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DIVISION 400
CONCRETE

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 ..... **DIVISION 1100**
Admixtures, Plasticizers and Silica Fume ..... **DIVISION 1400**
Cement, Fly Ash and Ground Granulated Furnace Slag ..... **DIVISION 2000**
Water ..... **DIVISION 2400**

401.3 CONCRETE MIX DESIGN

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

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

b. 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 Aggregate (SECTION 1100)	lb. of Cement per cu. yd. of Concrete, minimum	lb. of Water per lb. of Cement, maximum*	Percent of Air by Volume
Coarse and Fine	602	0.49	See **subsection 401.3g.**
MA-2	602	0.49	See **subsection 401.3g.**
MA-1	620	0.49	See **subsection 401.3g.**

*Maximum limit of lb. of water per lb. of cement includes free water in aggregates, but excludes water of absorption of the aggregates.

c. Optimized, Air-Entrained Concrete for Pavement. 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. If the Optimized option is selected, provide the Engineer written notification of the selection, prior to the pre-construction conference.

Design optimized, air-entrained concrete for pavement according to **TABLE 401-2**.

TABLE 401-2: OPTIMIZED, AIR-ENTRAINED CONCRETE FOR PAVEMENT				
Type of Aggregate (DIVISION 1100)	**lb. of Cement per cu. yd. of Concrete, minimum***	**lb. of Water per lb. of Cement, maximum****	**Percent of Air by Volume**	**28-Day Compressive Strength psi**
MA-3	521	0.49	See **subsection 401.3g.**	4000

*The amount of cement listed is the designated minimum. It may be necessary to add additional cement or otherwise adjust the mix proportions as permitted by the specifications to provide a mix design that complies with the compressive strength requirement.

**Maximum limit of lb. of water per lb. of cement includes free water in aggregates, but excludes water of absorption of the aggregates.

Submit to the Engineer, the optimized concrete mix design, and supply the Engineer with the necessary materials to enable the Engineer to test the mix properties at least 6 weeks before the anticipated date of using the design on the project and include the following information:

(1) A single point grading for the combined MA-3 aggregates along with a plus/minus tolerance for each sieve. 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 shall be a minimum of 2 of the Contractor's normal standard deviations for this type of mix above 4000 psi (cylinders).

(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 5000 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. Concrete for Structures. Design concrete for structures according to **TABLE 401-3**.

TABLE 401-3: CONCRETE FOR STRUCTURES		
Grade of Concrete: Type of Aggregate (DIVISION 1100)	**lb. of Cement per cu. yd. of Concrete, minimum***	**lb. of Water per lb. of Cement, maximum**
Grade 5.0:		
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
Grade 4.5:		
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
Grade 4.0:		
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
Grade 3.0 and Grade 3.5:		
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
Grade 2.5:		
All Aggregates	526	0.55

*Maximum limit of lb. of water per lb. of cement includes free water in aggregates, but excludes water of absorption of the aggregates.

e. Air-Entrained Concrete for Structures. Design air-entrained concrete for structures according to **TABLE 401-4**.

TABLE 401-4: AIR-ENTRAINED CONCRETE FOR STRUCTURES			
Grade of Concrete Type of Aggregate (DIVISION 1100)	**lb. of Cement per cu. yd. of Concrete, minimum**	**lb. of Water per lb. of Cement, maximum[5]**	**Percent of Air by Volume[6]**
Grade 5.0(AE), Grade 5.0(AE)(SW) [1], Grade 5.0(AE)(SA) [2], Grade 5.0(AE)(AI) [3] and Grade 5.0(AE)(PB) [4] :			
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
Grade 4.5(AE), Grade 4.5(AE)(SW) [1], Grade 4.5(AE)(SA) [2], and Grade 4.5(AE)(AI) [3]:			
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
Grade 4.0(AE), Grade 4.0(AE)(SW) [1], Grade 4.0(AE)(SA) [2], and Grade 4.0(AE)(AI) [3]:			
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
Grade 3.0(AE) and Grade 3.5(AE):			
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
Grade 2.5(AE):			
All Aggregates	526	0.53	6.5±1.5

[1]Grade xx (AE)(SW) - Structural concrete with select coarse aggregate for wear

[2]Grade xx (AE)(SA) - Structural concrete with select coarse aggregate for wear and absorption.

