Kansas State University | Salina

Hardened Concrete Properties Workbook

Certified Inspector Training Program

Kansas Department of Transportation

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Hardened Concrete Properties Certification Workbook

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Last Updated: May 2026

HARDENED CONCRETE PROPERTIES
CIT PROGRAM

Written Test: Open book – 70 multiple choice questions

Grading: Must score at least 60% on each section of the written exam with an overall score of 70% or better to pass. Failure on any part of the written exam requires retaking the entire exam.

Must pass all performance exam sections. Failure of three or less performance subtest requires retest on only the subtest(s) failed. Failure of four or more subtests of the performance exam requires retest on the entire performance exam.

Exam Results: Exams will be graded in two to three weeks. Exam results are emailed to the student. Exam results are not given over the phone.

Exam Re-takes: Students who need to re-take either the written and/or performance exam need to register to do so. The re-take registration form can be found on the CIT website at www.citksu.com.

To be certified: Students must successfully pass the written exam and the performance exam. The student will be mailed a certification card and letter.

Reasons for Certified Inspector Training (CIT) Training Program

Overview

The Kansas Department of Transportation (KDOT) has established this training program to educate, test and certify those individuals responsible for performing inspection and testing functions on KDOT construction projects. KDOT's Bureau of Construction and Materials has responsibility for the establishment and administration of the materials portion of the KDOT's Quality Control/Quality Assurance (QC/QA) Program. The Bureau develops standards and specifications for materials, establishes sampling procedures and frequencies, and test procedures used in the laboratory and the field in order to assure compliance with specifications. It performs materials testing to assist each of the six KDOT districts in administering quality assurance functions of the QC/QA Program. Such testing includes tests on materials purchased by contractors or the State for use in maintenance or construction activities. The Bureau also conducts tests on soils, concrete, bituminous mixtures and numerous other specialized materials, the results of which are used by others for a variety of reasons.

Quality control and quality assurance activities involve the routine sampling, testing and analysis of various materials to determine the quality of a given product and to attain a quality product. The goal of the Certified Inspection and Testing Training Program (CIT^2) is to provide persons engaged in the inspection and/or testing of KDOT construction projects specific training in, but not limited to, soils, aggregates, and concrete and/or asphalt disciplines.

Each student is required to demonstrate specific abilities as defined by the training modules described in the CIT2 manual. The manual can be found online at: https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burMatrRes/Documents/CIT_Manual_2019.pdf

Federal Funding

On projects involving federal funds, KDOT must certify to the Federal Highway Administration as to the quality of each type of material used on each project before the State is completely reimbursed by the federal government.

The certification and training requirements contained in this manual are intended to comply with the requirements of 23 CFR Part 637 which states, "After June 29, 2000, all sampling and testing data to be used in the acceptance decision or the IA (Independent Assurance) program shall be executed by qualified sampling and testing personnel."

Reasons for Quality Control/Quality Assurance

Inspectors fulfill a very important job on any project—they safeguard the public interest in a number of ways.

The primary reason for materials inspection, sampling and testing requirements is to verify that all materials incorporated into the work will meet the requirements of the contract documents, including the plans, specifications, and special provisions.

Plans and specifications are prepared to require the use of certain specific materials known or expected to perform satisfactorily with minimum maintenance throughout the life of the facility or infrastructure project. Any material that deviates appreciably from the specifications requirements will not perform as expected and, in all probability, will shorten the useful life of the facility or add unexpected costs in maintenance. Because there are limited dollars available for transportation infrastructure, the useful life and long-term maintenance costs of every project are critical considerations.

Secondly, all contractors bidding or furnishing materials to a project should be treated equally. That is, the contract documents provide a fair and uniform basis for bidding because they define the requirements to be met--ideally with the least possible difference of interpretation. The contractor commits to furnish materials and complete work that will equal or exceed such requirements. For this reason it is essential that quality assurance be correctly understood and applied uniformly by engineers and inspectors from project-to-project so that all contractors and suppliers are treated alike.

Thirdly, the expenditure of public funds must be documented to substantiate whether taxpayers actually received the quantity and quality of materials specified in exchange for tax dollars spent. Whether or not to pay the costs invoiced by contractors is a decision which relies heavily upon inspection reports and test results. In a fundamental way, inspectors play a key role in serving the public--to justify the expenditure of public monies and the acceptance of any contractor's work. Through the work of knowledgeable, competent and skilled inspectors, KDOT can verify and confirm whether or not the contractor has fulfilled its obligations to build the project as intended.

Finally, the specification requirements for materials are constantly evolving, based on new developments, past performance of material in the field, research and technological innovations. Accurate recordkeeping of materials and test results using consistent inspection practices provides a basis to compare results over time—an indispensable advantage for meaningful research. Data properly collected and recorded by inspectors can confirm whether or not changes in material specifications and testing requirements have, in fact, resulted in a better product, state-wide or in a particular location or application.

All inspectors should review the applicable clauses of the Standard Specifications at regular intervals to refresh their understanding of material and testing requirements.

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 ≤ T	1	None
75 ≤ T < 90	1 ½	Set Retarder

In all cases, if the concrete temperature at time of placement is 90°F or above, or under conditions contributing to quick stiffening of the concrete, place the concrete within 45 minutes of adding the cement to the water. Do not use concrete that has developed its initial set. Regardless of the speed of delivery and placement, the Engineer will suspend the concreting operations until corrective measures are taken, if there is evidence that the concrete 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 501

PORTLAND CEMENT CONCRETE PAVEMENT (QC/QA)

Note: PCCP is considered QC/QA when the bid item Quality Control Testing is included in the contract. Note the exceptions in subsection 501.5.

501.1 DESCRIPTION

Construct Portland Cement Concrete Pavement (PCCP) on a prepared subgrade or base course. Develop and perform quality control testing.

Urban PCCP Environment: Projects or sections of the project classified as Urban Type are typically:

- within city limits;
- require pieced construction due to:
  - business and residential entrances;
  - frequency of side streets; or
  - project phasing.

Before paving, meet with the Engineer to determine if the project or sections of the project are classified as Urban Type.

BID ITEMS	**UNITS**
Concrete Pavement (* Uniform) (AE) (**)	Square Yard
Concrete Pavement (* Variable) (AE) (**)	Square Yard
Early Strength Concrete Pavement (*Uniform) (AE) (**)	Square Yard
Early Strength Concrete Pavement (*Variable) (AE) (**)	Square Yard
Quality Control Testing (PCCP)$^+$	Square Yard
Concrete Core (Set Price)	Each

* Thickness

** No entry denotes PCCP with mesh and dowel assemblies. "Plain" denotes PCCP without mesh and dowel assemblies. "NRDJ" denotes non-reinforced dowel jointed PCCP. "Br App" denotes bridge approach pavement.

$^+$ Br App pavement quantities are not included in this item.

501.2 CONTRACTOR QUALITY CONTROL REQUIREMENTS

a. General. Provide qualified personnel and sufficient equipment complying with the requirements listed in Part V to conduct quality control testing that complies with Appendix B, Sampling and Testing Frequency Chart for Concrete Construction Items for Quality Control/Quality Assurance Projects.

Allow the Engineer access to the Contractor's laboratory to observe testing procedures, calculations, test documentation and plotting of test results.

Calibrate and correlate the testing equipment with prescribed procedures, and conduct tests in compliance with specified testing procedures as listed in Part V.

Maintain a Quality Manual in the field laboratory showing the calibrations performed on all test equipment and when the next calibration is due for that equipment. As a minimum, follow the calibration/verification interval established in Table 1: Concrete Materials Test Equipment in Section 5.2.7.4-Concrete: Contractor's Quality Control Plan, Part V. See also Section 5.2.7.5-Example of a Laboratory Quality Manual for Concrete, Part V.

b. Quality Control Plan (QCP). At the pre-construction conference, submit to the Engineer for approval by the DME, a QCP as outlined in Section 5.2.7.4-Concrete: Contractor's Quality Control Plan, Part V. Follow 5.2.7.4: Concrete: Contractor's Quality Control Plan in Part V as a general guideline. Keep a printed copy of the approved QCP in the Contractor's laboratory and make available to the Engineer when requested.

The Contractor's laboratory and equipment will be inspected and approved as outlined in Section 5.2.7-Contractor's Quality Control Plan, Part V.

Include a listing of the names and phone numbers of individuals and alternates responsible for quality control administration and inspection. On the Contractor's organizational chart, show the specified lines of authority relating both to mix design and quality control operations during production. Post the organizational chart in the Contractor's test facility.

Provide a quality control organization or private testing firm having personnel certified according to the Policy and Procedures Manual for The Certified Inspection and Testing (CIT) Training Program. The testing for this type of construction will require personnel certified in Aggregate Field Tester (AGF), Aggregate Lab Technician (AGL), Profilograph (PO), ACI Concrete Field Testing Technician (CF), Nuclear Moisture Density Gauge Tester (NUC) and Hardened Concrete Properties (HCP) classifications. Provide a minimum of 1 employee on the project certified in the QC/QA Concrete/Cement Treated Base Specs (QCS) classification.

Only persons certified in the appropriate classifications covering the specific tests required shall perform such testing. At the beginning of the project, provide the Engineer with the list of certified technicians and alternates, phone numbers and tests/inspection they will be performing. As personnel changes and certifications may expire, continue to provide the Engineer with an accurate list.

Provide an organizational chart showing the specified lines of authority relating to both mix design and quality control operations during production. Identify the company official acting as liaison with KDOT, and the Certified Technician who will direct inspection and testing. Post the chart in the test facility.

c. Required Duties of Certified Technicians. Be available on the project site whenever concrete for pavement is being produced and being placed on the project site. Perform and utilize quality control tests and other quality control practices to assure that delivered materials and proportioning meet the requirements of the mix designs.

Periodically inspect all equipment utilized in transporting, proportioning, mixing, placing, consolidating, finishing and curing to assure it is operating properly and that placement, consolidation, finishing and curing comply with the mix design and other contract requirements.

d. Contractor's Testing Facilities. Describe the testing facility and its accreditation in the QCP.

Locate the testing facility either at the plant site or at the project. Obtain approval of the testing facilities and location from the DME before the commencement of mixture production.

Provide suitable space for the required testing equipment. Also, equip the testing facility with these items for the exclusive use of the testing facility's quality control personnel and the Engineer:

- A telephone with a private line;
- A copying machine; and
- Broadband internet connection (for 1 computer). If the Engineer determines that broadband internet service is not available, provide a fax machine, at no additional cost.

e. Documentation. Include in the QCP procedures, charts and forms to be used to provide the required documentation.

Record and document all test results and calculations. Record all original documentation in a bound field book or other KDOT approved bound record and turn over to KDOT at the end of the project.

At all times, have complete records of all inspections and tests readily available on site for the Engineer. All records documenting the Contractor's quality control inspections and tests become the property of KDOT upon completion of the work.

Indicate the nature and number of observations made, the number and type of deficiencies found, the quantities approved and rejected, and the corrective action taken in the records. Examples of quality control forms and charts are available in Part V, or Contractors may design their own. Documentation procedures are subject to approval by the Engineer before the start of the work and to compliance checks during the progress of the work.

Maintain control charts on an ongoing basis. Plot data according to **SECTION 106**.

Record specific test results on a Daily Quality Control Summary sheet designed to facilitate the computation of moving test averages. Base moving averages on 4 consecutive test results. Include a description of quality control actions taken (such as adjustment of aggregate or additive proportions in the mix, moisture adjustments) in the Daily Quality Control Summary Sheet.

Provide forms on a computer-acceptable medium, where required. Document tickets and gradation data according to KDOT requirements.

Complete testing and charting within 1 working day after sampling.

Keep all quality control charts current. Show both individual test results and moving average values. As a minimum on approved control charts, plot the single test values and the 4 test moving average values for these properties:

- Percent air in concrete mixture;
- Slump of concrete mixture;
- Concrete unit weight;
- In-place concrete density on plastic concrete as a percentage of determined unit weight; and
- Combined aggregate gradation (as a minimum, plot the 3/8" and No. 8 sieves).

Also plot the single test values for actual workability and target workability of the combined aggregates.

Provide the following test data to the KDOT Project Representative:

- Copies of all test results and control charts on a weekly basis, representing the prior week's production;
- Copies of the quality control summary sheet on a daily basis. Include, as a minimum, combined aggregate gradations, actual workability and target workability of combined aggregates, percent air content, slump, concrete unit weight and density of fresh concrete in-place; and
- Copies of all failing test results. Include all applicable sieves, actual workability, percent air content, slump and density of fresh concrete in-place.
- Copies of vibrator checks daily to the Inspector. Email a weekly recap to the Construction Engineer.

Email or fax the data to the Field Engineer and DME, weekly.

f. Testing Requirements. In the QCP, identify test methods, procedures and equipment proposed for use. Use standard KDOT test methods and properly calibrated measuring and testing equipment as outlined in Part V. Detail any alternative sampling method, procedure or inspection equipment proposed to be used. Such alternatives are subject to review and approval by the DME.

Take all samples for tests and perform in-place tests at random locations, selected according to the Contractor's QC Plan and at the rates specified in the Sampling and Testing Frequency Chart for Portland Cement Concrete Pavement for Quality Control/Quality Assurance Projects in Appendix B, Part V. Retain the latest 10 gradation samples for use by the Engineer.

g. Corrective Action. In the QCP, identify procedures for notifying the Engineer when corrective measures must be implemented, and for halting production.

Notify the Engineer when the moving average test result trend line for any property approaches the specification limits. Cease operations if 2 consecutive moving average points fall outside the specification limits. Ceasing operations is the Contractor's responsibility. Quality control tests for this determination include aggregate gradation, compliance with the mix design band, percent air content, concrete unit weight and density of fresh concrete in-place.

Failure to cease operations for the conditions cited above will subject all subsequent material to rejection, or acceptance at a reduced price, as determined by the Engineer.

The Engineer may examine materials represented by individual test results, which lie beyond the Contractor's normal quality control testing variation. The investigation may be based on either Contractor or KDOT test results. The information from additional testing (including testing of in-place pavement) may be used to define unacceptable work according to **SECTION 105**. The Engineer will apply appropriate price reductions or initiate corrective action.

If a dispute exists between the Engineer and Contractor about the validity of any test results other than compressive strengths or thickness determination, the KDOT District Materials Laboratory or MRC will perform referee testing. If one of the disputed KDOT test results was generated at the MRC, then an independent laboratory agreeable to both parties will be selected. The AASHTO Accreditation Program shall have approved the selected laboratory for the appropriate test procedure. If referee testing indicates that KDOT test results are correct, the

Contractor is responsible for the cost of additional testing, including referee testing performed at the MRC. If the referee testing indicates that the Contractor test results are correct, KDOT is responsible for the cost of additional testing.

Follow the procedures outlined in **subsection 501.5g.(4)** if a dispute arises for any test determining compressive strengths or thickness.

h. Non-Conforming Materials. In the QCP, specifically address how non-conforming materials will be controlled and identified.

Establish and maintain an effective and positive system for controlling non-conforming material, including procedures for its identification, isolation and disposition. Reclaim or rework non-conforming materials according to procedures acceptable to the Engineer.

