TABLE OF CONTENTS

DIVISION 400
CONCRETE

SECTION	PAGE
401 - GENERAL CONCRETE	400-1
402 - STRUCTURAL CONCRETE	400-14
403 - ON GRADE CONCRETE	400-17
404 - CONCRETE FOR PRESTRESSED CONCRETE MEMBERS	400-22
405 - CURING ENVIRONMENT	400-25

SECTION 401

GENERAL CONCRETE

401.1 DESCRIPTION

Provide the grades of concrete specified in the Contract Documents.
See **SECTION 402** for specific requirements for Structural Concrete.
See **SECTION 403** for specific requirements for On Grade Concrete.
See **SECTION 404** for specific requirements for Prestressed Concrete.

401.2 MATERIALS

Provide materials that comply with the applicable requirements.

Aggregate	**DIVISION 1100**
Admixtures and Plasticizers	**DIVISION 1400**
Grade 2 Calcium Chloride	**DIVISION 1700**
Cement, Fly Ash, Silica Fume, Slag Cement and Blended Supplemental Cementitious	**DIVISION 2000**
Water	**DIVISION 2400**

401.3 CONCRETE MIX DESIGN

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

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.

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

Provide aggregate gradations that comply with **DIVISION 1100** 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.

Submit all concrete mix designs to the Engineer for review and approval. Submit completed volumetric mix designs on KDOT Form No. 694 and all required attachments at least 60 days prior to placement of concrete on the project. The Engineer will provide an initial review of the design within 5 business days following submittal.

Include the following with the mix design data:

(1) Test data.

(a) Test data from KT-73 tested at 28 days, KT-79 tested at 28 days **or** AASHTO T-277 tested at 56 days for all bridge overlays, Moderate Permeability Concrete, and any project with over 250 cubic yards of concrete (this includes structural concrete, on grade concrete etc.). Provide the test data for each mix, tested at the highest paste content (cementitious and water) that meets **subsection 401.3h**. Submit accelerated cure procedures for the Engineer's approval. The field verification test procedure must be the same test procedure as the mix design approval test.

(b) Test data from ASTM C 1567 for field blended cements meeting **subsection 401.3d.(6)** for all concrete utilizing all actual materials proposed for use on the project at designated percentages.

(2) Single point grading for the combined 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.

(3) Laboratory 28 day compressive strength test results on a minimum of 1 set of 3 cylinders produced from the mix design with the highest water to cementitious ratio for the project, utilizing all actual materials proposed for use on the project at designated percentages.

(4) Historical mix production data for the plant producing concrete for the project to substantiate the standard deviation selected for use in **subsection 401.3b**.

(5) Necessary materials to enable the Engineer to test the mix properties and Surface Resistivity, if applicable.

After initial review, the Engineer will perform any testing necessary to verify the design. This may include a 3 cubic yard test batch at the producing plant.

Mix designs will remain approved when verification testing for strength and permeability conducted within the last 12 months indicate continued compliance with the specifications and percentages of constituents including aggregate and cementitious materials and product, type and supplier of admixtures remain the same. Test results on the same mix from other sources are acceptable. Provide ASTM C 1567 results on an annual basis if the mix includes supplemental cementitious materials (SCM).

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, approved by the Engineer, are acceptable in optimizing the mix design.

A water-reducing admixture for improving workability may be required. Adjust the designated slump accordingly.

With the exception of concrete for pavement as shown in **SECTION 403**, use the middle of the specified air content range of 6½ ± 1.5% for the design of air entrained concrete.

Maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

Determine air content by KT-19 (Volumetric Method). A regularly calibrated KT-18 (Pressure Method) meter may be used for production with random verification by the Volumetric Method. See KT-19 for special requirements when using the Volumetric Method with high cementitious concretes or mixtures with midrange water reducers or plasticizers.

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.

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.

Mixes tested with admixtures are not the same as mixes tested without those admixtures.

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

c. 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 401-1**.

Design concrete with a maximum water to cementitious ratio of 0.50 and minimum cementitious content of 480 lbs per cubic yard except for concrete for pavement and shoulders.

TABLE 401-1: PORTLAND CEMENT & BLENDED HYDRAULIC CEMENT	
Concrete for:	**Type of Cement Allowed**
On Grade Concrete	Type IP(x) Portland-Pozzolan Cement Type IS(x) Portland- Slag Cement Type IT(Ax)(By) Ternary Blended Cement Type II Portland Cement
All Concrete other than On Grade Concrete.	Type I Portland Cement Type IP(x) Portland-Pozzolan Cement Type IS(x) Portland- 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.

d. Blended Cement Concrete. When approved by the Engineer, the concrete mix design may include SCMs such as fly ash, slag cement, silica fume or blended SCM 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. Changes in SCM or cement will require a new mix design approval.