[3]Grade xx (AE)(AI) - Structural concrete with select coarse aggregate for wear and acid insolubility.

[4]Grade xx (AE)(PB) - Structural concrete with select aggregate for use in prestressed concrete beams.

[5]Maximum limit of lb. of water per lb. of cement includes free water in aggregates, but excludes water of absorption of the aggregates.

[6]The air content is not to exceed 10%. Take immediate steps to get the air down whenever the air content exceeds the maximum value shown in **TABLE 401-4**.

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**.

TABLE 401-5: PORTLAND CEMENT & BLENDED HYDRAULIC CEMENT

Concrete for:	Type of Cement Allowed
Bridge Deck Wearing Surface and Concrete Pavement	Type IP Portland-Pozzolan Cement Type I(PM) Pozzolan Modified Portland Cement Type IS Portland-Blast Furnace Slag Cement Type I(SM) Slag Modified Portland Cement Type II Portland Cement
All Structures other than Bridge Deck Wearing Surface and Concrete Pavement	Type I Portland Cement Type IP Portland-Pozzolan Cement Type I(PM) Pozzolan Modified Portland Cement Type IS Portland-Blast Furnace Slag Cement Type I(SM) Slag Modified Portland Cement Type II Portland Cement
High Early Strength Concrete	Type III Portland Cement Type I, IP, II, or I/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 5.5%; and
- a maximum air void spacing factor of 0.01 inch.

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

If the maximum air void spacing factor exceeds 0.01 inch, use the following formula to determine the target air content:

Target % air content at 0.01 inch = % air measured + (measured spacing factor – 0.01)/0.001

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.

(2) Air-Entraining Admixture. When specified, use an air-entrainer in the concrete mixture. If the concrete mixture also contains a plasticizer or a high-range water-reducer, use only vinsol resins or tall oil based air-entrainers.

(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 401.3h.(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**.

TABLE 401-6: ALLOWABLE CONCRETE SLUMP

Concrete for:	Maximum Allowable Slump (inches)
Concrete Pavement	2 ½[1,2]
Concrete for Structures & Air-Entrained Concrete for Structures	That required for satisfactory placement of the respective parts of the structure.[2]
Bridge Subdecks or Decks without Plasticizing Admixtures	3[2]
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[3]
Concrete with Plasticizers for Drilled Shafts	[4]

[1]If the Engineer approves, slumps in excess of 2 ½ inches are allowed for areas that are hand finished.

[2]If the designated slump is 3 inches or less, the tolerance is ±¾ 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 ±25% of the designated slump.

[3]If the Engineer approves the use of plasticizing admixture in the concrete, the tolerance from the designated slump is ±25% or ¾ inch, whichever is larger, limited by the maximum allowable slump for the individual type of construction. Maintain the required geometry.

[4]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 401.3h**.

j. Fly Ash Modified Concrete. When approved by the Engineer, the concrete mix design may include fly ash from an approved source as a partial replacement for portland cement or blended hydraulic cement. Do not substitute fly ash for Type III cement. The approved source of fly ash may not be changed during the project.

Substitute 1 pound of fly ash for 1 pound of cement. Substitution with Class C fly ash is limited to a maximum of 10% (by weight) of the total cementitious material. Substitution with Class F fly ash is limited to a maximum of 25% (by weight) of the total cementitious material. If fly ash is substituted for Type IP, Type IS, Type I(PM) or Type I(SM) cement, the amount of pozzolan in the blended cement plus the amount of fly ash substituted may not exceed 30% of the total weight of the cementitious material.

The maximum pound of water per pound of fly ash modified cementitious material is the same as specified in **TABLE 401-3** for a pound of cement.

Fly ash modified concrete shall equal or exceed the design strength requirements in **TABLE 401-7**.

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 the Cement and Concrete Reference Laboratory (CCRL), and

shall equal or exceed the strength requirements listed in **TABLE 401-7**. Prepare test specimens and perform flexural tests according to **DIVISION 2500**. Perform compressive strength tests according to ASTM C 39.

Provide the results of mortar expansion tests of ASTM C 1567 and/or ASTM C 227 using the project's mix design concrete materials at their designated percentages.