Identify all non-conforming materials and products to prevent use, shipment and intermingling with conforming materials and products. Provide holding areas, mutually agreeable to the Engineer and Contractor.

i. Concrete Information. Separately list the grades of concrete involved in the project. For each grade of concrete to be used, include at a minimum, the following:

- Mix designs. List mix design numbers if using existing mixes.
- Aggregate production.
- Quality of components.
- Stockpile management.
- Proportioning, including added water.
- Mixing and transportation.
- Initial mix properties.
- Placement and consolidation.
- Concrete yield.
- Compressive strength.
- Finishing and curing.
- Frequency of sampling and testing.
- How duties and responsibilities are to be accomplished and documented, and if more than one Certified Technician is required.
- The criteria used by the Certified Technician to correct or reject unsatisfactory materials.

501.3 MATERIALS

Provide materials that comply with the applicable requirements.

Concrete and Grout	**SECTIONS 401& 403**
Aggregates for On Grade Concrete	**SECTION 1116**
Reinforcing Steel	**DIVISION 1600**
Epoxy Coated Steel Bars for Concrete Reinforcement	**DIVISION 1600**
Joint Sealants	**DIVISION 1500**
Expansion Joint Filler	**DIVISION 1500**
Concrete Curing Materials	**DIVISION 1400**
Preformed Elastomeric Compression Joint Seals	**DIVISION 1500**
Cold Applied Chemically Cured Joint Sealant	**DIVISION 1500**
Hot Type Joint Sealing Compound	**DIVISION 1500**
Backer Rod	**DIVISION 1500**
Epoxy Resin-Base Bonding System for Concrete	**SECTION 1705**
Bond Breakers	**SECTION 1718**

501.4 CONSTRUCTION REQUIREMENTS

a. Preparation of the Subgrade. Before placing any surfacing material on any section, complete the ditches and drains along that section to effectively drain the highway. Trim the base or subgrade to the line, grade and typical cross-section as shown in the Contract Documents. Maintain the subgrade or base to the as-constructed condition under other bid items, repairing any encountered defects to the specifications of those bid items. Maintain the subgrade surface to readily drain at all times. Protect the subgrade from damage when handling materials, tools and equipment. Do not store or stockpile materials on the subgrade. Do not place material or lay pavement on a frozen or muddy subgrade, or when it is raining or snowing.

Lightly spray the subgrade or base with water to obtain a thoroughly moistened condition when the concrete is deposited on it. Do not puddle water on the grade.

Do not deposit any material until the subgrade or base has been checked and approved by the Engineer.

b. Slip Form Paving. When paving is performed with a slip form paving unit, use equipment as described in **subsection 154.5**.

Pave 24-foot wide mainline pavement in a single operation. Do not exceed 24-foot paving width in a single operation except as follows:

- The Contractor may pave a maximum of 2 lanes plus a 6-foot shoulder (30 feet maximum) in a single operation.
- For pavements of 3 lanes or more, pave a minimum of 2 lanes mainline (with the option of including a single shoulder for a maximum of 30 feet) in a single operation.
- Approval will be based on satisfactory performance of the Contractor's operation.

Place ramps and auxiliary lanes/shoulders as shown in the Contract Documents.

Once the paving operation has started, provide adequate equipment and supply of materials to maintain continuous placement for any given working period. Keep all concrete conveying equipment clean.

Do not apply any tractive forces to the slip form paver, except that which is controlled from the machine.

Trim to grade the subgrade or surface of the base over which the tracks of the paver will travel. Do not disturb this surface with other equipment. If the equipment or method of operation requires the subbase to be wider than shown in the Contract Documents, place additional material to provide an adequate surface for the tracks of the paver. Upon completion of the paving operations, remove or repair any base material damaged by the slip form paver's tracks. All necessary construction and removal of this additional base material is subsidiary to other items of the contract.

Operate the paver continuously, stopping only when absolutely necessary. If the forward motion of the paver is stopped, immediately stop the vibrator and tamping elements.

Deposit the concrete on the grade in successive batches to minimize re-handling. Place concrete over and against any joint assemblies so the joint assembly is retained in its correct position. Spread the concrete using approved mechanical spreaders to prevent segregation and separation of the materials.

After striking the concrete off with the spreader, leave sufficient concrete in place to allow the final shaping by the use of screeds, templates and pans, depending on make, model and type of machines approved for use in the paving train. Adjust the paving units to meet the required final cross-section, minimizing the need to carry back concrete to fill voids or depressions. Adjust each screed or template so a uniform roll of concrete extends the full length of the screed or template and allows just enough concrete to pass under the unit to properly feed the next machine. Do not shove large volumes of concrete with the screed or template. Adjust the screed or template to maintain a uniform cross-section.

Use multiple spreaders for single and multiple lift operations. Place concrete ahead of the initial spreader strikeoff no more than 30 minutes ahead of the final spreader strikeoff.

The use of any paving machine in the paving train is contingent on its ability to finish the pavement satisfactorily to the required grade, section and specified degree of consolidation. The Engineer may at any time require the adjustment, repair or replacement of the machine for unsatisfactory performance.

Correct any edge slump of the pavement in excess of ¼ inch, exclusive of edge rounding, before the concrete hardens. Excessive edge slumping will be sufficient reason to discontinue paving until machinery (or mix) is properly adjusted or removed from the project.

When the machine finishing has been completed, check the surface with a straightedge a minimum of 10 feet in length before texturing. Operate the straightedge parallel to the pavement centerline, starting at the center and progressing outward. Advance in successive stages of less than ½ the length of the straightedge. At the Contractor's option, this requirement may be eliminated when smoothness is to be determined by the profilograph.

Achieve grade control by use of 1 or more of the following grade reference devices. Approval of any of these devices will be based upon satisfactory performance.

Erected Stringline. Use an erected stringline consisting of a tightly stretched wire or string offset from and parallel to the pavement edge on 1 or both sides. Erect the stringline parallel to the established pavement surface grade and support at intervals as necessary to maintain the established grade and alignment.

Stringless Paving. Control line, grade and pavement cross-section as shown in the Contract Documents. Use electronic guidance systems that meet the requirements and tolerances listed in **SECTION 802**. Horizontal control is guided by GPS. Vertical control is guided by Total Stations. GPS will not be allowed for Vertical control.

When paving on a fresh subgrade that has not been trimmed by an automatically controlled machine, use an erected stringline or stringless paving to establish grade. When directed by the Engineer, use an erected stringline or stringless paving to match grade control points such as bridges.

c. Placing Reinforcement. Place pavement reinforcement at the locations shown in the Contract Documents. Use a sufficient number of approved metal, bar supports or pins to hold all dowel bars and tie bars in proper position as required by the Contract Documents. Install tie-bars perpendicular to the concrete face being tied together. Do not use stones, concrete or wood to support the reinforcement.

Joint tie bars may be installed mechanically if approved by the Engineer. The satisfactory placement of the bars depends on the ability of the Contractor’s operation to place and maintain the bars in their true position. When satisfactory placement is not obtained by mechanical means, the Engineer may require the tie bars be installed ahead of placing the concrete, and that they be securely held in their exact position by staking and tying.

Do not install dowel bars mechanically. Install the dowel bars ahead of placing the concrete, and hold them securely in their exact position by staking or tying.

Thoroughly coat each dowel with hard grease or other approved bond breaker as shown in the Contract Documents. The bond breaker coating shall not exceed 15 mils ± 5 mils in thickness when averaged over 3 points measured at the ¼ points on the bar at 90º intervals around the bar.

When reinforced concrete pavement is placed in 2 layers, strike off the entire width of the bottom layer to such length and depth that the sheet of fabric or bar mat may be laid full length on the concrete in its final position without further manipulation. Place the reinforcement directly on the concrete, then place the top layer of concrete, strike it off and screed it. Remove any portion of the bottom layer of concrete that has been placed more than 30 minutes, and replace it with fresh mixed concrete at the Contractor’s expense. When reinforced concrete is placed in 1 layer, the reinforcement may be positioned in advance of the concrete placement or it may be placed in the plastic concrete after initial spreading, by mechanical or vibratory means.

Place the wire mesh reinforcement in the pavement at the locations shown in the Contract Documents. When 2 layers of wire mesh reinforcement are required, support the bottom layer in the required position with bar chairs. Use separators for the top layer if the strike-off can not be used properly for the operation. Lap the reinforcement as shown in the Contract Documents. Laps parallel to the centerline of the pavement are prohibited except for unusual width of pavement lanes or for irregular areas. If the Contract Documents do not show dimensions for laps, the minimum lap either perpendicular or parallel to the centerline of the pavement is 6 inches. Fasten or tie adjacent wire mesh sheets together to hold all parts of the wire mesh sheets in the same plane.

If a “wire pattern” appears on the surface of the fresh pavement, immediately modify placement procedures to eliminate the problem.

Use reinforcing steel free from detrimental materials that could impair the bond between the steel and concrete.

d. Consolidation and Finishing. Perform hand spreading with shovels, not rakes. Do not allow workers to walk in the fresh concrete with boots or shoes coated with earth or foreign substance.

Do not apply moisture to the surface of the concrete pavement unless the Engineer approves the use of additional water on the fresh concrete surface to lubricate the float of the longitudinal finisher. If unusual weather conditions require the addition of superficial water to the concrete surface, apply it only in the form of a fine, fog mist.

Uniformly consolidate the concrete without voids, and finish to the cross-section and elevation shown in the Contract Documents.

Use vibrators or other approved equipment to consolidate each layer of concrete, when placed in more than 1 lift, or full depth if placed in 1 lift. Uniformly vibrate the concrete across the full width and depth of the pavement so that the density of pavement concrete is a minimum of 98% of the consolidated unit weight. The 98% density requirement may be eliminated on miscellaneous areas such as entrance pavement, median pavement and gore areas.

Vibrators, either of the surface type (pan or screed) or the immersion type (tube or spud) may be attached to the spreader, paver or finishing machine, or may be mounted on a separate carriage. Only operate the vibrators when the machine they are mounted on is moving forward. Do not operate hand vibrators more than 15 seconds, or less than 5 seconds in any one location unless approved otherwise by the Engineer. Place vibrators in and withdraw from concrete vertically in a slow deliberate manner.

On mainline paving, every 4 hours, check the electronic monitoring system vibrator frequencies with the vibrator under load to comply with the frequencies shown in **subsection 154.2e**.

If the system indicates a vibrator is not working properly, manually check the vibrators, immediately. If a vibrator is not functioning properly, immediately replace.

If the electronic monitoring system fails to operate properly, manually check the vibrators, immediately. If the vibrators are functioning properly, paving may continue but make all efforts to correct the problem within 3 paving days. The Engineer may allow additional time if circumstances are beyond the Contractor's control. Perform the vibrator checks manually until the system is fixed.

Document the checks, and give the data to the Inspector, daily. Email a recap of the data to the Engineer, weekly.

Maintain a uniform, continuous roll of concrete over the vibrators ahead of the strike-off. The height of the roll shall be approximately the same height as the thickness of the pavement being vibrated.

In order to obtain concrete consolidation in the vicinity of joint assemblies, the Engineer may require that these areas be hand vibrated with an immersion spud vibrator.

In the event the specified density is not attained, cease paving operations and make necessary adjustments to produce concrete to conform to the density requirements.

Use an approved nuclear density measuring device to monitor in-place density. Provide a moveable bridge and move it to test locations as required to allow the Inspector to work over the fresh concrete.

On projects or areas within projects where the use of conventional equipment is impracticable, other consolidation and finishing equipment may be used with approval of the Engineer.

e. Fixed Form Paving. At the Contractor's option, the fixed form paving method may be used.

(1) Forms. Use straight, metal forms having adequate strength to support the equipment. Each section shall be a minimum of 10 feet in length. Use forms with a depth equal to the prescribed edge thickness of the concrete, a base width at least equal to the depth of the forms and without a horizontal joint. Use flexible or curved forms of proper radius for curves of 150-foot radius or less, except approved straight forms of 5-foot lengths may be used for curves of a radius from 75 to 150 feet. Flexible or curved forms must be approved by the Engineer. The Engineer may approve the use of wood forms in areas requiring hand finishing. Secure the forms in place to withstand the impact and vibration of the consolidating and finishing equipment without visible spring or settlement. Extend flange braces outward on the base a minimum of ⅔ the height of the form. Remove forms with battered top surfaces or bent, twisted or broken forms. Do not use repaired forms until they have been inspected and approved by the Engineer. Do not use buildup forms, except where the total area of pavement of any specified thickness on the project is less the 2,000 square yards. Do not vary the top face of the form from a true plane more than ⅛ inch in 10 feet, and do not vary the vertical face of the form by more than ¼ inch. The forms shall contain provisions for locking the ends of abutting form sections together tightly, and for secure setting.

(2) Base Support. Provide a foundation under the forms that is compact and true to the specified grade so that the whole length of the form will be set firmly in contact with the grade.

(3) Form Setting. Set forms sufficiently in advance of the point where concrete is being placed so that line and grade may be checked. After the forms have been correctly set, thoroughly tamp the grade mechanically at both the inside and outside edges of the base of the forms. Stake forms into place with a minimum of 3 pins for each 10 feet section. Place a pin at each side of every joint. Tightly lock form sections, free from play or movement in any direction. Do not deviate the form from true line by more than ¼ inch at any point. No excessive settlement or springing of forms under the finishing machine is permitted. Clean and oil forms before the placing of concrete.

(4) Grade and Alignment. Check the alignment and grade elevations of the forms immediately before placing the concrete and make any necessary corrections. When any form has been disturbed or any grade has become unstable, reset and recheck the form.

(5) Placing Reinforcement and Consolidating and Finishing Concrete. Meet the requirements in **subsections 501.4c.** and **d**.

(6) Removing Forms. Unless otherwise provided, do not remove forms from freshly placed concrete until it has set for a minimum of 12 hours, except auxiliary forms used temporarily in widened areas. Remove forms carefully to avoid damage to the pavement.

f. Texturing. Use texturing equipment and devices as described in **subsection 154.7**.

Use a burlap drag as soon as all excess moisture has disappeared and while the concrete is still plastic enough to make a granular surface possible.

Following the dragging operation, use a mechanical device to make a final finish or texture by giving the surface of the plastic pavement a longitudinal tining, unless shown otherwise in the Contract Documents. Perform the operation at such time to minimize displacement of larger aggregate particles and before the surface permanently sets.

Small or irregular areas may be tined by hand methods.

On projects of less than 5,000 square yards, or projects with longitudinal tining, the tining and curing devices may be mounted on the same carriage when approved by the Engineer. Operations of this type will be based on satisfactory performance.

Before final texturing, finish the exposed edge of the pavement to a radius of ¼ inch with an edger. Edge the interior longitudinal joints on multiple-lane pavement to a radius of ⅛ inch. Eliminate any tool marks appearing on the slab adjacent to the joints or edge of the slab. Do not disturb the rounding of the corner of the slab.

g. Joints.

(1) General. Construct joints according to the Contract Documents. Failure to construct the joints in the best possible manner will be cause for suspension of work until the cause of the defective work is remedied.

If existing pavement of any type is required to abut with the new pavement, and the termination of the removal is not at an existing joint, make the new joint by sawing the existing pavement full depth with a diamond saw before removal.