(1) Cements meeting **SECTION 2001** are not field blended cements.

(2) Cements with SCMs added at the concrete mixing plant are field blended cements.

(3) Supplementary materials can be combined with cement to create field blended cements. Do not exceed allowable substitution rates noted in **TABLE 401-2**. Substitute 1 pound of SCM for 1 pound of cement.

(4) SCMs in prequalified cements are to be included in the total combined substitution rate.

TABLE 401-2: ALLOWABLE SUBSTITUTION RATE FOR SUPPLEMENTARY CEMENTITIOUS MATERIAL.	
Material	**Substitution Rate***
Slag Cement	40% Maximum
Fly Ash	25% Maximum
Blended SCM	25% Maximum
Silica Fume	5% Max
Total Combined	50%

* Total Substitution Rate includes material in preblended cements and blended SCMs.

(5) 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 401.3a**.

(6) For field blended cementitious material provide mortar expansion test results from 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.

ASTM C 1567 is not necessary for concrete modified with **only** silica fume.

When used, add silica fume with other cementitious materials during batching procedures. If the silica fume cannot be added to the cementitious materials, add the loose silica fume to the bottom of the stationary drum that is wet, but has no standing water, before adding the dry materials. The Engineer may approve shreddable bags on a performance basis, only when a central batch mixing process is used. If so, add the bags to half of the mixing water and mix before adding cementitious materials, aggregate and remainder of water.

Mix silica fume modified concrete for a minimum of 100 mixing revolutions.

(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 Cement and Concrete Reference Laboratory (CCRL), and shall equal or exceed the strength requirements for the Grade specified in the Contract Documents as determined by **subsection 401.3b**. Perform compressive strength tests according to KT-76.

e. Strength. Design concrete to meet **TABLE 401-3**.

TABLE 401-3: CONCRETE STRENGTH REQUIREMENTS	
Specified 28 Day Compressive Strengths, minimum, psi *f'c*	
Grade of Concrete:	**Non Air Entrained/Air Entrained Concrete**
Grade 7.0	7,000
Grade 6.0	6,000
Grade 5.0	5,000
Grade 4.5	4,500
Grade 4.0	4,000
Grade 3.5	3,500
Grade 3.0	3,000
Grade 2.5	2,500

f. 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.

g. Slump. Designate a slump for each concrete mix design that is required for satisfactory placement of the concrete application not to exceed 5 inches except where controlled by maximum allowable slumps stated in **SECTIONS 402, 403** and **404**. Reject concrete with a slump that limits the workability or placement of the concrete.

h. Permeability. Except for Structural Concrete as shown in **SECTION 402**, supply a concrete 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 3,000 Coulombs as per AASHTO T-277. The field verification test procedure must be the same test procedure as the mix design approval test.

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

Redosing is permitted to control slump 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 according to manufacturer's recommendations.

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-entraining admixture 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. Verify that the admixtures will work as intended without detrimental effects. If the Engineer approves the use of water-reducers and set-retarders, their continued use depends on their performance. If at any point, a water-reducer is used to produce a slump equal to or greater than 7 ½ inches, comply with **subsection 401.3g**.

(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 while maintaining a cohesive nature.

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 water reducer or 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 in the presence of the Engineer 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.

Do not add water after plasticizer is added to the concrete mixture.

401.4 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) Supplemental Cementitious Materials. Supplemental cementitious materials proportioning and batching equipment is subject to the same controls as required for cement. Provide positive cut off with no leakage from the cut off valve. Cementitious materials 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 accurate to within 1% throughout the range of use.

(4) Aggregates. Measure the aggregates by weight, accurate to within 0.5% throughout the range of use.

(5) Admixtures. Measure liquid admixtures by weight or volume, accurate to within 3% of the quantity required. 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.

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 verify 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 cannot 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, fine and intermediate 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.

(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 and Supplemental Cementitious. Protect cement and supplemental cementitious materials 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 material testing.

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

401.5 MORTAR AND GROUT

a. General. Follow the proportioning requirements in **subsection 401.5b.** 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, FA-M 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 FA-M 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 FA-M 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.

401.6 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 material per cubic yard of concrete.
- The water-cementitious ratio is as designated by the Engineer. The maximum water-cementitious ratio permitted may not exceed 0.50 pounds of water per pound of cementitious material including free water in the aggregate.
- Type I, II, III, IP, IS or IT cement may be used unless otherwise designated. Fly ash, slag cement and blended supplemental materials 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 judgment 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.

401.7 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. Contact the DME for additional information.

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.

401.8 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 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 material. 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 to 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). An additional 60 mixing revolutions may be allowed by the Engineer when plasticizers are designated in the mix design.

