water-cementitious ratio) may be used in limited areas such as crossovers, etc. Unauthorized changes in any aspect of production are cause for rejection of the pavement.

Random checks of the air void spacing factor of the concrete in the path and gap of the vibrators will be conducted by the Engineer to verify a maximum spacing factor of 0.01 inch at the measured air content.

**APPENDIX A - Non-Mandatory Information**

**a. Concrete for Structures.** Design field blended cement concrete meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability using the parameters described in subsection 401.3b.

<b>TABLE 401-A1: CONCRETE FOR STRUCTURES</b>		
<b>Grade of Concrete: Type of Aggregate (DIVISION 1100)</b>	<b>lb. of Cementitious per yd<sup>3</sup> of Concrete, minimum</b>	<b>lb. of Water per lb. of Cementitious, maximum<sup>1</sup></b>
<b>Grade 5.0:</b>		
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.36
Coarse and Fine Aggregate	602	0.36
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.36
<b>Grade 4.5:</b>		
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.42
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.42
Coarse and Fine Aggregate	602	0.42
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.42
<b>Grade 4.0<sup>2</sup>:</b>		
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.46
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.46
Coarse and Fine Aggregate	602	0.46
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.46
<b>Grade 3.0 and Grade 3.5:</b>		
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	639	0.48
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	602	0.48
Coarse and Fine Aggregate	564	0.48
MA-2 with 45% or more (by weight) on the No. 4 sieve	564	0.48
<b>Grade 2.5:</b>		
All Aggregates	526	0.55

<sup>1</sup>Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

<sup>2</sup>Take measures to control bleeding on Grade 4.0 concrete for drilled shafts through the use of a lower w/c ratio, the addition of air, or any other proven method to control bleeding.

**b. Air-Entrained Concrete for Structures.** Design air-entrained concrete for structures meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability, according to **TABLE 401-A2**.

<b>TABLE 401-A2: AIR-ENTRAINED CONCRETE FOR STRUCTURES</b>			
<b>Grade of Concrete Type of Aggregate (DIVISION 1100)</b>	<b>lb. of Cementitious per yd<sup>3</sup> of Concrete, minimum</b>	<b>lb. of Water per lb. of Cementitious, maximum<sup>5</sup></b>	<b>Percent of Air by Volume<sup>6</sup></b>
<b>Grade 6.0(AE)(SA)<sup>2</sup>:</b>			
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	752	0.35	6.5±1.5
Coarse and Fine Aggregate	752	0.35	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	700	0.35	6.5±1.5
<b>Grade 5.0(AE), Grade 5.0(AE)(SW)<sup>1</sup>, Grade 5.0(AE)(SA)<sup>2</sup>, Grade 5.0(AE)(AI)<sup>3</sup> and Grade 5.0(AE)(PB)<sup>4</sup>:</b>			
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.35	6.5±1.5
Coarse and Fine Aggregate	602	0.35	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.35	6.5±1.5
<b>Grade 4.5(AE), Grade 4.5(AE)(SW)<sup>1</sup>, Grade 4.5(AE)(SA)<sup>2</sup>, and Grade 4.5(AE)(AI)<sup>3</sup>:</b>			
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.40	6.5±1.5
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.40	6.5±1.5
Coarse and Fine Aggregate	602	0.40	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.40	6.5±1.5
<b>Grade 4.0(AE), Grade 4.0(AE)(SW)<sup>1</sup>, Grade 4.0(AE)(SA)<sup>2</sup>, and Grade 4.0(AE)(AI)<sup>3</sup>:</b>			
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.44	6.5±1.5
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.44	6.5±1.5
Coarse and Fine Aggregate	602	0.44	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.44	6.5±1.5
<b>Grade 3.0(AE) and Grade 3.5(AE):</b>			
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	639	0.46	6.5±1.5
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	602	0.46	6.5±1.5
Coarse and Fine Aggregate	564	0.46	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	564	0.46	6.5±1.5
<b>Grade 2.5(AE):</b>			
All Aggregates	526	0.53	6.5±1.5

<sup>1</sup>Grade xx (AE)(SW) - Structural concrete with select coarse aggregate for wear.

<sup>2</sup>Grade xx (AE)(SA) - Structural concrete with select coarse aggregate for wear and absorption.

<sup>3</sup>Grade xx (AE)(AI) - Structural concrete with select coarse aggregate for wear and acid insolubility.

<sup>4</sup>Grade xx (AE)(PB) - Structural concrete with select aggregate for use in prestressed concrete beams.

<sup>5</sup>Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

<sup>6</sup>The maximum air content is 10%. Take immediate steps to get the air down whenever the air content exceeds 8%.

**c. Silica Fume Modified Concrete.** When silica fume is specified in the Contract Documents, meet the mix design and production requirements in **TABLE 401-A3**.

<b>TABLE 401-A3: SILICA FUME CONCRETE CRITERIA</b>	
lbs. of Cement per cu. yd. maximum	595
lbs. of Silica Fume per cu. yd., maximum	30
lbs. of water per lbs. of (Cement + Silica Fume), Max	0.40
Percent of Air by Volume	6.5±1.5 <sup>1</sup>
Maximum 56 day Rapid Chloride Permeability AASHTO T-277 <sup>2</sup>	1000 coulombs
or Maximum 28 day Permeable Voids KT-73 <sup>2</sup>	9.50%
or Minimum 28 day Surface Resistivity KT-79 <sup>2</sup>	27.0 kΩ-cm

<sup>1</sup>As Determined by KT-19 (Rollometer). A regularly calibrated air meter may be used for production with random verification by the rollometer. See KT-19 for special requirements when using the rollometer with high cement concretes or mixtures with midrange water reducers or plasticizers.