The objective is to create or form a plane of weakness in the fresh concrete before uncontrolled or erratic cracking occurs. The following methods are acceptable:

- Use concrete saws to saw all contraction joints no wider than the initial saw cut and to a depth of D/3 ± ¼ inch. Extreme conditions could exist which make it impracticable to prevent erratic cracking by sawing the joints early. At the onset of the project, devise methods, with the approval of the Engineer, to control this cracking.
- Make a “plastic concrete cut” straight and well defined so it can be sawed out by the saw crew. The “plastic concrete cut” would replace the specified initial saw cut. Suggested procedures could be the use of a stiff metal parting strip, with or without handles that would be gently inserted in the fresh concrete and removed, thereby parting the interlocking coarse aggregate and providing a plane of weakness.
- Cut the fresh concrete with a mason’s trowel and straightedge from a worker’s bridge. It is imperative that the “plastic concrete cut” joint and the second stage saw cut are in the same exact location.
- At the Contractor’s option, “early entry” saws may be used based on satisfactory performance and depth of cut recommended by the equipment manufacturer.
- Procedures to control erratic cracking are not limited to these examples.

Edge any transverse joint requiring hand finishing and edging with a tool having a radius of ⅛ inch. Do not indent the surface of the pavement with the horizontal face of the edger.

(2) Pressure Relief Joints. Install pressure relief joints according to the bridge approach details in the Contract Documents.

Form or saw openings for the joint material approximately 1 ¾ inches wide for the 2-inch joint and approximately 3 ¾ inches wide for the 4-inch joint at the locations shown in the Contract Documents. Use the lubricant adhesive as recommended by the manufacturer of the pressure relief joint material.

Just before the installation of the joint material, clean the faces of the joint by sandblasting, followed by an air blast to clean all dust from joint faces.

The Engineer may approve pre-positioning of the 2-inch material if adequate means are taken to obtain proper placement and retention, and if deformation of the material does not occur when the fresh concrete is placed against it.

Use a foam spacer block beneath the 4-inch joint filler material to maintain the specified grade. The spacer block is an easily compressed foam material cut to fill the void beneath the joint filler.

(3) Contraction Joints. Install contraction joints of the type, dimensions and spacing shown in the Contract Documents.

Stretch a stringline along the centerline of the joint, or otherwise adequately mark it to verify dowel bar joint assembly alignment.

Install the dowel bar joint assembly so the centerline of the assembly is perpendicular to the centerline of the slab, and the dowels lie parallel to the slab surface and slab centerline. Place concrete so it will not displace or disarrange the joint assembly. Mark the location of contraction joints to assure the joints are sawed in the proper location.

(4) Longitudinal Joints. Construct longitudinal joints according to the Contract Documents. When sawed joints are specified or used, provide approved guide lines or devices to cut the longitudinal joint on the true line as shown in the Contract Documents. Perform the sawing of longitudinal joints at a time that will prevent erratic or uncontrolled cracking. When "plastic concrete cut" methods are used, no sawing or widening of the joint will be required to make a sealant reservoir.

(5) Construction Joints. Make a butt construction joint perpendicular to the centerline of the pavement at the close of each day's work, or when the process of depositing concrete is stopped for a length of time sufficient for the concrete to take its initial set. Form this joint by using a clean header having a nominal thickness of 2 inches, and minimum cross-sectional area equal to pavement thickness by pavement width. Cut the header true to the crown of the finished pavement. Accurately set and hold it in place in a plane at right angles to centerline and perpendicular to the surface of the pavement.

Protect the top surface of the header with steel. Securely fasten a trapezoidal piece of metal or wood approximately 2 inches wide and a minimum of 1 inch in depth on the face of the header, along the center of the header to form a grooved or keyed joint.

With approval of the Engineer, the Contractor may pave beyond the joint location a distance to maintain the line and grade. Saw the construction joint when the concrete has hardened. Drill holes for reinforcing tie bars and epoxy the bars in-place. Place fresh concrete against the previously placed concrete taking care to avoid injury to the edge. Vibrate the concrete to obtain an interlocking joint and prevent a honeycombed face of the joint. The additional concrete, removal of debris and other work created by this alternative is at the Contractor's expense.

Unless shown otherwise in the Contract Documents, do not place any construction joint within 5 feet of an expansion, contraction or other construction joint.

(6) Special Joint Construction. Construct special joints as shown in the Contract Documents or as ordered by the Engineer around drainage, utility and other structures located within the concrete pavement boundaries. Hold temporary forms securely in place during the concrete placement operation.

(7) Joint Construction. Construct all joints as shown in the Contract Documents. Repair or replace any curing medium damaged during joint construction. Construct joints as follows:

(a) Induced Plane of Weakness. The first saw cut is a relief cut at the proper joint location, approximately ⅛ inch wide and to the full joint depth as shown in the Contract Documents (D/3 ± ¼ inch). Make the relief cut as soon as the concrete has hardened enough so that no excess raveling or spalling occurs, but before any random cracks develop. The sequence of the relief sawing is at the Contractor's option, provided all relief sawing is completed before random cracking develops. Use suitable guide lines or devices to cut the joint straight and in the correct location. Repair curing membrane damaged during sawing as directed by the Engineer. See **subsection 501.4g.(1)** for alternate methods to the first stage sawing.

(b) Reservoir Construction. Do not perform widening of the relief joints to full width until the concrete is a minimum of 48 hours old. Delay it longer if the sawing causes raveling of the concrete. If second stage sawing is performed before completion of the curing period, maintain the cure by use of curing tapes, plastic devices or other materials approved by the Engineer. Center the joint groove over the relief cut, and saw it to the dimensions shown in the Contract Documents. Should any spalling of the sawed edges occur that would detrimentally affect the joint seal, patch it with an approved epoxy patching compound and allow it to harden before installing the joint material. Make each patch true to the intended neat lines of the finished cut joint.

(8) Cleaning Joints.

(a) Immediately clean freshly cut sawed joints by flushing with a jet of water under pressure and other necessary tools to remove the resulting slurry from the joint and immediate area.

(b) To clean joints, use air compressors equipped with suitable traps capable of removing all surplus water and oil from the compressed air. The Engineer will check the compressed air for contamination, daily. When contaminated air is found to exist, work will be stopped until suitable adjustments are made, and the air stream is found to be free of contaminants.

(c) Just before applying the hot or cold joint sealant, complete a final cleaning by air blasting to clean incompressibles from the joint.

(d) Before installing preformed elastomeric joint seals, use water or sandblasting equipment to clean the seal reservoir of the transverse joint a minimum of the vertical height of the installed elastomeric joint material plus ½ inch measured from the pavement surface. Use a multiple pass technique until the surfaces are free of dirt, curing compound or any residue that might prevent ready insertion of the seal, or uniform contact with the concrete. (Note: These seals are held in place by compressive forces and friction acting on the faces of the joint, not chemical bonding as with other joint sealants.) After final cleaning, and immediately before installing the seal, blow out the joint seal reservoir with compressed air until it is free of debris and visible water.

(9) Sealing Joints. The joint location, size and configuration is shown in the Contract Documents. Use applicable materials to obtain the required joint sealant configuration. Seal transverse pavement joints with preformed elastomeric compression joint seals, unless shown otherwise in the Contract Documents. Seal longitudinal pavement joints full depth with either a cold applied chemically cured joint sealant or a hot joint sealing compound. Use only 1 type of longitudinal joint sealant on a project, unless otherwise approved by the Engineer. Seal joints before opening to traffic. For opening to construction traffic, see **subsection 501.4i.(3)(a)**.

When using cold applied chemically cured joint sealant, hot joint sealing compound or preformed elastomeric compression joint seals, arrange for a technical representative of the manufacturer to be present during installation of the joint seal to provide guidance on cleaning, preparation of the joint and installation of the seal.

Keep the manufacturer's technical representative on the project until Contractor and KDOT personnel have been thoroughly trained in the proper installation of the material. The Engineer may waive this requirement for Contractors that are experienced in installing the type and brand of material being used. Provide the Engineer with a résumé of experience for evaluation.

(a) Cold Applied Chemically Cured Joint Sealants. Do not seal joints until they are clean and dry, and the pavement has attained the age recommended by the manufacturer of the sealant. Do not apply sealant to damp concrete, or install it during inclement weather. Do not apply joint sealant when the ambient air temperature is below 40ºF, or as specified by the manufacturer. Place the sealer full depth in close conformity with dimensions shown in the Contract Documents. Any deviation will be cause for rejection of the joint until satisfactory corrective measures are taken.

Apply the joint sealant by an approved mechanical device. Any failure of the joint material in either adhesion or cohesion will be cause for rejection. Repair the joint to the Engineer's satisfaction.

Some cold applied, chemically cured sealants are not self-leveling and will not position properly in the joint under its own weight. Tool the sealant surface as shown in the Contract Documents. Accomplish tooling before a skin forms on the surface. Do not use soap or oil as a tooling aid.

After a joint has been sealed, promptly remove all surplus joint sealer from the pavement or structure surfaces.

Do not permit traffic over sealed joints until the sealer is tack free, or until debris from traffic can not embed into the sealant.

(b) Hot Applied Joint Sealing Compound. Do not seal joints until they are clean and dry, and the pavement has attained the age recommended by the manufacturer of the joint sealing compound. Install joint sealing compound according to the manufacture's recommendations.

Completely clean out the application unit when changing brands of materials, or if the material exhibits any sign of changes in application characteristics, polymer or oil separation, balling or any signs of jelling. If the application unit contains compatible material from a previous project at start-up, provide the Engineer a certification covering the material in the application unit, including the manufacturer, type, etc. Before start-up, completely clean out any material that can not be identified and certified.

After a joint has been sealed, promptly remove all surplus joint sealer from the pavement or structure surfaces.

Do not permit traffic over sealed joints until the sealer is tack free, or until debris from traffic can not embed into the sealant.

(c) Preformed Elastomeric Joint Seals. Concrete that has reached an age that permits proper sawing and cleaning without causing deterioration of the joint edges and joint faces, is considered acceptable for seal installation.

Under normal construction procedures, seal transverse joints full width with no splices made in the preformed joint seal. However, under phased construction of widenings, where the lanes placed earlier have been opened to traffic, the preformed joint seal may be spliced at the construction joint. When the existing seal is peeled back to saw the construction joint, clean it, reapply the lubricant/adhesive and reinstall as soon as possible. After the new seal is installed, place the longitudinal joint sealant through the intersection with the transverse joint, with the transverse seals butted in. Place the longitudinal sealant to encase and seal the ends of the preformed seals.

Install the joint seal with a machine especially designed to compress and install the sealant in an upright position, without cutting, nicking, distorting or otherwise damaging the seal. Apply lubricant to the concrete or the preformed seal (or both), and install the seal in a substantially compressed condition. Place the top of the seal at a depth below the finished surface of the pavement, recommended by the manufacturer.

Use a method of installation such that the joint seal will not be stretched or compressed longitudinally more than 3% of the length, unless stated otherwise in the manufacturer's instructions. The method of installation will be checked for stretching or compression by comparing the distance between 2 marks on the surface of the seal measured before and after the installation. If the check indicates stretching or compression beyond the limits stated above, modify the method of installation to correct the situation. The Contractor may proceed slightly out of specification for a short distance under the supervision of the manufacturer's technical representative, while making corrections and adjustments to return to specification limits. This material may remain in place, provided the stretching does not exceed 5%, and the Contractor makes a good faith effort to correct the problem. Once the machine is in proper adjustment and the installation is proceeding satisfactorily, further checks (approximately every 100 joints) will be made to verify proper installation.

Remove any joint seal not conforming to the above stated limits of installation and replace with new material. After being removed for any reason, no seal may be reused.

(10) Sawed (Non-Sealed) Joints.

(a) Joint Construction. The joint location, size and configuration are shown in the Contract Documents. Use concrete saws to saw all joints a nominal 1/8 inch wide to the full joint depth, D/3± ¼ inch, unless shown otherwise in the Contract Documents.

Make the saw cut as soon as the concrete has hardened enough so that no excess raveling or spalling occurs, but before any random cracks develop. The sequence of the sawing is at the Contractor's option, provided all sawing is completed before random cracking develops. Use suitable guide lines or devices to cut the joint straight and in the correct location.

(b) Cleaning Joints. Immediately clean freshly cut sawed joints by flushing with a jet of water under pressure and other necessary tools to remove the resulting slurry from the joint and immediate area. Repair curing membrane damaged during sawing and cleaning, as directed by the Engineer.

(c) Backer Rod. Install and maintain backer rod (of a size sufficient to prevent debris from entering the joint) in the joint. When major construction traffic is no longer driving on the pavement, and prior to opening to the public, remove the backer rod, and follow with an air blast to remove any debris.

(d) Repair of Joints. If the sawed joint is ≥ ¼ inch, seal the joint using Hot Applied Joint Sealing Compound, according to **subsections 501.4g.(7)** thru **(9)(b)**. Seal transverse joints the full width of pavement. Seal longitudinal joints the full length of the panel. If the joint can not be properly sealed, see **subsection 501.4k**.

(e) Opening to Traffic. When no joints require sealing, disregard **subsection 501.4i.(3)(a)**, third bullet and **501.4i.(3)(b)**.
(f) Side Roads and Entrance Pavement. If the PCCP is designated with sawed (non-sealed joints), construct the side road and entrance pavement joints according to **subsection 501.4g.(10)**, unless otherwise specified in the Contract Documents.
(g) Curb and Gutter/Valley Gutter. Unless specified otherwise in the Contract Documents, if the PCCP is designated with sawed (non-sealed) joints, construct the curb and gutter/valley gutter joints according to **subsections 501.4g.(10)(a)** thru **(c)** with the following exception: saw to a depth a minimum of 1 ¼ inches below the surface of the gutter. If the curb and gutter is placed monolithically with the pavement, saw to the same depth as the pavement.

h. Hand Finishing. Hold hand finishing methods to a minimum. Generally, hand methods of placement and finishing will be permitted as follows:

- For pavement when a breakdown of some portion of the paving train occurs, making the hand finishing of that portion of the concrete already in place necessary.
- For pavement lanes that may be too narrow or a length too short to accommodate a full paving spread.
- For all irregular shaped areas.
- For special approach sections to bridges, widened portions at bridges, intersections and sections widened beyond traffic lanes.
- When the dimensions of the work make the use of a complete power operated paving impossible, or impracticable.

For uniform width areas or transition width areas using false forms, finish handwork with a mechanical finishing machine or approved vibrating screed, whenever possible.

Use spud hand vibrators on any area considered impracticable to vibrate with a vibrating screed. Approved metal or wood floats may be used if needed to help close an open or porous surface condition.

Continue the operation of consolidation and screeding or striking off the concrete until the concrete is uniformly consolidated and the surface is true to line, grade and cross-section.

After the pavement has been properly struck off, straightedge the pavement for trueness and finish it. Use a burlap drag to remove surface straightedge marks. The burlap drag may be pulled by hand, but the results shall be similar to that on the mainline pavement.

Manual methods may be used for texturing hand finished pavement areas. Where applicable, the tined texture applies. Use a metal comb with dimensions and spacing shown in **subsection 154.7c**. Obtain a finished textured surface similar to that produced mechanically.

On miscellaneous areas such as entrance pavement, median pavement and gore areas, texturing with the metal comb may be eliminated. Final finish may be attained by the use of a drag that consists of a seamless strip of damp burlap, cotton fabric or other suitable material capable of producing a uniform surface of gritty texture.

i. Protection and Curing of Concrete. Cure the pavement by using burlap, liquid membrane-forming compounds, white polyethylene sheeting, concrete curing blankets or reinforced white polyethylene sheeting. Failure to provide proper curing is cause for immediate suspension of the concreting operations.