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 materials 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 evaluate the haul time, and whether tickets will be collected for every load. Thereafter, random checks of the loads will be made. Maintain all batch tickets when not collected.

When non-agitating equipment is used for transportation of concrete, place within 30 minutes of adding the cement to the water. Provide approved covers for protection against the weather when required by the Engineer.

When agitating equipment is used for transportation of the concrete, place concrete within the time and temperature conditions shown in **TABLE 401-5**.

TABLE 401-5: AMBIENT AIR TEMPERATURE AND AGITATED CONCRETE PLACEMENT TIME

T = Ambient Air Temperature at Time of Batching (°F)	Time limit agitated concrete must be placed within, after the addition of cement to water (hours)	Admixtures
$T < 75$	1 ½	None
$75 \leq T$	1	None
$75 \leq T < 90$	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 cannot be adequately consolidated.

Weather conditions and the use of admixtures can affect 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. Reject concrete that cannot 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. Conduct all testing for acceptance and produce any required cylinders after all water or admixtures have been added.

Do not add water at the work site if the slump is within the designated slump tolerance, even if water was withheld.

Do not add water at the work site if the percent air is above 8%, regardless of the slump, even if water was withheld.

Do not withhold and add water if plasticizer is added to the concrete mixture at the batch site.

If at any time during the placement of concrete it is determined that redosing with water is adversely affecting the properties of the concrete, the concrete will be rejected and the Engineer will suspend the practice.

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.

Make adjustments for potential longer set time and slower strength gain for concrete with SCMs. Adjust minimum time requirements as stated in **SECTION 710** for concrete used in structures. For concrete paving, be aware of the effect that the use of SCMs (except silica fume) may have on the statistics and moving averages.

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.

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.

APPENDIX A – NON-MANDATORY INFORMATION

GENERAL CONCRETE

Design general concrete according to **TABLE 401-A1** meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability as required in **subsection 401.3h**.

TABLE 401-A1: GENERAL CONCRETE		
Grade of Concrete	**lb. of Cementitious per yd of Concrete, minimum**	**lb. of Water per lb. of Cementitious, maximum**
Grade 7.0(**):MA Gradation	700	0.35
Grade 6.0(**):MA Gradation	650	0.35
Grade 5.0(**):MA Gradation	602	0.35
Grade 4.5(**):MA Gradation	602	0.40
Grade 4.0(**):MA Gradation	602	0.44
Grade 3.5 and 3.0(**):MA Gradation	564	0.46
Grade 2.5(**):MA Gradation	526	0.50

General Concrete (*) (**)
*Grade as specified in the Contract Documents
Air Entrained meeting **subsection 401.3a.

Air entrained concrete with a target air of 6.5 ± 1.5 percent.

Maximum water to cementitious ratio of 0.50 and a minimum cementitious content of 480 lbs per cubic yard. Maximum limit of lb. of water per lb. of cementitious material includes free water in aggregates, but excludes water of absorption of the aggregates.

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. **SECTIONS 1102 and 1116**, 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 **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 kΩ-cm min, or
RCPT 3000 Coulombs max.

The SPC requirements 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 kΩ-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 (LPC) Requirements:

Volume of Permeable Voids 9.5% max, or
Surface Resistivity 27.0 kΩ-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.

SECTION 402

STRUCTURAL CONCRETE

402.1 DESCRIPTION

Provide the grades of concrete specified in the Contract Documents.

This specification is specific to Structural Concrete. See **SECTION 401** for general concrete requirements.

402.2 MATERIALS

Provide materials that comply with the applicable requirements.

General Concrete	**SECTION 401**
Aggregate	**DIVISION 1100**
Admixtures, and Plasticizers	**DIVISION 1400**
Cement, Fly Ash, Silica Fume, Slag Cement and Blended Supplemental Cementitious	**DIVISION 2000**
Water	**DIVISION 2400**

402.3 CONCRETE MIX DESIGN

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

b. Concrete Mix Design. Two options are available for mix design procedures. Use the procedures outlined in **SECTION 401** or Appendix A to design structural concrete mixes. Mixes developed using Appendix A must meet permeability requirements of **TABLE 402-1**.

c. Concrete Strength Requirements. Design concrete to meet the strength requirements of **SECTION 401**.

d. Portland Cement, Blended Hydraulic Cement, and Individual and Blended Supplemental Cementitious Materials. Unless specified otherwise in the Contract Documents, select the type of portland cement, blended hydraulic cement and individual and blended supplemental cementitious materials according to **SECTION 401**.

e. Structural Concrete Specific Requirements. Design concrete to meet the following requirements:

(1) Maximum water to cementitious ratio of 0.50 and a minimum cementitious content of 480 lbs per cubic yard.

(2) Air entrain concrete with a target air content of 6.5 ± 1.5 percent.