<sup>2</sup>Provide Silica Fume Modified Concrete with either a maximum 28-day Volume of Permeable Voids of 9.5% as per KT-73, a minimum 28-day Surface Resistivity of 27.0 kΩ-cm as per KT-79, **or** a maximum 56-day Rapid Chloride Permeability of 1000 Coulombs as per AASHTO T-277. Submit accelerated cure procedures for the Engineer's approval.

## **APPENDIX B - Non-Mandatory Information**

### **Suggested Guidelines for Meeting KDOT's Permeability Specifications**

#### **General**

Water and chlorides permeate through the mortar and paste of the concrete mixes. They do not readily permeate through the larger aggregates. Permeability can be improved by decreasing the mortar and paste of the concrete mix and increasing the coarse aggregate portions.

The use of optimized mix designs, blended cements, and/or supplementary cementitious materials (SCMs) can reduce the permeability of concrete. The latest revisions of **SECTION 1102**, Aggregates for Concrete describes optimized aggregate gradations for concrete mixes. Additional testing for alkali silica reaction (ASR) is required when SCMs are used in concrete as per the latest revision of **SECTION 401**. The amount of SCMs required to pass the ASR testing may be different than the amount required to comply with the permeability specifications. SCMs may also lower the necessary water cement (w/c) ratio and may slow set times and strength gain.

Optimizing the coarse aggregate gradations can decrease permeability. This includes mixes with more than 60% retained on the # 8 sieve and gradations with fineness modulus above 4.75. A fineness modulus of over 5.0 can yield even better results. Use the largest practical nominal maximum size aggregate allowed.

In general, keeping the w/c ratio below 0.43 may help meet the permeability specifications, as may lower cementitious content mixes when using Type I/II cements. These two properties control the paste in the mix. Concrete mixes with less than 25% paste (as displayed on KDOT Form 694) are more likely to pass the permeability specifications. Acceptable concrete can be mixed with paste contents of 23% or lower. Water cement ratios below 0.39 often do not provide enough water for all constituents to properly react, especially when admixtures are used, and may be counterproductive. High early strength concrete mixes using Type III cement and higher cementitious contents have also been able to pass the Standard Permeability requirements because of their low w/c ratios.

In general, the use of water reducers is helpful in reducing the paste content. Material compatibilities, following the admixture suppliers' recommendations for dosage rates, and the order of introduction of the chemicals into the mix are paramount to meeting KDOT specifications. Contractors should work with their admixture suppliers to find an admixture that works well with their combination of materials.

Changes made to an approved mix design will change the permeability, especially additional water, or redosing water that was withheld from the mix at a concrete plant. It is also recommended that concrete producers verify their mixes with a minimum of 3 cubic yards after doing their laboratory mix designs.

### **Standard Permeability Concrete (SPC)**

#### **Requirements:**

Volume of Permeable Voids 12.0% max, or  
Surface Resistivity 9.0 k $\Omega$ -cm min, or  
RCPT 3000 Coulombs max.

The SPC specification may be met without the use of optimized mix designs, blended cements, or SCMs. With certain aggregates, 25% slag cement will be required to pass the ASR testing. With other aggregates, a minimum of 30% slag cement by weight of total cementitious materials is usually needed. Some fly ashes require a minimum of 18% to 20% of the total cementitious material to pass the ASR test. Class C fly ash will react differently than Class F fly ash.

Some people believe that lower absorption aggregates have a better chance of meeting the permeability specification, but higher absorption aggregates have been used in concrete mixes utilizing these guidelines and have met the SPC specifications. KDOT has found that the properties of the concrete are often more important than the absorption of the aggregate when meeting this specification.

### **Moderate Permeability Concrete (MPC)**

#### **Requirements:**

Volume of Permeable Voids 11.0% max, or  
Surface Resistivity 13.0 k $\Omega$ -cm min, or  
RCPT 2000 Coulombs max.

Concrete mixes for MPC will require aggregates with a minimum Soundness of 0.95, a maximum LA Wear of 40, and a minimum Acid Insoluble Residue of 85%. These aggregates, by nature, are harder aggregates with very low absorption. MPC may rely more heavily on optimized gradations, blended cements or SCMs in order to meet the specification. Consideration could be given to ternary blends of cementitious materials, using more than one SCM, or combining a blended cement with an additional SCM. Combinations of 25% to 30% slag cement with as little as 10% to 25% Class C fly ash have been very effective in keeping permeabilities below the level required for MPC. Incorporation of 20% Class F Fly Ash will often satisfy the requirements of the MPC specification.

### **Low Permeability Concrete**

#### **Requirements:**

Volume of Permeable Voids 9.5% max, or  
Surface Resistivity 27.0 k $\Omega$ -cm min, or  
RCPT 1000 Coulombs max.

LPC will also use harder aggregates with very low absorption. These mixes must be optimized with the MA-6 gradation. Mix designs with 5% silica fume and 95% Type I/II cement often meet the LPC requirements. These mixes have traditionally been known as silica fume concrete. Ternary mix designs are useful in meeting these requirements. Consider using 3% to 5% silica fume with 25% to 30% slag cement, or 25% to 30% slag cements with 10% to 25% Class C fly ash. Class F fly ash alone may also be effective in reducing the permeability to these levels.

Contact KDOT's Bureau of Research or the District Office for additional guidance in meeting the Permeability Specifications.