(1) Burlap, Concrete Curing Blankets, White Polyethylene Sheeting and Reinforced White Polyethylene Sheeting. Place the curing material on the pavement immediately after the pavement has been finished, and the concrete has hardened sufficiently to avoid harmful marring of the surface, yet early enough to prevent undue loss of moisture from the concrete. If the pavement becomes dry before the curing material is placed, moisten the concrete with a fine spray of water. Dampen burlap and place on the surface. Place burlap-polyethylene blankets with the dampened burlap side down. Keep burlap damp throughout the entire curing period.

Lap adjacent units of curing materials approximately 18 inches. Upon removal of the forms, extend the material to completely cover the full depth of the exposed pavement.

Weigh the curing material down using continuous windrows of earth placed along the sides and edges of the pavement and transversely across the pavement on the laps to cause the material to remain in contact with the covered surface throughout the curing period. Other methods may be used with approval of the Engineer.

Walking on the pavement surface to place the curing material is prohibited. Walking on the curing material is prohibited until the pavement has cured sufficiently to prevent damage to the surface.

Leave the curing material in place for a minimum of 4 days, unless otherwise directed by the Engineer. Immediately repair any tears or holes appearing in the material during the curing period, or replace it with material in good condition.

The material may be reused, provided it is kept serviceable by proper repairs, and if in the judgment of Engineer it will provide water retention during the curing period.

(2) Type 2 White Liquid Membrane-Forming Compound. After finishing operations have been completed and immediately after the free water has left the surface, completely coat and seal the surface of the slab with a uniform layer of compound. Apply the compound in 1 application at a minimum rate of 1 gallon per 150 square feet of surface. Thoroughly mix the compound at all times during usage. Do not dilute the compound. Daily provide the Inspector documentation of the quantity of curing compound used.

Protect the treated surface from injury a minimum of 4 days, unless otherwise directed by the Engineer. If the newly coated film is damaged in any way, apply a new coat of material to the affected areas equal in coverage to that specified for the original coat. A minimum of foot traffic will be permitted on the dried film as necessary to properly carry on the work, provided any damage to the film is immediately repaired by application of an additional coat of compound.

Immediately after the forms are removed (fixed form and slip form), coat the entire area of the sides of the slab with compound at the rate specified for the pavement surface, regardless of whether or not further concrete placement will be made against the pavement edge. Approved hand spray equipment will be permitted only for the application of compound on the sides of the slab, for repairing damaged areas and for hand finished areas. Repair any damaged areas caused by joint sawing.

(3) Opening to Traffic. No motorized traffic is allowed on the pavement until all of the following conditions are met.

(a) Construction Traffic Only.

- The flexural strength of the pavement shall meet or exceed 450 psi. Determine the flexural strength of the pavement by testing flexural strength specimens utilizing the third point loading method, or by use of a calibrated maturity meter.
- If flexural strength does not meet or exceed 450 psi, observe a 10 day curing period before allowing motorized traffic on the pavement. Provide a strength gain curve of concrete cured at 45°F to justify a curing period of less than 10 days.
- Provide protection to keep foreign material out of the unsealed joints by an approved method.

(b) All Traffic. In addition to **subsection 501.4i.(3)(a)**, seal the joints according to **subsection 501.4g.(9)**.

The Contractor may, at own expense, increase the cement content from the minimum shown in **SECTION 403** to accelerate the strength gain of the PCCP.

(4) Cold Weather Curing. Maintain the concrete pavement at a minimum temperature of 40ºF, as measured along the surface of the concrete, for a minimum of 4 days after placing. When the ambient air temperature is expected to drop below 35ºF anytime during the curing period, take precautions to maintain the concrete temperature. Keep a sufficient supply of approved moisture barrier material, other than liquid curing compound, and suitable blanketing material, such as straw, hay and burlap close by. Be prepared to cover the pavement with a moisture barrier and protect all pavement less than 4 days old with blanketing material. Remove, dispose of and replace concrete damaged by cold weather, as determined by the Engineer.

(5) Early Strength Concrete Curing. The curing period shall conform to the requirements specified for regular concrete pavement in **subsection 501.4.i**. Construct joints according to the manufacturer's recommendations for early strength concrete pavement.

j. Cold Weather Limitations. If concrete is placed in cold weather, comply with **SECTION 401**.

k. Repair of Defective Pavement Slabs. It is the responsibility of the Contractor to repair any spalled, cracked or broken panels as specified hereinafter at no cost to KDOT. Completely remove and replace pavement panels (area between contraction joint and contraction joint) containing both transverse and longitudinal cracks (separating the panel into 4 or more parts) through the full depth of the slab.

Properly seal the joints of the repaired or replaced panels.

(1) Repair of Spalls.

- In no case shall an individual patch of a spall be less than 1 square foot with no dimension less than 1 foot.
- For spalls greater than ¼ inch and less than or equal to ½ inch from edge of the original sawed joint, repair with hot pour.
- For spalls greater than ½ inch and less than or equal to 1 inch from the edge of the original sawed joint, blast clean and repair with epoxy patch material.
- For spalls greater than 1 inch from the edge of original sawed joint, repair by making a saw cut a minimum of 1 inch outside the spalled area to a minimum depth of 2 inches. The interior angles formed by the intersection of adjacent sides of the patch shall be a minimum of 60º. When the spalled area abuts a joint, make the saw cut to a depth of 2 inches or 1/6 the slab thickness, whichever is greater. Chip out the concrete between the saw cut and the joint or primary crack to solid concrete. Do not use chipping hammers greater than 15 pounds. Thoroughly clean all loose material from the formed cavity. Apply a coat of an approved concrete bonding epoxy to the dry, cleaned surface of all sides of the cavity, except the joint. Apply the epoxy by scrubbing the material into the surface with a stiff bristle brush. Place portland cement concrete, epoxy resin concrete or mortar, immediately following application of the epoxy, according to the manufacturer's recommendations. If the spalled area to be patched abuts a working joint, use an insert or other bond breaking medium during the repair work to maintain working joints. Remove and replace major honeycombed areas found after removal of the forms. Removed areas or sections so removed shall be a minimum of 6 feet in length if less than full width of the lane involved. When it is necessary to remove a section of pavement, also remove and replace any remaining portion of the slab adjacent to the joints that is less than 6 feet in length.

(2) Repair of Cracks in New Reinforced, Dowel Jointed PCCP.

(a) Transverse and Diagonal Cracks.

(i) Full Depth.

- When a single full-depth transverse crack falls within the middle ⅓ of the panel, no corrective work will be required.
- Should a second full-depth crack develop within the middle ⅓ of the panel, remove and replace the panel to the nearest planned contraction joint, eliminating both cracks. If the location of the mid-panel full-depth crack is within 6 feet of the boundaries of the area to be repaired, extend the area to be repaired to include the mid-panel crack.
- When any portion of a full-depth crack falls outside the middle ⅓ of the panel, remove and replace the portion of panel between the contraction joint and the crack. Make 1 full-depth saw cut parallel to the contraction joint on the mid-panel side of the crack to be removed. Make another cut in the adjacent panel, parallel to the contraction joint, clear of the basket assembly, but not less than 6 feet from the first cut. Remove the cracked section and basket assembly. Drill holes in both sawed faces, and insert bars to make 2 contraction joints. Use dowels of the same size and spaced the same distance as those shown in the Contract Documents. Drill bar holes ¼ inch ± 0.05 inch larger than the diameter of the bar and fill them with epoxy or grout and insert the new dowel. Support the free ends of the bars parallel to the pavement surface until the epoxy or grout has set, obtaining proper alignment of the bar. Apply grease or an approved bond breaker to the free ends.
- If the boundaries of consecutive areas to be repaired are less than 6 feet apart, also remove and replace the areas between the patches.
- Saw off the longitudinal joint tie bars at the longitudinal joint. Drill holes midway between the existing bars and insert tie bars to make a new tied longitudinal hinged joint. Use tie bars of the same size and spacing as those in the Contract Documents. Drill bar holes ¼ inch ± 0.05 inch larger than the diameter of the bar and fill them with epoxy or grout and insert new tie bars.

(b) Longitudinal Cracks. When a single longitudinal crack falls within a panel, no corrective work will be required.

When a second full-depth longitudinal crack falls within a panel, remove and replace the panel to the nearest planned contraction joint, eliminating both cracks.

(3) Repair of Cracks in both New Non-reinforced Dowel Jointed PCCP and Mainline Plain PCCP.

(a) Transverse and Diagonal Cracks.

(i) Full Depth.

- If a maximum of 4 panels per any lane mile has a crack, repair according to **SECTION 504 - DOWEL BAR RETROFIT-REPAIR**, or remove and replace the pavement.
- If 5 to 18 of the panels per any lane mile has a crack, repair according to **SECTION 504 - DOWEL BAR RETROFIT-REPAIR**. When 2 consecutive panels have a crack, remove and replace the panels from contraction joint to contraction joint.
- If more than 18 of the panels per any lane mile have a crack, remove and replace the pavement bounded by the cracks in that segment. Remove and replace until ¼ mile segment has less than 4 panels cracked, then repair or replace.

(ii) Partial Depth. If coring (at no additional cost to KDOT) verifies the transverse cracks are not full depth, repairs may be made by **SECTION 505 - TIE BAR INSERTION-REPAIR**.

(iii) When required or at the Contractor's option, remove and replace pavement panels containing any transverse or diagonal crack according to the following:

- Make a full-depth saw cut in the abutting panel nearest to the crack, parallel to the contraction joint, just clear of the basket assembly to allow the existing dowel basket assembly to be completely removed. Make a second saw cut parallel with the contraction joint on the opposite side of the crack away from the contraction joint. For plain PCCP, make the saw cut at the joint nearest to the crack. Make the second saw cut opposite the first cut a minimum of 6 feet from the first saw cut to include the crack. Remove the resulting area.
- The minimum longitudinal length of a patch is 6 feet.
- Do not permit a patch to fall within 6 feet of a contraction joint.
- The maximum distance between doweled/non-doweled contraction joints is 18 feet.
- Drill holes and insert dowel bars to make new contraction joints within the vertical faces of both newly created panel ends. Use dowels of the same size and spaced the same distance as shown in the Contract Documents. Drill bar holes ¼ inch ± 0.05 inch larger than the diameter of the bar and fill with epoxy or portland cement grout and insert the new dowel. Support the free ends of the bars until the epoxy or grout has set to obtain proper alignment of the bar. Apply grease or an approved bond breaker to the free ends. Do not use dowel bars in plain PCCP.
- Saw off the longitudinal joint tie bars at the longitudinal joint. Drill holes midway between the existing bars and insert tie bars to make a new tied longitudinal hinged joint. Do not place new tie bars within 12 inches of doweled joint. Use tie bars of the same size and spacing as those in the Contract Documents. Drill bar holes ¼ inch ± 0.05 inch larger than the diameter of the bar and fill them with epoxy or grout and insert new tie bars.

(b) Longitudinal Cracks. Repair or remove and replace pavement panels that contain a single longitudinal crack, according to the following:

- Repair longitudinal cracks that are within 3 inches of the planned longitudinal joint for their entire length with a partial depth patch as specified for spall in **subsection 501.4k.(1)**, except make the transverse dimension of the patch 6 inches and saw cuts to D/3 ± ¼ inch.
- For longitudinal cracks between 3 and 6 inches from the planned longitudinal joint, fill the entire planned longitudinal joint full depth with epoxy through the length of the longitudinal crack.
- Repair longitudinal cracks that are 6 inches or more from the planned longitudinal joint by removing and replacing pavement panels, or repair pavement by **SECTION 505 - TIE BAR INSERTION-REPAIR**.

Remove and replace pavement panels that contain 2 or more longitudinal cracks.

(4) Repair of Cracks in Shoulder Plain PCCP.

(a) Transverse and Diagonal Cracks.

- When a single transverse crack falls within a panel and is within 3 feet of the transverse contraction joint, fill the contraction joint according to the Contract Documents and rout and seal the crack.
- When 2 or more transverse cracks fall within a panel, remove and replace the panels.

(b) Longitudinal Cracks.

- When a single longitudinal crack falls within a panel, repair pavement by **SECTION 505 - TIE BAR INSERTION-REPAIR**.
- When 2 or more longitudinal cracks fall within a panel, remove and replace the panels.

l. Protection of Pavement from Rain. Before placing PCCP, prepare and submit to the Engineer for approval, a Protection Plan to address the onset of rain during concrete placement. As a minimum, the plan shall include protective covering and side forms available at the project site at all times to protect the surfaces and edges of the newly placed concrete pavement. Polyethylene, burlap or other covering materials may be used. Side forms may be of wood or steel and shall have a depth a minimum of the thickness of the pavement. Specify the location of the storage site in order that a review of the protective materials may be conducted by the Engineer.

Include the type and amount of protective materials as well as the methods proposed to protect the pavement.

When rain appears imminent, stop all paving operations and initiate the Protection Plan. Extend the covering back to the point where the rain will not indent the surface. Exercise care to prevent unnecessary damage to the surface with the covering.

m. Pavement Smoothness. Evaluate pavement smoothness for pay according to **SECTION 503**.

501.5 MEASUREMENT AND PAYMENT

a. Plan Quantity Measurement. The quantities of concrete pavement for which payment will be made are the quantities shown in the Contract Documents for the traveled way lanes and the various paved approaches, exits and interchanges, provided the project is constructed essentially to details shown in the Contract Documents.

When the Contract Documents have been altered, or when a disagreement exists between the Contractor and the Engineer as to the accuracy of the Contract Document quantities in any location or the entire project, either party has the right to request and cause the quantities involved to be measured according to **subsection 501.5b**.

b. Measured Quantities. The quantity to be paid for under this item will be the number of square yards of concrete pavement as measured in-place. The width for measurement will be the width of the pavement shown on the typical cross-section of the Contract Documents, additional widening where added, or as otherwise directed in writing by the Engineer. The length will be measured horizontally along the centerline of each roadway or ramp.

c. Excavation Included in Contract. On projects where the grading and the pavement or base construction is included in the same contract, the Engineer will not measure additional excavation required to obtain the specified subgrade elevation.

d. Sawing and Sealing Joints. The Engineer will not measure this work for separate payment. All costs of complying with the requirements specified herein are included in the contract price for the concrete pavement in which the joints are located.

e. Quality Control Testing. The Engineer will measure the Contractor's quality control testing by the square yard of PCCP placed on the project. The Engineer will measure each concrete core when the results from the core information (required for disputed tests) increases payment to the Contractor. All other cores taken as required by this specification are subsidiary to this item.

f. Water. The Engineer will not measure water used in dust control on haul roads, around plant installations, etc.

g. Pavement Thickness and Compressive Strength Determination.

(1) General. Make the required corrections for pavement smoothness before making the pavement thickness determinations. Determination of pavement thickness and pavement compressive strength for the purpose of establishing pay adjustments will be based on test results from cores taken from each lot of pavement.

- For mainline pavement, pay adjustments will be made for both thickness and compressive strength.
- For acceleration lane, deceleration lane, frontage road, side road and ramp pavement, pay adjustments will be made for thickness, but not compressive strength, unless the Contract Documents specifically require compressive strength pay adjustments.
- For gore areas, bridge approach slabs, intersection curb returns, entrances, shoulders, medians and widenings, pay adjustments will not be made for thickness or compressive strength, and pavement cores will not be required.