(3) Determine the air loss due to pumping operations once in the AM and once in the PM. Determine the difference between the air content from concrete sampled before the pump, and concrete sampled after pumping. Make adjustment to the mix to compensate for the pumping of the concrete.

(4) Maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

(5) Determine air content by KT-19 (Volumetric Method). A regularly calibrated KT-18 (Pressure Method) meter may be used for production with random verification by the Volumetric Method. See KT-19 for special requirements when using the Volumetric Method with high cementitious concretes or mixtures with midrange water reducers or plasticizers.

(6) Concrete permeability requirements according to **TABLE 402-1**.

(7) Use Quality Requirements for Structural Aggregates as listed in **SECTION 1102**, Aggregates For Concrete Not Placed on Grade.

(8) Use gradation requirements for aggregates as listed in **SECTION 1102**, Aggregates For Concrete Not Placed on Grade.

(9) Use MA-6 optimized gradation for Low Permeability Concrete for Bridge Overlays.

(10) 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. The field verification test procedure must be the same test procedure as the mix design approval test.

(11) To meet permeability requirements, the use of supplemental cementitious materials may be necessary. See **SECTION 401**.

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

Mix silica fume modified concrete for a minimum of 100 mixing revolutions.

(13) ASTM C-1567 is required if supplementary cementitious materials (SCMs) are utilized. See **subsection 401.3d.(6)** for requirements. ASTM C 1567 is not necessary for concrete modified with only Silica Fume.

TABLE 402-1: REQUIREMENTS FOR STRUCTURAL CONCRETE

	Volume of Permeable Voids, maximum	Surface Resistivity, minimum	Rapid Chloride Permeability, maximum	ASTM C-1567 Accelerated Mortar Bar Expansion
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 structural concrete not specified as Low or Moderate Permeability.	12.0%	9.0 kΩ-cm	3000 Coulombs	0.10% @ 16 days

f. Slump.

(1) Designate a slump for each concrete mix design that is required for satisfactory placement of the concrete application. Reject concrete with a slump that limits the workability or placement of the concrete.

(2) If the designated slump is 3 inches or less, the tolerance is ±3/4 inch, or limited by the maximum allowable slump for the individual type of construction.

(3) If the designated slump is greater than 3 inches the tolerance is ±25% of the designated slump.

(4) For drilled shafts the target slump just prior to being pumped into the drilled shaft is 9 inches. If the slump is less than 8 inches, redose the concrete with admixtures as permitted in **subsection 401.3i**.

(5) Do not designate a slump in excess of 5 inches for all other structural concrete.

APPENDIX A – NON-MANDATORY INFORMATION

GENERAL CONCRETE FOR STRUCTURES AND SILICA FUME MODIFIED CONCRETE

CONCRETE FOR STRUCTURES

Design concrete for structures according to **TABLE 402-A1** meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity or Rapid Chloride Permeability as required in **TABLE 402-1**.

TABLE 402-A1: CONCRETE FOR STRUCTURES		
Grade of Concrete	**lb. of Cementitious per yd of Concrete, minimum**	**lb. of Water per lb. of Cementitious, maximum**
Grade 6.0(**)(***)(****): MA Gradation	700	0.35
Grade 5.0(**)(***)(****): MA Gradation	602	0.35
Grade 4.5(**)(***)(****): MA Gradation	602	0.40
Grade 4.0(**)(***)(****): MA Gradation	602	0.44
Grade 3.5 and 3.0(**): MA Gradation	564	0.46
Grade 2.5(**): MA Gradation	526	0.50

Structural Concrete (*) (**) (***)(****)
*Grade as specified in the Contract Documents
Air Entrained meeting **subsection 402.3e.
***Aggregate as specified in **DIVISION 1100**.
****MPC (Moderate Permeability Concrete)

Air entrained concrete with a target air of 6.5 ± 1.5 percent.

Maximum water to cementitious ratio of 0.50 and a minimum cementitious content of 480 lbs per cubic yard. Maximum limit of lb. of water per lb. of cementitious material includes free water in aggregates, but excludes water of absorption of the aggregates.

SILICA FUME MODIFIED CONCRETE

When silica fume is selected for use in structural concrete, meet the mix design and production requirements in **TABLE 402-A2**.

Use MA-6 Aggregate Gradation for Bridge Overlay concrete.

TABLE 402-A2: SILICA FUME BRIDGE OVERLAY CONCRETE CRITERIA	
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), maximum	0.40
Percent of Air by Volume	6.5±1.5
Maximum 28 day Permeable Voids KT-73	9.50%
or Minimum 28 day Surface Resistivity KT-79	27.0 kΩ-cm
or Maximum 56 day Rapid Chloride Permeability T-277	1000 coulombs

SECTION 403

ON GRADE CONCRETE

403.1 DESCRIPTION

Provide the grades of concrete specified in the Contract Documents.