Provide a mix that complies with one of the following criteria:

- ASTM C 1567 with a maximum expansion of 0.10 % at 16 days after casting; or
- ASTM C 227 with maximum expansions of 0.05% at 3 months and 0.10% at 6 months.

Expansion greater than 0.05% at 3 months should not be considered excessive when the 6-month expansion remains below 0.10%.

The results shall be provided to the Engineer at least 15 days before placement of concrete on the project.

After sufficient data has been collected, the strength test requirements may be waived, but only with the approval of the Bureau Chief of Materials and Research.

k. Ground Granulated Blast Furnace Slag (GGBFS) Modified Concrete. The concrete mix design may include GGBFS from an approved source as a partial replacement for portland cement or blended hydraulic cement. Do not substitute GGBFS for Type III cement. The approved source of GGBFS may not be changed during the project.

GGBFS is considered a field blended cement and is subject to **DIVISION 2000**, except for the optional physical requirements.

Substitute 1 pound of GGBFS for 1 pound of cement. Substitution with GGBFS is limited to a maximum of 35% (by weight) of the total cementitious material. If GGBFS is substituted for Type IS or Type I(SM) cement, the amount of GGBFS in the blended cement plus the amount of GGBFS substituted may not exceed 35% of the total weight of the cementitious material.

The maximum pound of water per pound of GGBFS modified cementitious material is the same as specified in **TABLE 401-3** for a pound of cement.

GGBFS modified concrete shall equal or exceed the design strength requirements listed in **TABLE 401-7**.

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 a CCRL, and shall equal or exceed the strength requirements listed in **TABLE 401-7**. Prepare test specimens and perform flexural tests according to **DIVISION 2500**. Perform compressive strength tests according to ASTM C 39.

Provide the results of mortar expansion tests of ASTM C 1567 and/or ASTM C 227 using the project's mix design concrete materials at their designated percentages.

Provide a mix that complies with one of the following:

- ASTM C 1567 with a maximum expansion of 0.10 % at 16 days after casting; or
- ASTM C 227 with maximum expansions of 0.05% at 3 months and 0.10% at 6 months.

Expansion greater than 0.05% at 3 months should not be considered excessive when the 6-month expansion remains below 0.10%.

The results shall be provided to the Engineer at least 15 days before placement of concrete on the project.

After sufficient data has been collected, the strength test requirements may be waived, but only with the approval of the Bureau Chief of Materials and Research.

TABLE 401-7: DESIGN STRENGTH REQUIREMENTS FOR FLY ASH MODIFIED & GGBFS MODIFIED CONCRETE

Grade of Concrete	Specimen Age	Unit Strength, psi
Grade 5.0 or Grade 5.0(AE)	28 days	6500 Compressive
Grade 4.5 or Grade 4.5(AE)	28 days	5600 Compressive
Grade 4.0 or Grade 4.0(AE)	28 days	5200 Compressive
Grade 3.5 or Grade 3.5(AE)	28 days	4600 Compressive
Grade 3.0 or Grade 3.0(AE)	28 days	4100 Compressive
Grade 2.5 or Grade 2.5(AE)	---	Not required
Pavement	7 days	600 Flexural (third point loading)

l. Silica Fume Modified Concrete. When silica fume is specified in the Contract Documents, meet the mix design and production requirements in **TABLE 401-8**.

TABLE 401-8: SILICA FUME CONCRETE CRITERIA	
lbs. of Cement per cu. yd. minimum	581
lbs. of Silica Fume per cu. yd., minimum	44
lbs. of water per lbs. of (Cement + Silica Fume), Max	0.37
Percent of Air by Volume	6.5±1.5*

*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.

(1) Use a ratio of the coarse aggregate (SCA-5) to the fine aggregate of 50:50 by weight.

(2) Use only Type IP, Type II or Type I/II Cement. Fly ash modified concrete is prohibited.

(3) Designate a target slump within the range of 2 to 5 inches. A tolerance of ± 25% or ¾ inch, whichever is larger, will apply to the target slump.

(4) A water-reducing admixture for improving workability may be required, and may be used when approved by the Engineer. Adjust the designated slump accordingly.

(5) Adjust the yield cement factor (ycf) for higher air within specification limits, as allowed in the Contract Documents.