Where coring is not required, verify that the thickness of the pavement meets or exceeds the Contract Document requirements by use of stringline, survey or other suitable depth measurement. For pavement types not cored for strength, use only concrete mix designs approved for use in the mainline pavement. The Engineer will observe and document the Contractor's measurement or other means of ensuring the appropriate thickness of the plastic concrete, and the Engineer will verify that only approved mixes are used. Prior to placing any pavement not specifically defined above, reach an agreement with the Engineer as to the applicability of pay factors.

(2) Lots and Sublots Defined.

(a) For mainline and other pavement subject to coring for pay adjustments for both thickness and strength, a lot is defined as the surface area of mainline lane placed in a single day. Normally, divide a lot representing a day's production into 5 sublots of approximately equal surface area.

For high daily production rates, rates exceeding 6000 square yards per day, the Contractor may choose to divide the day's production into 2 approximately equal lots consisting of 5 sublots each. Prior to taking any core samples, notify the Engineer of the decision to divide a day's production into 2 equal lots. For low daily production rates (and not in an urban PCCP environment), the Contractor may choose to divide the lot into a lesser number of sublots as shown in **TABLE 501-1**. When daily production rates are less than 1000 square yards, and not in an urban PCCP environment, combine the day's production with the next day's production to form a lot. When a day's production involves less than 1000 square yards while completing a particular mix design or project, combine with the previous day's production and treat as a single lot.

For low daily production rates less than 1000 square yards in an urban PCCP environment, consider each day's production as a separate lot. KDOT's representative will core (or have cored) a minimum of two randomly-determined sublots per day; one in the morning and one in the afternoon. Each randomly-determined location will be cored for both strength and thickness, and results inserted into the "Urban PCCP" worksheet for pay adjustment.

TABLE 501-1: PCCP SUBLOT BREAKDOWN

Daily Production Rate in square yards	Number of Sublots
Under 1000 (Urban)	2
1001 – 2000	3
2001 – 4000	4
4001 or more	5

(b) For pavement that is to be cored for thickness only, group each continuous section of acceleration lane, deceleration lane, side road, frontage road and ramp pavement of equal plan thickness and contract unit price into a lot a maximum of 5000 square yards in area. Divide each lot into a minimum of 3 sublots of approximately equal surface area. Sublots shall be a maximum of 1000 square yards in size. Sample each sublot in a manner so that each square yard of pavement has a chance of being randomly selected for coring.

(3) Coring. The Engineer reserves the right to generate the random locations. If KDOT plans to generate the random locations, the Contractor will be notified before taking cores for thickness determination.

(a) For mainline and other pavement subject to coring for pay adjustments for both thickness and strength, take 1 core sample having a minimum diameter of 4 inches from a randomly selected site within each sublot. The Contractor has the option of taking an additional core sample having a minimum diameter of 2 inches from a randomly selected site within each sublot for the purpose of making an early determination of the pavement thickness only. Select sites according to the approved QCP. Additionally, take 1 companion core having a minimum diameter of 4 inches per each lot at a randomly selected site as designated by the Engineer. Repair all core holes in a manner approved by the Engineer. Perform all coring for the purpose of determining strength a minimum of 21 days after the pavement has been placed, and in time to determine 28-day compressive strengths. Coring prior to the 21-day minimum will be permitted with approval of the Engineer, when opening to early traffic is desired. If the companion cores will be measured and tested by the MRC, the Engineer will deliver the companion cores to the MRC within 25 days after the pavement has been placed. No initial QC compressive strength data will be accepted for concrete paving that is more than 28 days of age, unless approved by the Engineer.

(b) For all other PCCP subject to coring for pay adjustment, thickness only, define the lots prior to placement with the Engineer's approval.

After placement, randomly select each sublot location. Take 1 core sample having a minimum diameter of 2 inches. Repair all core holes in a manner approved by the Engineer. Coring may be performed at any time after all pavement in the lot has been placed.

(4) Mark each core with the lot and sublot number from which it was selected. Transport the cores to the laboratory as soon as possible and perform the thickness determination. Take 3 caliper measurements on each core at approximately 120º apart. Record these 3 measurements to the nearest 0.01 inch, and average them to represent the height of that core.

Do not test 2-inch core samples for compressive strength. Do not measure 4-inch cores for pavement thickness determination if a separate 2-inch core sample was taken in a sublot for that purpose.

The measured core height will represent the constructed pavement thickness for each pavement sublot. The Engineer will witness thickness determinations and initial the Contractor's documentation.

Moist cure the 4-inch cores to be tested for compressive strength as required in KT-49, until they are tested. Perform the 28-day compressive strength testing on the entire length of the core after squaring the ends according to KT-49. The compression machine shall be capable of testing cores up to and including 12 inches in length. Remove only the excess length that exceeds compression machine capabilities from the bottom of the cores. Determine length and diameter to the nearest 0.01 inch. Determine the length/diameter ratio (LD), and round the result to the nearest hundredth using the following formula:

$$LD = \text{Length} / \text{Diameter}$$

After performing the strength test, correct the compressive strength using a correction factor determined by using the appropriate formula in **TABLE 501-2**.

TABLE 501-2: COMPRESSIVE STRENGTH CORRECTION FACTOR FORMULAS	
LD	**Correction Factor**
LD < 2	$\frac{100}{95 + 0.2(1/LD) + 19.5(1/LD)^2}$
LD = 2	1.000
LD >2	$\frac{100}{110 - 5(LD)}$

The compressive strength correction factor may also be obtained by using **TABLE 501-3**. If a discrepancy should arise due to rounding numbers or the appropriate value is not shown in the table, the value determined by the above formulas shall govern.

TABLE 501-3: COMPRESSIVE STRENGTH CORRECTION FACTOR			
LD	**Compressive Strength Correction Factor**	**LD**	**Compressive Strength Correction Factor**
1.00	0.872	2.60	1.031
1.10	0.898	2.70	1.036
1.20	0.920	2.80	1.042
1.30	0.937	2.90	1.047
1.40	0.952	3.00	1.053
1.50	0.963	3.10	1.058
1.60	0.973	3.20	1.064
1.70	0.982	3.30	1.070
1.80	0.989	3.40	1.075
1.90	0.995	3.50	1.081
2.00	1.000	3.60	1.087
2.10	1.005	3.70	1.093
2.20	1.010	3.80	1.099
2.30	1.015	3.90	1.105
2.40	1.020	4.00	1.111
2.50	1.026		

Correct the compressive strength determined during testing by multiplying that amount by the compressive strength correction factor.

The Engineer will witness all compressive strength tests for each sublot and initial the Contractor's documentation.

Companion cores will be measured and tested at KDOT's laboratory to verify the Contractor's test results. Supply 28-day compressive strength data to KDOT. Acceptance of the pavement and pay adjustments will be on the basis of Contractor quality control test results on random samples taken from a lot, provided the statistical comparison is favorable.

KDOT will routinely compare the variances (F-test) and the means (t-test) of the verification test results with the quality control test results for thickness and compressive strength as appropriate using a KDOT spreadsheet. The F and t-tests, along with the KDOT Spreadsheet used to compare the Contractor's Quality Control (QC) results and KDOT's verification (QA) results, are described in Section 5.2.6-Comparison of Quality Control and Verification Tests, Part V. If KDOT verification test results do not show favorable comparison with the Contractor's quality control test results, KDOT verification test results will be used for material acceptance, material rejection and the determination of any pay adjustment for thickness and compressive strength. Follow the requirements stated in **subsection 501.5h.(6)** for failing t-tests. If the Contractor disputes KDOT's verification test results, and the Contractor and the Engineer cannot mutually agree on the use of KDOT test results to determine pay adjustments, the test results for the lot in question will be voided. In such case, new cores to represent each sublot will be taken on a 2-for-1 frequency, tested in the presence of the Engineer, and a new pay factor will be calculated using the KDOT spreadsheet. These cores shall be obtained in time to determine the 35-day compressive strengths unless approved by the Engineer. If the new pay factor results in the same or less pay due the Contractor than the voided pay factor, no payment will be made for the additional coring. If the new pay factor results in greater payment to the Contractor, KDOT will pay for each additional core at the contract set unit price.

(5) When the measurement of any core is deficient by more than 1 inch from plan thickness or has a 28-day compressive strength less than 2900 psi, take exploratory cores at a minimum of 10 foot intervals along a line passing through the deficient core and parallel to the centerline of the pavement unit. Continue along this line until an exploratory core taken in each direction is not deficient in length by more than 1 inch, or the compressive strength is a minimum of 2900 psi, depending on which case is being investigated. Exploratory cores will be used only to determine the length of pavement in a unit that is to be removed and replaced as provided below. Discard the original core representing the sublot. Randomly select another core (outside the defective area if left in place) to

represent the remainder of the sublot and use to compute the pay factor for the lot. All exploratory cores will be obtained in time to determine the compressive strengths within 35 days from the time the pavement was placed, unless approved by the Engineer. Obtain all cores representing the remainder of the sublot and used to compute the pay factor for the lot in time to determine the 35-day compressive strengths, unless approved by the Engineer.

When the Engineer determines that deficient pavement must be removed, the Contractor is required to remove the deficient areas and replace them with pavement of satisfactory quality, strength and thickness. When it is necessary to remove and replace a length of pavement and one end of the deficient pavement is less than 10 feet from an expansion, contraction or construction joint, remove and replace the entire pavement up to the joint. Remove the area so that new joints are a minimum of 10 feet apart. No additional compensation for materials or labor involved in the removal or replacement of the deficient concrete pavement will be made.

(6) For sublot thickness results greater than 1 inch more than design thickness, change the sublot thickness result to 1 inch more than the design thickness. The KDOT spreadsheet will calculate a new lot mean and sample standard deviation based on the corrected value.

h. Pay Adjustments for Mainline and Other Specified Pavement.

(1) General. A single combined pay adjustment for thickness and compressive strength will be made on a lot-by-lot basis and will be based on Contractor quality control test results on all quality control samples representing the lot of the completed pavement provided the statistical check is favorable. Otherwise follow **subsection 501.5g.(4)**. Compute the combined pay factor (***P***) (positive or negative) as shown in Equation 1.

Combined Pay Adjustment = ***P*** x (the number of square yards included in the lot) x (the contract unit price per square yard)

The thickness component of the combined pay factor will be based on values determined by using the difference between plan thickness and the measured core sample thickness, and the lower specification limit (*LSL*). *LSL* is defined as 0.2 inch less than plan thickness. The compressive strength component of ***P*** will be based on the corrected measured compressive strength of core samples taken from the pavement (see **subsection 501.5g.(4)** for LD correction). The pay adjustment amount will be added or subtracted as Concrete Pavement Composite Pay Adjustment on the pay estimate.

Note 1: A lot will normally be comprised of the results of 5 tests performed on a day's placement of a given pavement type. Lot and sublot size is defined in **subsection 501.5g.(2)**.

Note 2: The sample standard deviation (***S***) will be computed as shown in Section 5.2.1-Statistics, Part V.

(2) Thickness Quality Index ($\boldsymbol{Q_T}$) Computation. Calculate $\boldsymbol{Q_T}$ for each lot as shown in 5.2.1, Part V, using the following definitions, and round to hundredths.

Where: $\overline{X}$ is the average measured core length of all QC samples representing a lot, rounded to the nearest 0.1 inch.
LSL is the lower specification limit for thickness, and equals plan thickness minus 0.2 inch.
S is the sample standard deviation of the measured core lengths of all QC samples representing a lot, rounded to the nearest hundredth.

(3) Compressive Strength Quality Index ($\boldsymbol{Q_S}$) Computation. Calculate $\boldsymbol{Q_S}$ for each lot as shown in Section 5.2.1-Statistics, Part V, using the following definitions, and round to the nearest 0.1 inch.

Where: $\overline{X}$ is the average measured compressive strength of all QC core samples representing a lot, rounded to 1 psi.
LSL is the lower specification limit for compressive strength and is defined as 3900 psi.
S is the sample standard deviation of the compressive strength of all QC samples representing a lot, rounded to the hundredth.

(4) Determination of the Percent within Limits Values. First, use the computed $\boldsymbol{Q_T}$ to determine the thickness percent within limits value ($\boldsymbol{PWL_T}$) by locating $\boldsymbol{Q_T}$ in the left column of the Percent Within Limits (PWL) Table in Section 5.2.1-Statistics, Part V. Select the appropriate ($\boldsymbol{PWL_T}$) by moving across the selected *Q* row to the

column representing the number of samples in the lot. Next, follow the same procedure using the computed $\boldsymbol{Q_S}$ value to select the appropriate compressive strength percent within limits value ($\boldsymbol{PWL_S}$).

If either computed $\boldsymbol{Q_T}$ or $\boldsymbol{Q_S}$ is a negative value ($\overline{X}$ is less than *LSL*), the Engineer will determine if the material in the lot may remain in place. If the material is left in place, a value of 50.00 is assigned as $\boldsymbol{PWL_T}$ or $\boldsymbol{PWL_S}$, respectively. If both $\boldsymbol{Q_T}$ and $\boldsymbol{Q_S}$ are negative, assign a value of 50.00 for each **PWL** component.

If either $\boldsymbol{Q_T}$ or $\boldsymbol{Q_S}$ is greater than the largest $\boldsymbol{Q}$ shown in the table, a value of 100.00 is assigned as $\boldsymbol{PWL_T}$ or $\boldsymbol{PWL_S}$, respectively, or for both should $\boldsymbol{Q_T}$ and $\boldsymbol{Q_S}$ both exceed the values shown in the table.

(5) Computation of Combined Pay Factor. Compute $\boldsymbol{P}$ for thickness and compressive strength using Equation 1 and round to nearest hundredth.

Equation 1:
$$\boldsymbol{P} = \left(\frac{(\boldsymbol{PWL_T} + \boldsymbol{PWL_S}) * 0.60}{200}\right) - 0.54$$

(6) Failing t-test. If the t-test fails, KDOT's test result will be used to calculate that particular pay factor for the lot. Follow the procedures given in **subsection 501.5h.(4)** to determine the pay factor or disposition of the lot.

Use the following values to determine $\boldsymbol{Q_T}$ or $\boldsymbol{Q_S}$:

Where: $\overline{X}$ will be KDOT's test result for the lot.
N is equal to the number of Contractor's sublots.
S will be ⅜ inch for thickness and 500 psi for strength.
LSL will be as stated in **501.5h.(2)** for determining $\boldsymbol{Q_T}$, and **501.5h.(3)** for determining $\boldsymbol{Q_S}$.

i. Pay Adjustments for Pavements Cored for Thickness Only.

(1) General. A single pay adjustment for thickness only will be made on a lot-by-lot basis. It will be based on Contractor quality control test results on all quality control thickness samples representing the lot of the completed pavement provided the statistical check is favorable. Otherwise, follow **subsection 501.5h.(4)**. Compute the thickness pay factor ($\boldsymbol{P_T}$) (positive or negative) as shown in Equation 2.

Thickness Pay Adjustment = $\boldsymbol{P}_T$ x (the number of square yards included in the lot) x (the contract unit price per square yard)

The thickness component will be based on values determined by using the difference between plan thickness and the measured core sample thickness, and the lower specification limit (*LSL*). The pay adjustment amount will be added or subtracted as Concrete Pavement Composite Pay Adjustment on the pay estimate.