This specification is specific to On Grade Concrete. See **SECTION 401** for general concrete requirements.

403.2 MATERIALS

Provide materials that comply with the applicable requirements.

General Concrete.. **SECTION 401**
Aggregate .... **DIVISION 1100**
Admixtures and Plasticizers .... **DIVISION 1400**
Grade 2 Calcium Chloride.. **DIVISION 1700**
Cement, Fly Ash, Silica Fume, Slag Cement and Blended Supplemental Cementitious.. **DIVISION 2000**
Water .... **DIVISION 2400**

403.3 CONCRETE MIX DESIGN

a. General. Design the concrete mixes for on grade concrete as specified in the Contract Documents.

b. Concrete Mix Design. Use procedures outlined in **SECTION 401**.

c. Portland Cement and Blended Hydraulic Cement and Supplemental Cementitious Materials. Unless specified otherwise in the Contract Documents, select the type of portland cement, blended hydraulic cement and supplemental cementitious materials as specified in **SECTION 401**.

d. On Grade Concrete Specific Requirements. Use Optimized, Air-Entrained Concrete. Provide the Engineer written notification of the selection prior to the pre-construction conference.

(1) Design air-entrained concrete for pavement meeting **TABLE 403-1**.

(2) Design air-entrained concrete for shoulders meeting **TABLE 403-2**.

(3) Design air-entrained concrete for other uses with a maximum water to cementitious ratio of 0.50 and a minimum cementitious content of 480 lbs per cubic yard.

(4) For projects that are not QC/QA paving projects, verify the mix design in the field by performing 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.

(5) Control air content for PCCP by **subsection 403.4**.

(6) The amount of cementitious material listed in **TABLES 403-1** and **403-2** is the designated minimum for concrete pavement and shoulders respectively. It may be necessary to add additional cementitious material or otherwise adjust the mix proportions as permitted by the specifications to provide a mix design that complies with the compressive strength requirement.

(7) Maximum limit of lb. of water per lb. of cementitious material includes free water in aggregates, but excludes water of absorption of the aggregates.

(8) Provide On Grade Concrete that meets either the 28-day Volume of Permeable Voids KT-73, 28-day Surface Resistivity KT-79, **or** 56-day Rapid Chloride Permeability AASHTO T-277. Submit accelerated cure procedures for the Engineer's approval. The field verification test procedure must be the same test procedure as the mix design approval test.

(9) Permeability requirements do not apply for concrete patching material used in **SECTION 833** when existing pavement to be patched is more than 10 years old.

TABLE 403-1: AIR-ENTRAINED CONCRETE FOR PAVEMENT						
lb. of Cementitious per yd^3 of Concrete, minimum	**lb. of Water per lb. of Cementitious, maximum**	**Percent of Air by Volume**	**28-Day Comp Strength, psi minimum**	**Volume of Permeable Voids, maximum**	**Surface Resistivity, minimum**	**Rapid Chloride Permeability, maximum**
517	0.45	See **subsection 403.3e.**	4000	12.0%	9.0 kΩ-cm	3000 Coulombs

TABLE 403-2: AIR-ENTRAINED CONCRETE FOR SHOULDERS					
lb. of Cementitious per yd^3 of Concrete, minimum	**lb. of Water per lb. of Cementitious, maximum**	**Percent of Air by Volume**	**Volume of Permeable Voids, maximum**	**Surface Resistivity, minimum**	**Rapid Chloride Permeability, maximum**
480	0.45	See **subsection 403.3e.**	12.0%	9.0 kΩ-cm	3000 Coulombs

(10) Concrete for shoulders using the same aggregates, gradations, and water to cementitious ratio 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.

e. Design Air Content. 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 0.0100 inch behind the paver.

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

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

If the air void spacing factor exceeds 0.0100 inch, use the following formula as a guide to determine the target air content:

Minimum % air content at 0.0100 inch = % air measured + (measured spacing factor – 0.0100)/0.0010.

Mixes with Laboratory or Field Prequalification spacing factors greater than 0.0100 inch will not be approved.

When AVA spacing factors exceed 0.010 inches (0.25 mm) take immediate steps to reduce the spacing factor.

The Field Engineer will conduct an investigation using the following steps. If any one of the steps 1 through 9 corrects the problem, the Field Engineer will stop the investigation. The steps may be completed in combination and/or out of order. For example some may want to conduct steps 5 or 6 before some of the other steps.