(6) Add silica fume with the cement during batching procedures. If the silica fume can not be added to the cement it shall 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, provided the bags are added to half of the mixing water and mixed before adding the aggregate and remainder of water.

(7) Mix the silica fume concrete for 100 mixing revolutions.

(8) 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.

m. High Early Strength Concrete. Design the high early strength concrete mix to comply with strength and time requirements specified in the Contract Documents.

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 cement content of 6 sacks, 564 lbs, of cement per cubic yard of concrete.
- The water-cement ratio is as designated by the Engineer. The maximum water-cement ratio permitted may not exceed 0.55 pounds of water per pound of cement including free water in the aggregate.
- Type I, II, III, IP or I(PM) 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 provide 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); and
- 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 shall be accompanied by a ticket listing mix proportions, time of batching and setting on revolution counter, total mixing revolutions and shall 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 shall 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 cutoff 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 shall be accurate to within 1% throughout the range of use.

(4) Aggregates. Measure the aggregates by weight. The measurement shall 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 shall be accurate to within 3% of the quantity required.

b. Testing of Aggregates.

(1) Production of Class I Aggregate. If Class I aggregate is required, notify the Engineer in writing a minimum of 2 weeks in advance of producing the Class I 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 as Class I aggregate. Maintain separate stockpiles at the quarry for Class I aggregate and identify them accordingly.

(2) Testing Aggregates at the Batch Site. At the batch site, provide the Engineer with reasonable facilities 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. 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 so 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 indicate 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 ± 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 projects.

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 shall provide for the proper handling, placing and finishing of the concrete.

Seek the Engineer's approval of the concrete plant/batch site 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 approval 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 cement. Uniformly flow materials into the drum throughout the batching operation. All mixing water shall 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 shall comply with Table A1.1, of ASTM C 94, Standard Specification for Ready Mixed Concrete. Five of the 6 tests listed in Table A1.1 shall 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 time slip 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 cement and aggregates.

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**.

TABLE 401-9: AMBIENT AIR TEMPERATURE AND AGITATED CONCRETE PLACEMENT TIME

T = Ambient Air Temperature at Time of Batching (°F)	Specimen Age Time limit agitated concrete shall be placed within, after the addition of cement to water (hours)	Admixtures
T < 75	1 ½	None
75 ≤ T < 90	1	None
75 ≤ T < 90	1 ½	Set Retarder
90 ≤ T	1	None

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.

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 40ºF.

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

Obtain samples of fresh concrete for the determination of slump, weight per cubic yard and percent of air from locations shown in the Contract Documents, or at other points designated by the Engineer.

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 cement content, if it is due to the air content of the concrete exceeding the designated air content, but only up to the plus 1.5% 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 cement 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 401.3g**.

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 2 samples from the unit weight bucket for testing by the AVA. Valid results shall have a minimum of 2 spacing factor readings within a range of 0.0025 inch. 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 401.3g.**, 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 60ºF 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 3 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 401.3g**.

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-cement 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, determined by KT-19 or KT-18, which meets **subsection 401.3g**. 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 cement content and the water-cement 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.

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 401.3g**.

Other similar designs using higher cement contents and the same admixture types and dosage (with the same or lower water-cement 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.

401.11 AIR-ENTRAINED CONCRETE PAVEMENT (QC/QA APPROACH)

The Bureau of Materials and Research will certify the Contractor's equipment and personnel.

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

Using fresh concrete, 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 as stipulated below.

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 2 samples from the unit weight bucket for testing by the AVA. Valid results shall have a minimum of 2 spacing factor readings within a range of 0.0025 inch. 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 401.3g.**, 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 grading is similar. The new aggregate source is required to comply with the same qualifications as the previous aggregate source. Alternately, produce a trial batch at a minimum air temperature of 60^{o}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 401.3g**.

d. Initial Startup. 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-cement ratio. Obtain production samples from behind the paver to establish the target air content on the first paving day. Take samples 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 by 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, determined by KT-19 or KT-18, which meets **subsection 401.3g**. 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 cement content and the water-cement 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 slip formed 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.

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 401.3g**.

Other similar designs using higher cement contents and the same admixture types and dosage (with the same or lower water-cement 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.