Note: A lot will normally be comprised of the results of tests performed on all sublots within a given pavement type. Lot and sublot size for pavements cored for thickness only is defined in **subsection 501.5g.(4)**.

(2) Determine $\mathbf{PWL}_T$ as shown in **subsection 501.5h.(4)**.

(3) Computation of Thickness Pay Factor. Compute the pay factor for thickness using Equation 2 and round to nearest hundredth.

Equation 2:
$$\boldsymbol{P_T} = \left(\frac{(\boldsymbol{PWL_T}) * 0.30}{100}\right) - 0.27$$

(4) Failing t-test. If the t-test fails, KDOT's test result will be used to calculate that particular pay factor for the lot. Follow the procedures given in **subsection 501.5h.(4)** to determine the pay factor or disposition of the lot.

Use the following values to determine $\boldsymbol{Q_T}$:

Where: $\overline{X}$ will be KDOT's test result for the lot.
N is equal to the number of Contractor's sublots.
S will be ⅜ inch for thickness.
LSL will be as stated in **501.5 i.(2)**.

j. Pay Adjustments for Urban PCCP Environment.

(1) General. A single pay adjustment will be made on a sublot-by-sublot basis. The adjustment will be based on a single randomly-selected (by KDOT) core for both strength and thickness. Compute the pay factor ($\mathbf{P}_U$) (incentive or disincentive) as shown in **Equation 3**.

The thickness component will be based on values determined by using the difference between plan thickness and the measured core sample thickness. When the measured core sample thickness is greater than the plan thickness, the "Δ thickness" of **Equation 3** is positive. When the core thickness is less than the plan thickness, the "Δ thickness" is negative. The compressive strength component will be based on values determined by breaking the core. Pay adjustment amount will be added or subtracted on the pay estimate. Remove and replace when values are less than those stipulated in **subsection 501.5g.(5)**. Maximum individual or combined pay adjustment is 103%.

(2) Computation of Urban PCCP Pay Factor. Compute the pay factor for thickness and strength using **Equation 3** and round to nearest hundredth.

Equation 3: $\mathbf{P}_U = (\mathbf{P}_{UC} + \mathbf{P}_{UT})/2$

Where:

$P_{UC} = 0.0001*(\text{strength}) + 0.59$; where strength is measured to the nearest 1 psi.

$P_{UT} = 0.15*(\Delta \text{ thickness}) + 1.00$; where Δ thickness is measured to the nearest 0.01 inch from plan thickness.

(3) Computation of Urban PCCP Pay Adjustment. Compute the sublot pay adjustment using **Equation 4**.

Equation 4: Urban PCCP Pay Adjustment = ($\mathbf{P}_U - 1$) x (the number of square yards included in the sublot) x (the contract unit price per square yard)

This adjustment will be paid for under the bid item Concrete Pavement Composite Pay Adjustment.

k. Computations and Rounding. KDOT will use a MICROSOFT EXCEL spreadsheet program to calculate pay adjustments for thickness and compressive strength and to compare the Contractor's QC and KDOT's verification test results. KDOT will provide a copy of this program to the Contractor, when requested. Additional information on the program may be obtained from the Bureau of Construction and Materials. It is the Contractor's responsibility to obtain the software required to run this program.

Values computed using equations referenced in this specification may vary slightly from the spreadsheet values due to rounding of numbers. In such cases the numbers computed by the spreadsheet take precedence.

l. General Payment. Payment for "Concrete Pavement", "Early Strength Concrete Pavement" and "Quality Control Testing" with pay adjustments as specified above is full compensation for the work specified.

Payment for "Concrete Core (Set Price)" at the contract set unit price will be paid when the results from the core information (required for disputed tests) increases payment to the Contractor.

In the event of overruns or underruns of the Contractor quality control testing, the Engineer will not adjust the contract unit price.

Pay adjustments for thickness-only and pay adjustments for thickness and strength combined will use the bid item "Concrete Pavement Composite Pay Adjustment", and will be shown as an added item to the contract.

Hardened Concrete Properties

KT-23: Flexural Strength of Concrete
(Three-Point Loading Method)

1

Outcome

- Determine the flexural strength of concrete by testing the simple beam with three-point loading. (AASHTO T97)

2

Tools

- Testing Machine that will apply a measured load to the beam at the three points of the span, having a total span of 18 inches. (Make sure it is clean and lubricated every 6 months)
- Calipers
- Steel ruler graduated in 0.01 inches that is at least 12 inches long
- Leather Shims – ¼ by 1 ½ by 6+ inches. The shims must be slightly longer than the width of the test specimen (6 inches)
- Feeler Gauges

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3

Test Specimen

- Beam should be molded and cured according to KT-22
- The beams should be kept moist until time for test
- The nominal size should be 6 inches by 6 inches by 21 inches
- Lines should be drawn at 6-inch intervals equally spaced to represent the support and load applying block locations
- The marks will help to line up the beam in the breaker

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4

Example of Beam Breaker

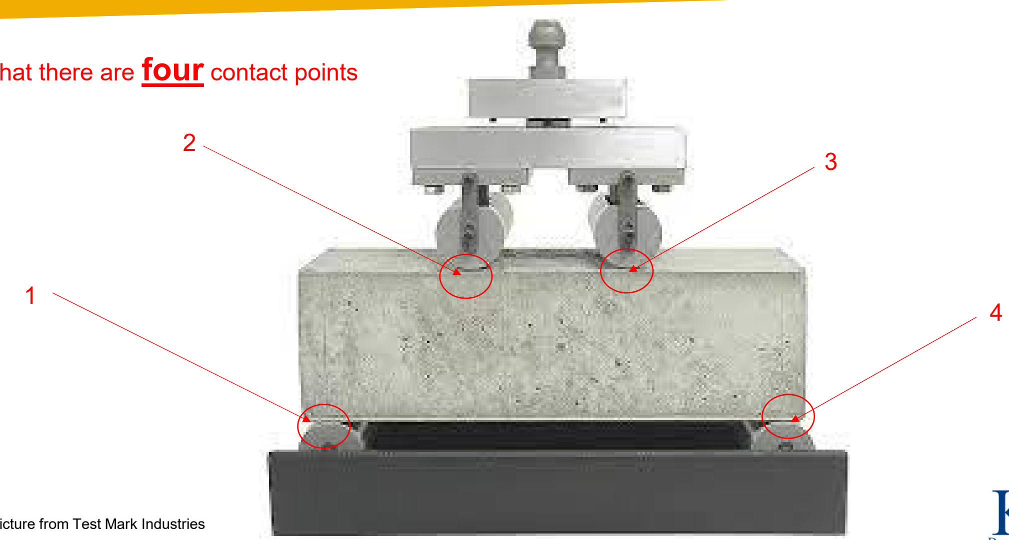
Picture from Test Mark Industries

Kansas Department of Transportation

5

Example of Beam Breaker w/ Contact Pts

Note that there are **four** contact points



Picture from Test Mark Industries

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6

Test Procedure

- Beams are tested to determine if recently placed concrete can be opened to traffic or to determine if it is safe to remove forms from recently placed structures.
- The beam should be tested in a manner that the top of the beam (the surface you finished) is facing either side.
- If beam is twisted or warped by more than 1/8 inch at any plane, the beam should be discarded, and the mold should be repaired or replaced before using the molds again.

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Placing the Beam

- Center the beam in the machine so that a minimum of 1 inch of the beam extends outside the support rollers
- Apply a load of between 3% and 6% of the expected load
- The gap at the contact points need checked
  - If the gap is less than 0.004 inches, proceed with the test
  - If the gap is between 0.004 inches and 0.015 inches, shims are needed before testing
  - If the gap is greater than 0.015 inches, then grind the contact surfaces and recheck the gap before testing the beam
  - The gap should not be wider than 1 inch at any point

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Applying the Load

- The load may be applied rapidly until approximately 50% of the breaking load has been reached.
- Beyond that point, reduce the rate of loading so that the rate remains within 125 psi and 175 psi per minute until the beam breaks
- Note and record the load required to break the beam

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9

Measuring the Beams

- Take 3 measurements at the fracture across each dimension
- One at each edge and at the center to the nearest 0.05 inches to determine the average width, average depth and the line of fracture on each beam
- The measurements should be taken how the beam is placed in the break machine (hand-finished surface facing sideways)

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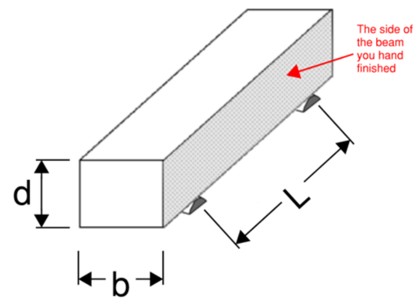
Calculations

- If the fracture initiates in the tension surface (the side that was facing down in the break machine) within the middle third of the span use:

$$R = \frac{(P)(L)}{bd^2}$$

R ≡ Modulus of Rapture (PSI)
P ≡ Maximum applied load (lb_f)
L ≡ span length (inches)
b ≡ Avg. Width of specimen (inches)
d ≡ Avg. Depth of specimen (inches)



Beam Layout in Breaker

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Example 1

- Depth of beam = 5.70 inches
- Width of beam = 6.12 inches
- Load at break = 4,800 lb_f

$$R = \frac{4{,}800(18)}{6.12\ (5.70)^2}$$ = 434.52 PSI → 435 PSI

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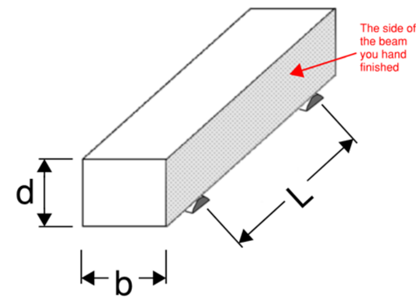
Calculations (Cont.)

- If fracture occurs outside the middle third but less than 5% outside of the span length use:

$$R = \frac{3(P)(a)}{bd^2}$$

R ≡ Modulus of Rapture (PSI)
P ≡ Maximum applied load (lb_f)
L ≡ span length (inches)
b ≡ Avg. Width of specimen(inches)
d ≡ Avg. Depth of specimen (inches)
a ≡ Avg. Distance between fracture and nearest support (inches)



Beam Layout in Breaker

Calculations (Cont.)

- If the fracture occurs outside of the middle third of the span length by more than 5%, then the results should be discarded from the average PSI.
- Report to the nearest 5 PSI. Take the average of the three breaks to determine the set average

Example 2

- Depth of beam = 5.70 inches
- Width of beam = 6.12 inches
- Load at break = 4,800 lb_f
- Avg. Distance between fracture and nearest support = 5.75 inches

$R = \frac{3(4{,}800)(5.75)}{6.12\ (5.70)^2}$ = 416.41 PSI → 415 PSI

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Questions?

16

5.9.23 FLEXURAL STRENGTH OF CONCRETE (THIRD-POINT LOADING METHOD) (Kansas Test Method KT-23)

1. SCOPE

This method of test covers the procedure for determining the flexural strength of concrete by test of a simple beam with third-point loading. **KT-23** reflects testing procedures found in **AASHTO T 97**.

2. REFERENCED DOCUMENTS

2.1. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

2.2. AASHTO T 23; Making and Curing Concrete Test Specimens in the Field

2.3. AASHTO T 97; Flexural Strength of Concrete (Using Simple Beam with Third Point Loading)

3. APPARATUS

3.1. A testing machine which will apply a measured load to the beam at the third points of the span. The machine will have a span length of 18 in (460 mm). Suitable machines are made available to the Field Engineer by the District Materials Engineer.

3.1.1. Clean and lubricate the apparatus every six months.

3.2. Caliper and a 12 in (300 mm) steel rule graduated in 0.01 in (0.1 mm).

3.3. Leather shims, 1/4 by 1 1/2 by 6+ in (6.4 by 38 by 160 mm). The shim must be slightly longer than the 6 in (160 mm) width of the test specimen.

3.4. Feeler gauges.

4. TEST SPECIMEN

4.1. A nominal 6 by 6 by 21 in[1] (152.4 by 152.4 by 530 mm) concrete beam, molded and cured according to **KT-22** of this manual. The beam must be kept moist until time of test.

4.2. Draw lines on the beam at 6" intervals equally spaced from the end of the beam representing the support and load applying block locations. Use these marks when installing the beam in the test fixture.

5. TEST PROCEDURE

5.1. Age of testing:

5.1.1. Beams tested to determine the safe date for removal of forms from structures shall be tested at ages mutually agreed upon by the Engineer and the Contractor. Other times for testing are contained in the standard specifications.

5.2. Install specimen:

[1] The length dimension is 1 in (25.4 mm) longer than **AASHTO T 23**.

5.2.1. Place the specimen on its side, centered in the machine in such a manner that a minimum of 1 in (25 mm) of the beam extends outside the support rollers. Apply a load of between 3 and 6% of the expected ultimate load. If full contact is obtained between the specimen and the load-applying blocks and the supports so that there is no gap longer than 1 in (25 mm) or the gap is less than 0.004 in (0.1 mm) deep, test the specimen without further preparation. If full contact is not obtained between the specimen and the load-applying blocks and the supports so that there is a 1 in (25 mm) or longer gap in excess of 0.004 in (0.1 mm) and not more than 0.015 in (0.38 mm) deep, grind the contact surfaces of the specimen, or shim with leather strips.

5.2.1.1 If full contact is not obtained between the specimen and the load-applying blocks and the supports so that there is a 1 in (25 mm) or longer gap in excess 0.015 in (0.38 mm), grind the contact surfaces of the specimen until it complies with the requirements stated in **Section 5.2.1.** above.

5.2.1.2. If the specimen is twisted or warped 1/8 inch (3.2 mm) or more in any plane, discard the specimen and repair or replace the mold.

5.3. Application of load:

5.3.1. The load may be applied rapidly until approximately 50% of the breaking load has been reached. Beyond that point, reduce the rate of loading so that the rate of increase in extreme fiber stress remains within 125 to 175 psi (861 to 1207 kPa) per minute until the specimen breaks, (1500 to 2100 lbf per minute).