1. If the failing sample came from behind the paver, the Engineer will take the following steps. Obtain an AVA sample from a unit weight bucket of concrete obtained from grade in front of the paver. Also, measure the total air content in the concrete on the grade in front of the paver. Obtain AVA and total air samples from behind the paver. Determine the loss of air and spacing factor due to the paving operation. Adjust for air loss due to paving.
2. Verify calibration of the AVA.
3. Change the location of the AVA during testing.
4. Call in the Research Unit or another AVA machine for comparison testing.
5. Check the mix design for compliance with **SECTION 401**.

6. Check all of the gradations.
7. Check the total air content vs. target air content.
8. Check for Contractor compliance with admixture supplier's recommendations on dosage rates and order of introduction of the chemicals into the mix.
9. Check for material compatibility by using different admixtures or sources of admixtures.

Refer to the "11 Strategies to Improve the Air-Void Spacing Factor" in **APPENDIX B**.
If the problem is not corrected, the Field Engineer will take the following steps:
Obtain 2 cores from any area with an AVA spacing factor >0.0125 inches and send to Materials Research Center for hardened air evaluation.

- If the AVA spacing factor > 0.0125 inches and the average hardened air spacing factor is > 0.0080 inches, then suspend paving and submit new mix design.
- If the AVA spacing factor > 0.0125 inches and the average hardened air spacing factor < 0.0080 inches, then accept PCCP.

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.

Air Void Spacing Factor does not apply to concrete used in **SECTION 833** when existing pavement to be patched is more than 10 years old.

The maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

f. Slump.

(1) Maximum design slump for slip form On Grade Concrete is 2 ½ inches. Do not designate a slump in excess of 5 inches for all other On Grade Concrete

(2) For all other On Grade Concrete placement, designate a slump that is required for satisfactory placement of the concrete application. Reject concrete with a slump that limits the workability or placement of the concrete.

(3) If the designated slump is 3 inches or less, the tolerance is ±3/4 inch, or limited by the maximum allowable slump for the individual type of construction.

(4) If the designated slump is greater than 3 inches the tolerance is ±25% of the designated slump.

403.4 AIR-ENTRAINED ON GRADE CONCRETE

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

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. Additional AVA testing will be required if the concrete plant is changed during the course of the project.

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.

The Engineer will perform the following: 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 2 do not meet these criteria. Determine the air content of the trial mix by KT-19 (Volumetric Method) or KT-18 (Pressure Method) 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 403.3e.**, when applicable.

c. Field Prequalification. Produce a trial batch at a minimum air temperature of 60ºF using the batch plant and project materials.

The Engineer will perform the following: 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 0.0100 inch, using the equation in **subsection 403.3e**.

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. AVA 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 403.3e**. 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 403.3e**.

Other similar designs using higher cementitious contents (this may adversely affect permeability) 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 0.0100 inch at the measured air content.

APPENDIX A – NON-MANDATORY INFORMATION

GENERAL ON GRADE CONCRETE

Design On Grade Concrete according to **TABLE 403-A1** meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity or Rapid Chloride Permeability as required in **TABLE 403-1**.

TABLE 403-A1: ON GRADE CONCRETE		
Grade of Concrete	**lb. of Cementitious per yd of Concrete, minimum**	**lb. of Water per lb. of Cementitious, maximum**
Grade 4.0: MA Gradation	602	0.44
Grade 3.5 and 3.0: MA Gradation	564	0.46
Grade 2.5: MA Gradation	526	0.50

Air Entrained On Grade Concrete meeting **subsection 403.3e**.

Maximum water to cementitious ratio of 0.50 and a minimum cementitious material content of 480 lbs per cubic yard. Maximum limit of lb. of water per lb. of cementitious material includes free water in aggregates, but excludes water of absorption of the aggregates.

APPENDIX B – NON-MANDATORY INFORMATION

STRATEGIES TO IMPROVE THE AIR VOID SPACING FACTOR

Better air-void characteristics are obtained by a more thorough mixing of the sand and the air-entraining agent. Below are listed some strategies to help the mixing process.

1. Increase the mixing time of the plant or mixing revolutions of the truck.
2. Use a higher dosage of water reducer, up to 390 ml per 100 kg (6 oz. per 100 lbs) of cement. Use a non-retarding water reducer above 195 ml per 100 kg (3 oz. per 100 lbs) if needed.
3. Reduce the Paste Content (less water or less cement).
4. Use a higher proportion of rock.
5. Use a third, mid-sized aggregate.
6. Use coarser graded sand, or a finer sand if the current one is extremely coarse.
7. Maintain a higher air content (use more air-entraining agent).
8. Use coarser cement.
9. Change types or brands of the water reducer or the air entraining agent or both.
10. Cool the mix ingredients; i.e., use chilled water.
11. Use a different plant or modify the plant configuration. Introduce aggregates together on the belt feed (multiple weigh hoppers), use live bottoms aggregate bins, use dual drums, etc.

SECTION 404

CONCRETE FOR PRESTRESSED CONCRETE MEMBERS

404.1 DESCRIPTION

Provide concrete with the release and 28 day compressive strengths specified in the Contract Documents.

This specification is specific to Concrete for Prestressed Concrete Members. See **SECTION 401** for general concrete requirements.

404.2 MATERIALS

Provide materials that comply with the applicable requirements.

General Concrete... **SECTION 401**
Aggregate .... **DIVISION 1100**
Admixtures and Plasticizers .... **DIVISION 1400**
Grade 2 Calcium Chloride.. **DIVISION 1700**
Cement, Fly Ash, Silica Fume, Slag Cement and Blended Supplemental
Cementitious.. **DIVISION 2000**
Water .... **DIVISION 2400**

404.3 CONCRETE MIX DESIGN

a. General. Design concrete mixes specified in the Contract Documents. A mix design must be approved by the Engineer before the mix can be used in the production of prestressed concrete members.

b. Concrete Mix Design. Two options are available for mix design procedures. Use the procedures outlined in **SECTION 401**, or use **TABLE 404-2** to design structural concrete mixes.

c. Concrete Strength Requirements. Unless shown otherwise in the Contract Documents, design concrete to meet the compressive strength requirements of **TABLE 404-1**. For prestressed bridge beams, the Engineer will determine the strength requirements from the table except when specified elsewhere in the Contract Documents.

TABLE 404-1: COMPRESSIVE STRENGTH REQUIREMENTS		
Type of Unit	**For Stress Application (Release) and/or moving* (Minimum) (psi)**	**Age 28 Days (Minimum)** (psi)**
Prestressed Bridge Beams	5800	7000
	4800	6000
	4000	5000
Prestressed Piles	3000	5000
Prestressed Panels	4000	5000

* From casting bed to producer's storage only. Not a shipping strength.
** Also required for shipping strength.

d. Portland Cement, Blended Hydraulic Cement and Individual and Blended Supplemental Cementitious Materials. Unless specified otherwise in the Contract Documents, select the type of portland cement, blended hydraulic cement and individual and blended supplemental cementitious materials according to **SECTION 401**.

e. Specific Requirements for Concrete used in Prestressed Concrete Members. Design concrete to meet the requirements of **TABLE 404-2**.

TABLE 404-2: CONCRETE REQUIREMENTS						
Self-Consolidating Concrete (SCC)			**Non SCC**	**All Concrete**		
Slump Flow From Target (Inches)	**Blocking Assessment (Inches)**	**Visual Stability Index**	**Maximum Slump (Inches)**	**Minimum Cementitious per Cubic Yard (Lbs)**	**Mixing Water: Maximum lb. per lb. Cementitious**	**Air Content (%)**
± 2	2 maximum	0 or 1	5 or 7 ± 25%	602	0.44	6.5 ± 1.5

(1) Determine the slump flow using ASTM C 1611, "Standard Test Method for Slump Flow of Self-Consolidating Concrete." The target value is determined during the mix design and approval process (see below). At the point of placement, slump flow can deviate from target by no more than 2 inches.

(2) Determine the blocking assessment using ASTM C 1621, "Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring."

(3) Determine the visual stability index (VSI) using Appendix X1 of ASTM C 1611. When approved by the Engineer, the VSI may be determined using additional concrete stability observations.

(4) Designate a slump for each concrete mix design that is no greater than 5 inches when not using mid-range or high-range water reducing admixtures. When a water reducing admixture is being used, designate a slump no greater than 7 inches. The tolerance from design at the point of delivery is ± 25%.

(5) It may be necessary to adjust the mix proportions, as permitted by the specifications, to provide a mix that complies with placement, and the release and 28-day strength requirements.

(6) Maximum limit of lb. of water per lb. of cementitious material includes free water in aggregates, but excludes water of absorption of the aggregates.

(7) Non-air entrained concrete may be used in concrete piling not subject to freezing and thawing and wetting and drying.

(8) There are no permeability requirements.

(9) Determine air content by KT-19 (Volumetric Method). A regularly calibrated KT-18 (Pressure Method) meter may be used for production with random verification by the Volumetric Method. See KT-19 for special requirements when using the Volumetric Method with high cementitious concretes or mixtures with midrange water reducers or plasticizers.

(10) Use Quality Requirements for Structural Aggregates as listed in **SECTION 1102**, Aggregates For Concrete Not Placed on Grade. Keep a copy of the KDOT Official Quality test report from the approved source on file at the prestress plant and available for review by the Engineer.

(11) Use gradation requirements for aggregates as listed in **SECTION 1102**, Aggregates For Concrete Not Placed on Grade.