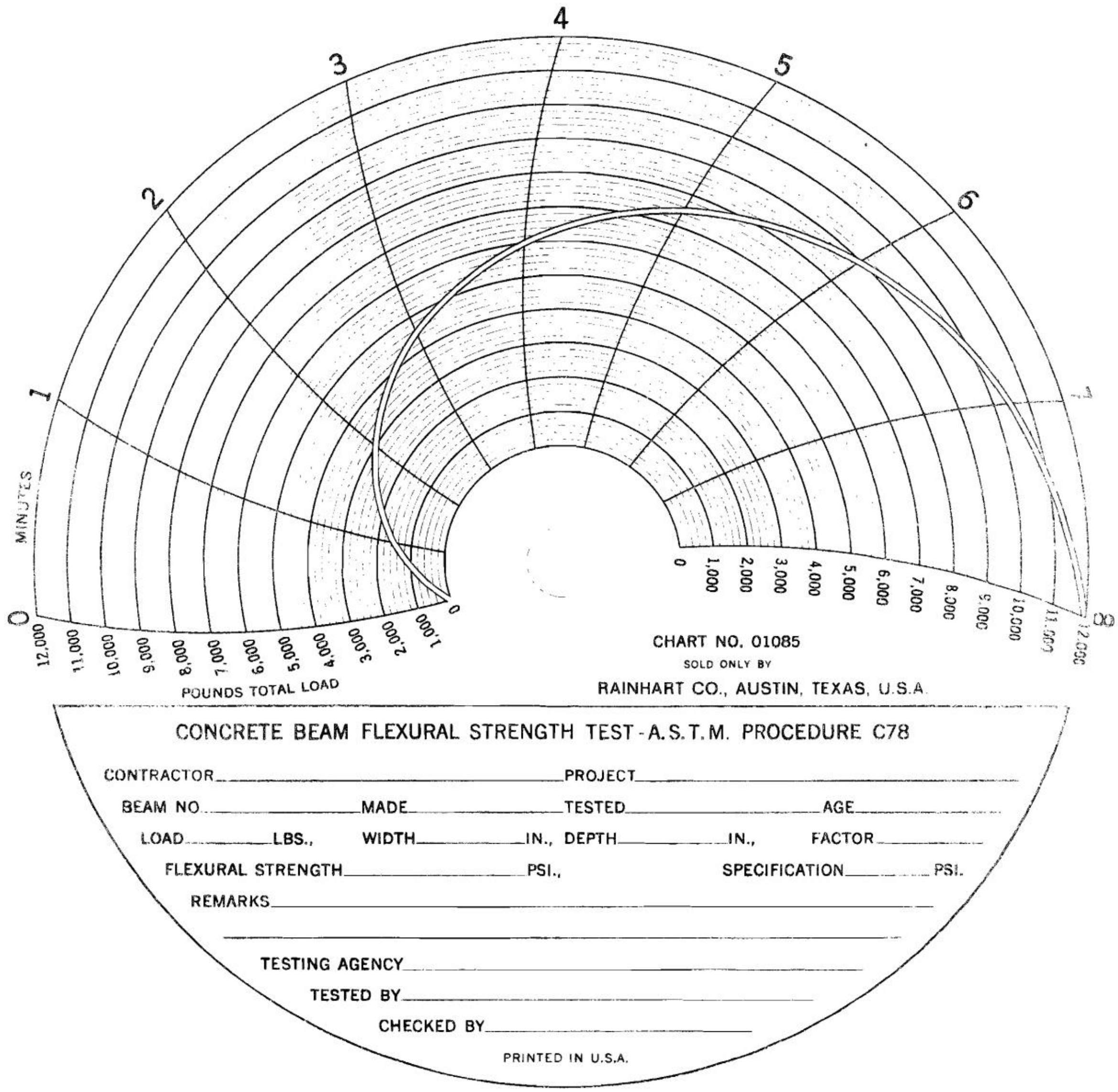
5.3.1.1. Chart No. 01085, Figure 1 is the correct chart to use on the Rainhart Beam Breaker. This chart loads at a rate of 1746 lbf/min (1016 kPa/min).

Note and record the total load required to break the beam.

5.4. Measurement:

5.4.1. Take and record three measurements at the fracture across each dimension (one at each edge and at the center) to the nearest 0.05 in (1.3 mm) to determine the average width, average depth and line of fracture location of the specimen at the section of failure.

Figure 1 Chart No. 01085



6. CALCULATIONS

6.1. If the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture to the nearest 5 psi as follows:

(ENGLISH)

$$R = \frac{(P)(L)}{bd^2}$$

(SI)

$$R = \frac{1000(P)(L)}{bd^2}$$

Where: R= Modulus of rupture in psi (kPa)
P= Maximum applied load in lbf (N)
L= Span length in (mm)
b= Avg. Width of specimen in (mm) (as tested)
d= Avg. Depth of specimen in (mm) (as tested)

Sample Calculations (English):

Depth of beam = 5.70 in
Width of beam = 6.12 in
Load at break = 4800 lbf

$$R = \frac{4800\ (18)}{6.12\ (5.70)(5.70)} = 435 \text{ psi}$$

Sample Calculations (SI):

Depth of beam = 145 mm
Width of beam = 155mm
Span length = 460 mm
Load at break = 21400 N

$$R = \frac{1000\ (21400)(460)}{155\ (145)(145)} = 3020 \text{ kPa}$$

6.2 If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5% of the span length, calculate the modulus of rupture as follows:

(ENGLISH)

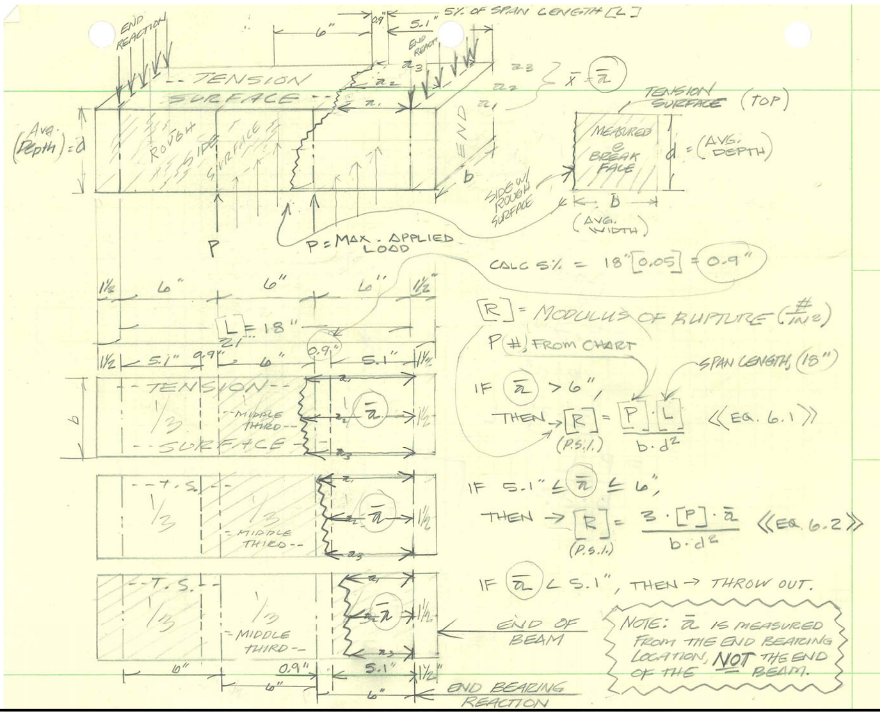
$$R = \frac{3(P)(a)}{bd^2}$$

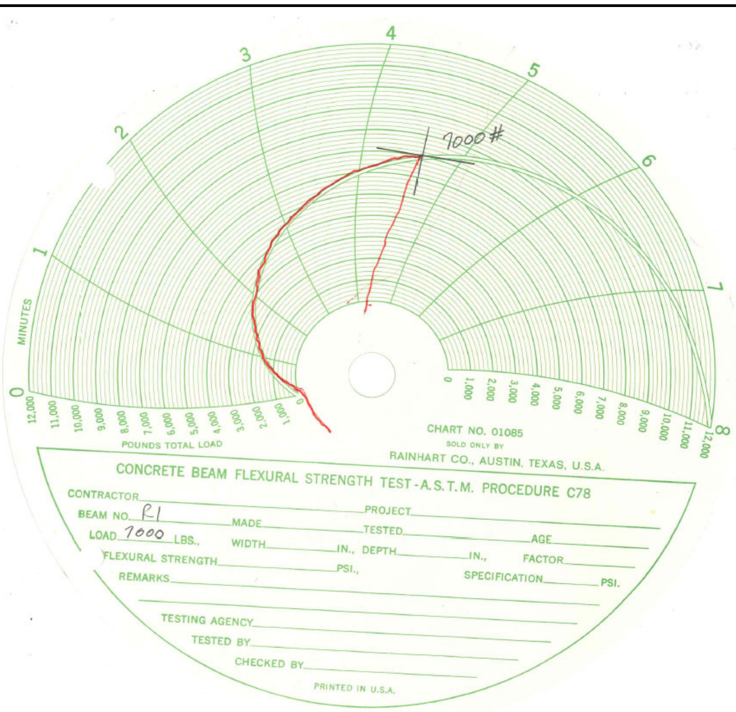
(SI)

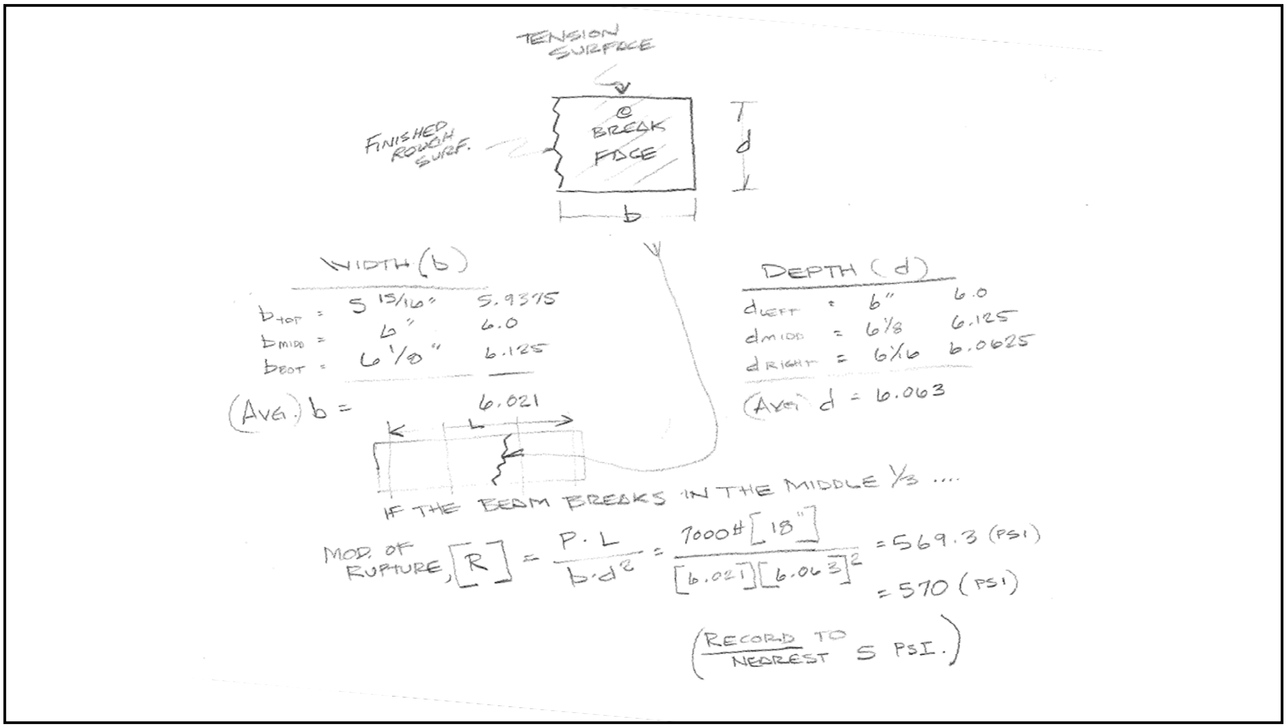
$$R = \frac{3000(P)(a)}{bd^2}$$

Where: a = average distance between line of fracture and the nearest support measured on the tension surface of the beam, in (mm).

If the fracture occurs in the tension surface outside of the middle third of the span length by more than 5% of the span length, discard the results of the test.


5% OF SPAN LENGTH [L]
TENSION SURFACE
END REACTION
P = MAX. APPLIED LOAD
CALC 5% = 18"[0.05] = 0.9"
L = 18"
[R] = MODULUS OF RUPTURE (#/IN²)
P (#) FROM CHART
SPAN LENGTH (18")
IF x̄ > 6",
THEN [R] = [P]·[L] / b·d² «EQ. 6.1»
IF 5.1" ≤ x̄ ≤ 6",
THEN [R] = 3·[P]·x̄ / b·d² «EQ 6.2»
IF x̄ < 5.1", THEN → THROW OUT.
END OF BEAM
NOTE: x̄ IS MEASURED FROM THE END BEARING LOCATION, NOT THE END OF THE BEAM.
END BEARING REACTION


7000#
MINUTES
POUNDS TOTAL LOAD
CHART NO. 01085
SOLD ONLY BY
RAINHART CO., AUSTIN, TEXAS, U.S.A.
CONCRETE BEAM FLEXURAL STRENGTH TEST - A.S.T.M. PROCEDURE C78
CONTRACTOR
PROJECT
BEAM NO. R1
MADE
TESTED
LOAD 7000 LBS.
WIDTH IN., DEPTH IN.,
AGE
FLEXURAL STRENGTH PSI.,
FACTOR
REMARKS
SPECIFICATION PSI.
TESTING AGENCY
TESTED BY
CHECKED BY
PRINTED IN U.S.A.


TENSION SURFACE
@ BREAK FACE
FINISHED ROUGH SURF.
d
b
WIDTH (b)
b TOP = 5 15/16" 5.9375
b MIDD = 6" 6.0
b BOT = 6 1/8" 6.125
(AVG.) b = 6.021
DEPTH (d)
d LEFT = 6" 6.0
d MIDD = 6 1/8 6.125
d RIGHT = 6 1/16 6.0625
(AVG) d = 6.063
IF THE BEAM BREAKS IN THE MIDDLE 1/3 ....
MOD. OF RUPTURE, [R] = P · L / b·d² = 7000# [18"] / [6.021][6.063]² = 569.3 (PSI)
= 570 (PSI)
(RECORD TO NEAREST 5 PSI.)

Hardened Concrete Properties

KT-44 Method of Testing the Strength of Portland Cement Concrete by use of the Maturity Meter

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1

Scope

- This two-step process covers the procedure for using the maturity concept as a non-destructive method to determine in-place concrete strength.
- It may be used for determining the strength of concrete for opening to traffic or for removal of formwork

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Procedure

- First, a relationship must be established between the measured maturity values and the concrete strength by destructive methods (testing of beams or cylinders)
- Second, the instrumentation of the in-place concrete. Temperature probes are installed in the concrete and the temperature is measured. From those measurements along with the age at which the measurements were taken, maturity values are determined
- A maturity meter or temperature measuring device and a computer/calculator may be used to determine the maturity values

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Implementation

- When using this method, the Contractor and KDOT shall jointly develop a plan that includes:
  - The Contractor is responsible for the development of the maturity curve, KDOT should monitor the curve
  - The temperature monitoring process of the constructed pavement or structure should be the responsibility of the Contractor, monitored by KDOT

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Implementation (Cont.)

- For concrete furnished from a construction or stationary mixer, a maturity curve may be established ahead of actual construction of the specified project
- The mixer should be in place prior to construction of the specific project
- The test specimens should be cast with concrete made from the same plant using the same mixture that will be used on the project
- The engineer should be informed and have the opportunity to observe the development of the maturity curve

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5

The Maturity Concept

- The hydration of cement and gain in strength of the concrete are dependent on both curing time and temperature
- The strength of the concrete may be expressed in some function of time and temperature
- The information can be used to determine the strength of concrete without conducting physical tests

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The Maturity Concept (Cont.)