(12) When used, add silica fume with other cementitious materials during batching procedures. If the silica fume cannot be added to the cementitious materials, add the loose silica fume to the bottom of the stationary drum that is wet, but has no standing water, before adding the dry materials. The Engineer may approve shreddable bags on a performance basis, only when a central batch mixing process is used. If so, add the bags to half of the mixing water and mix before adding cementitious materials, aggregate and remainder of water. The presence of visible chunks or wads of bag paper at the point of placement will be cause for rejection.

Mix silica fume modified concrete for a minimum of 100 mixing revolutions, unless high speed mixing equipment is used.

(13) ASTM C-1567 is required if supplementary cementitious materials (SCMs) are utilized. See **subsection 401.3d.(6)** for requirements. ASTM C 1567 is not necessary for concrete modified with only Silica Fume.

(14) For the approved source of water, keep a copy of the KDOT test report on file at the prestress plant and available for review by the Engineer.

(15) Use admixtures that are prequalified. Maintain a copy of the Type C certification on file at the prestress plant and available for review by the Engineer. No other additives may be used without written approval by the Engineer.

f. Additional Design Requirements for Self-Consolidating Concrete (SCC). SCC is defined as a concrete mixture which can be placed by means of its own weight with little to no vibration. It is accomplished by adjusting traditional mix designs using special admixtures.

(1) Do not rod or vibrate when making test cylinders.

(2) Provide scales capable of determining test block weights for the strand bond test that are calibrated (NIST traceable) and approved by the Engineer.

(3) Perform a strand bond test (KT-83) for each mix and strand to be used in the future production of prestressed beams. Any change in admixture, aggregate source or gradation, cementitious material content or source, and strand producer or size requires that a new strand bond test be completed using the replacement materials. Make 2 test beams for each bond test. Cure the test beams in an environment that is representative of future production (i.e. – moisture and heat until release then ambient conditions).

(a) With the Engineer observing, perform a single Slump Flow test for each pair of test beams cast. This spread establishes a target value from which future point of placement values are to be compared to. Assign a Visual Stability Index (VSI) number to the concrete spread.

(b) With the Engineer observing, perform a single J-Ring test for each pair of test beams cast. Calculate a "blocking assessment" value.

(c) Make a minimum of 2 sets of 3 cylinders for each pair of test beams cast. Cure the cylinders with the test beams they represent.

(i) With the Engineer observing, test 1 set of cylinders at the producer's plant to measure for release (equal to the release strength of future production). De-tension the strand in both test beams only after this cylinder set indicates that release strength has been attained.

(ii) With the Engineer observing, test 1 set of cylinders at the producer's plant to measure for 28-day strength (equal to the 28-day strength of future production). Perform the bond test on both test beams only after this cylinder set indicates that the 28-day strength has been attained.

(iii) In both cases, the required strength is met when the average compressive strength of the 3 cylinders equals or exceeds the required strength, and no more than 1 cylinder in the tested set had a strength that was no more than 5% below the required strength.

(d) With the Engineer observing, measure the dimensions of both test beams to verify the required casting tolerances. Calculate the weight of the required test loads.

(e) With the Engineer observing, load the test beams using the calculated loads and KT-83.

(f) Submit all beam dimensions, calculations (intermediate and final), release and 28-day strengths, observations, measurements, pictures, and test results related to strand bond, cylinder strength, slump flow, and J-ring testing to the Engineer for review.

(g) In addition to the requirements of this section and **SECTION 401**, the mix design represented by this testing may be approved provided there are 2 passing bond tests, and the assigned blocking assessment and the calculated VSI satisfy the requirements of **TABLE 404-2**.

SECTION 405

CURING ENVIRONMENT

405.1 DESCRIPTION

Provide a curing environment for storage of KDOT concrete cylinders made during open span bridge concrete placements. The curing environment would be utilized by KDOT to store the cylinders during the first 48 hours of their initial cure (KT-22). The curing environment needs to be of sufficient size to hold test samples required for the project at any given time. The quantity of test samples will be based on the appropriate sampling and testing frequency chart in Part V.

The curing environment does not apply to test specimens made for PCCP, curb and gutter, sidewalk, etc.

BID ITEM	UNITS
Curing Environment	Lump Sum

405.2 MATERIALS

Provide a curing environment that meets the Initial Curing requirements of KT-22.

Provide a thermometer that records the high and low temperatures within the curing environment.

405.3 CONSTRUCTION REQUIREMENTS

During the preconstruction meeting, discuss with the Engineer the necessary capacity and location of the curing environment. Locate the curing environment to allow the Engineer access at all times.

When KDOT cylinders are stored in the curing environment, provide the Engineer with the recorded high and low temperatures within the curing environment, daily.

4005.4 MEASUREMENT AND PAYMENT

The Engineer will measure curing environment by the lump sum.

Payment for "Curing Environment" at the contract unit price is full compensation for the specified work.