$M(°F \times hours) = \sum[(T - T_o)\Delta t]$

Where M is the maturity in degree F-hours (TTF), Δt is the interval in hours(or days), T is the average concrete temperature during the time interval Δt, and T_o is the datum temperature at which concrete ceases to gain strength with time. The value T_o = 14°F (-10°C) is most commonly used. As a result, the equation becomes:

$M(°F \times hours) = \sum[(T - 14)\Delta t]$

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Apparatus

- Appropriate testing machine as described in KT-23 and KT-76
- Maturity Meter and sensors that automatically compute and display either temperature/time factor or equivalent age
- Hand-held thermometer with thermocouple wire and connectors

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Procedure (1/4)

- To establish a maturity/strength relationship for the concrete mix, use a maturity meter/thermal meter and a testing machine
- Before using any maturity meter, check to be sure that the datum temperature is set to 14°F (-10°C)
- Cast/cure a minimum of twelve 6” x 6” x 21” beams or twelve 4” x 8” or 6” x 12” or more cylinders (per KT-22)
- Test the air content and slump of the concrete and record the values
- Make sure that the concrete meets the mix specifications
- The specimens should be cast from a field batch of at least 3 yd^3

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Procedure (2/4)

- Embed a sensor probe in one test specimen to monitor temperature. This specimen will be the last to be tested
- The probe should be inserted at approximately the center of the specimen
- Secure the wire to prevent the wire from being inadvertently pulled out
- For field cast specimens, the meter can be stored in a lab trailer or vehicle with the probes running outside to the beam in a sandpit.

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Procedure (3/4)

- Determine maturity values and strength at four different ages
- Test three specimens for strength at each age and calculate the average strength at each age
- The maturity value shall be calculated using the average temperature reading from the previous test for strength
- The tests shall be spaced such that they are performed at somewhat consistent intervals of time and span the range of strength(s) required

Additional test specimens can be cast at a later time and tested at earlier ages to add data to the strength/maturity relationship

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Procedure (4/4)

- Plot the measured strength against the corresponding values of maturity at different ages, as determined by the maturity meter
- The maturity number corresponding to the desired strength shall be used to determine when the concrete has reached the desired strength
- Due to influences on the maturity of the strength of concrete in various mixtures, a maturity/strength relationship established for one mixture shall not be used for another mix

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Validation (1/3)

- A validation test should be conducted to determine if concrete strength is being accurately represented by the maturity curve
- Cast and cure three specimens using the same procedure and manner as used to develop the current maturity curve
- Test all three specimens as close as possible to the maturity value which was determined to represent the desired strength
- If the test average is within +/- 50 psi for beams or +/- 500 psi for cylinders on the original curve, the original curve should be considered validated. If not, a new curve should be developed.

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Validation (2/3)

- The maturity values and strength should be determined at four different ages
- Calculate the maturity value by using the average temperature reading from the previous test for strength
- The tests should be spaced so that they are performed somewhat consistent time intervals and span the range of strength required

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Validation (3/3)

- Additional specimens can be cast at a later time and tested at earlier ages to add data and to aid in determining the appropriate time to saw
- Plot the measured strength against the values of maturity at different ages
- The maturity number corresponding to the strength should be used to determine when the concrete has reached the desired strength
- The validation tests should be conducted once per month to accurately represent the current maturity curve

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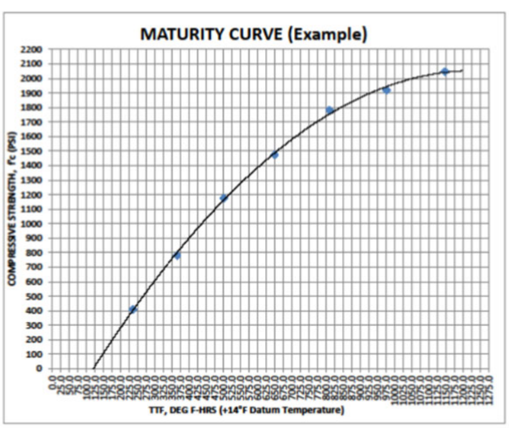
Maturity Curve Example



Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4	780
8	84.2	82.4	136.8	502.2	1178
10	91.4	87.8	147.6	649.8	1475
12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4	1920
16	98.6	98.6	169.2	1146.6	2049

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Calculations (1/5)

Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4	780
8	84.2	82.4	136.8	?	1178
10	91.4	87.8	147.6	649.8	1475
12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4	1920
16	98.6	98.6	169.2	?	2049

TTF = a + b

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Calculations (2/5)

Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4 (a)	780
8	84.2	82.4	136.8 (b)	?	1178
10	91.4	87.8	147.6	649.8	1475
12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4	1920
16	98.6	98.6	169.2	?	2049

TTF = a + b

18

Calculations (3/5)

Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4	780
8	84.2	82.4	136.8	502.2	1178
10	91.4	87.8	147.6	649.8	1475
12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4	1920
16	98.6	98.6	169.2	?	2049

TTF = a + b ⟶ TTF = 365.4 + 136.8 = 502.2

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Calculations (4/5)

Solve for the TTF at 16 hours:

a) 502.2
b) 1,144.8
c) 1,024.5
d) 1,146.6

Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4	780
8	84.2	82.4	136.8	502.2	1178
10	91.4	87.8	147.6	649.8	1475
12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4	1920
16	98.6	98.6	169.2	?	2049

TTF = a + b

20

Calculations (5/5)

Solve for the TTF at 16 hours:

a) 502.2
b) 1,144.8
c) 1,024.5
d) **1,146.6**

Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4	780
8	84.2	82.4	136.8	502.2	1178
10	91.4	87.8	147.6	649.8	1475
12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4 (a)	1920
16	98.6	98.6	169.2 (b)	1,146.6	2049

TTF = a + b ⟶ TTF = 977.4 + 169.2 = 1,146.6

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Questions?

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5.9.44 METHOD OF TESTING THE STRENGTH OF PORTLAND CEMENT CONCRETE USING THE MATURITY METHOD (Kansas Test Method KT-44)

1. SCOPE

1.1. This method covers the procedure for using the maturity concept as a non-destructive method to determine in-place concrete strength. It may be used for determining the strength of concrete for opening to traffic or for removal of formwork.

1.2. This is a two-step procedure. First, a relationship must be established between the measured maturity values and the concrete strength as measured by destructive methods (that is, through testing of beams or cylinders). The development of the maturity-strength curve is done in the field prior to the beginning of construction using project materials and the project proportioning and mixing equipment. The second step is the instrumentation of the in-place concrete. Temperature probes are installed in the concrete and the temperature is measured. From those measurements, along with the age at which the measurements were taken, maturity values are determined. A maturity meter or temperature measuring device and a computer or calculator may be used to determine the maturity values.

2. REFERENCED DOCUMENTS

2.1. KT-18; Air Content of Freshly Mixed Concrete by the Pressure Method

2.2. KT-21; Slump of Portland Cement Concrete

2.3. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

2.4. KT-23; Flexural Strength of Concrete (Third Point Loading Method)

2.5. KT-76; Method for Testing the Compressive Strength of Molded Cylindrical Concrete Specimens

2.6. ASTM C1074; Standard Practice for Estimating Concrete Strength by the Maturity Method

3. IMPLEMENTATION

3.1. When maturity testing is used, the Contractor and KDOT shall jointly develop a plan. The plan shall include:

- The Contractor shall be responsible for the development of the maturity curve. The curve development shall be monitored by KDOT.

- The temperature monitoring process of the constructed pavement or structure shall be the responsibility of the Contractor and monitored by KDOT.

3.2. For concrete furnished from a construction or stationary mixer, which is in place prior to construction of the specified project, a maturity curve may be established ahead of actual construction of the specified project. The test specimens shall be cast with concrete made from the same plant using the same mixture as will be used in the specified project. The engineer shall be informed and have an opportunity to observe the development of the maturity curve.

4. THE MATURITY CONCEPT

4.1. The hydration of cement and gain in strength of the concrete are dependent on both curing time and temperature. Thus, the strength of the concrete may be expressed as some function of time and temperature. This information can then be used to determine the strength of concrete without conducting physical tests. The time-temperature function commonly used is the maturity concept proposed by Nurse-Saul (**ASTM C1074**).

(1) $M(\,°F \times \text{hours}\,) = \sum[(T - T_o)\Delta t]$

4.2. Where M is the maturity in degree °F-hours [M is also termed the time-temperature factor (TTF)], Δt is the interval in hours (or days), T is the average concrete temperature during the time interval Δt, and T_o is the datum temperature at which concrete ceases to gain strength with time. The value of T_o= 14°F (-10°C) is most commonly used. As a result, Equation (1) becomes:

(2) $M(°F \times \text{hours}\,) = \sum[(T - 14)\Delta t]$

NOTE: If there are large differences in temperature between the test specimens and the in-place concrete, an equivalent age function may be needed. See **ASTM C1074**.

5. APPARTUS

5.1. See **KT-22** of this manual for specimen fabrication.

5.2. Appropriate testing machine as described in **KT-23 and KT-76** of this manual**.**

5.3. Maturity meter and sensors that automatically compute and display either temperature-time factor or equivalent age.

5.4. Hand-held thermometer with thermocouple wire and connectors.

6. PROCEDURE

6.1. To establish a maturity-strength relationship for a concrete mix, a maturity meter or a thermal meter and a testing machine are needed. The following procedure shall be used: Note: before using any maturity meter, check to be sure that the datum temperature is set to 14°F (-10°C).

6.1.1. Cast and cure a minimum of twelve 6 in x 6 in x 21 in (152 mm x 152 mm x 530) beams, or twelve 4 x 8 in (102 x 200 mm) or 6 x 12 in (152 x 300 mm) or more cylinders per **KT-22** of this manual. Test the air content and slump of the concrete per **KT-18** and **KT-21** of this manual, and record these values. The concrete shall meet specifications. The specimens shall be cast from a field batch of at least 3 cu. yd. (3 m^3).

6.1.2. Embed a sensor probe in one test specimen to monitor temperature. This specimen will be the last to be tested. The probe shall be inserted at approximately the center of the specimen. Secure the wire to prevent the wire from being inadvertently pulled out of the beam. When the thermal meter is used, the measured temperature should be substituted into Equation (2) to obtain values of maturity. When a maturity meter is used, the meter computes the values. Twelve test specimens shall be tested as described in **Section 6.1.4**. of this test method. An example calculation of the maturity factor is attached.

6.1.3. For field cast specimens the meter can be stored in a lab trailer or vehicle with the probes run outside, to the beam in a sandpit. This will allow a maturity meter to be protected from the weather and theft.

6.1.4. Determine maturity values and strength at four different ages. Test three specimens for strength at each age and calculate the average strength at each age. The maturity value shall be calculated using the average temperature reading since the previous test for strength. The tests shall be spaced such that they are performed at somewhat consistent intervals of time and span the range of strength(s) required.

6.1.4.1. Additional test specimens may be cast at a later time and tested at earlier ages to add data to the strength-maturity relationship as an aid to determine the appropriate time to saw.

6.1.4.2. Plot the measured strength against the corresponding values of maturity at different ages, as determined by the maturity meter or by hand methods. The maturity number corresponding to the desired strength shall be used to determine when the concrete has reached the desired strength. An example of Maturity-Strength Development Relationship is attached.

6.2. Since the influence of maturity on strength of concrete is somewhat different for various mixtures, a maturity-strength relationship established for one mixture shall not be used for another mixture.

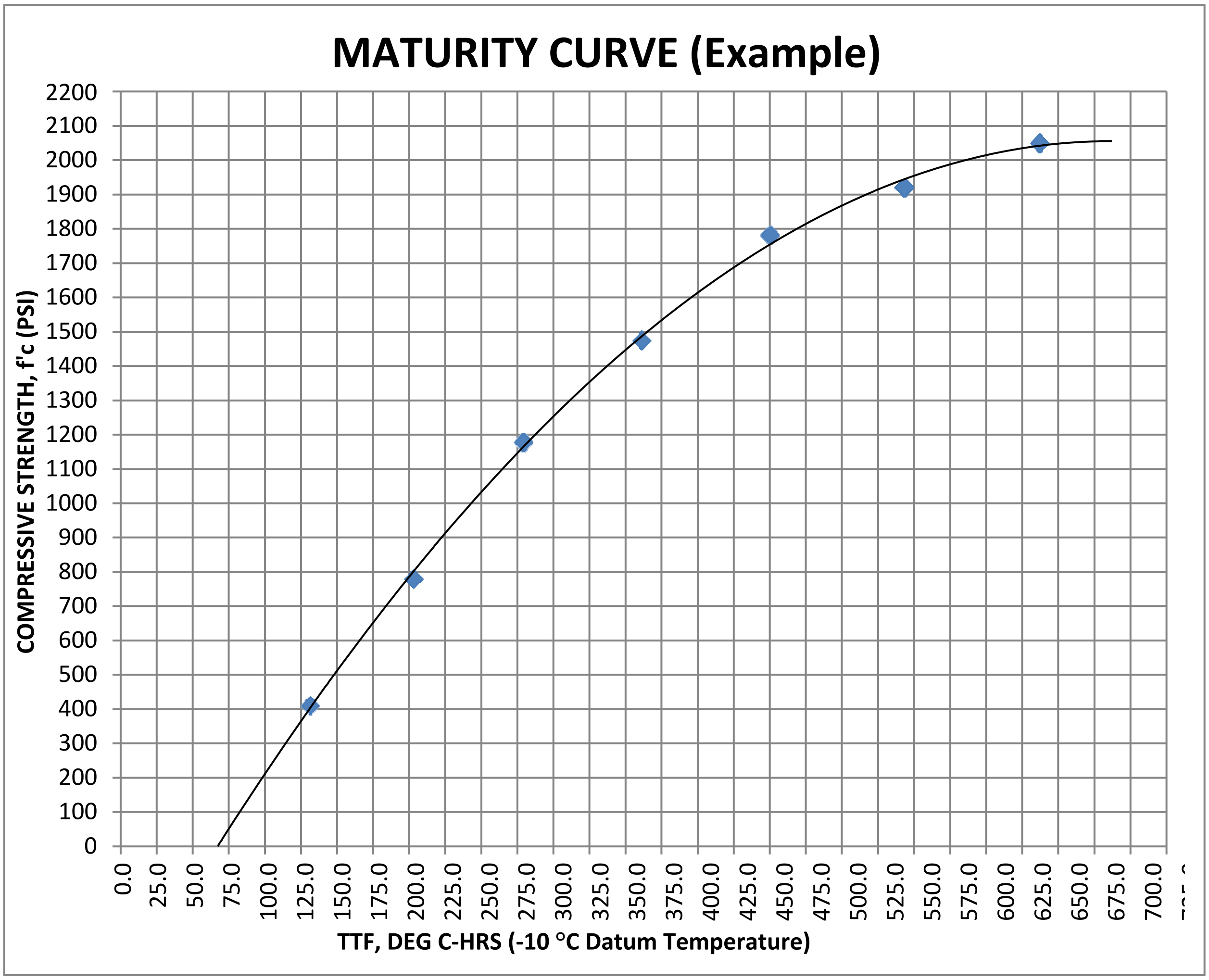
NOTE: To be considered the same mixture, no component may vary by more than 5% from the initial value.

7. VALIDATION

7.1. Once per month, a validation test shall be conducted to determine if concrete strength is being accurately represented by the current maturity curve. Cast and cure three specimens using the same procedure and manner as used to develop the current maturity curve. Test all three specimens as close as possible to the maturity value which was determined to represent the desired strength. If the average of these tests is within ± 50 psi (0.34 MPa) for beams or ± 500 psi (3.4 MPa) for cylinders of the original curve at the TTF, the original curve shall be considered validated. If the average value varies more than ± 50 psi (0.34 MPa) for beams or ± 500 psi (3.4 MPa) for cylinders of the original maturity curve value at the TTF at which the validation beams were tested, a new maturity curve shall be developed.

Examples:

Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees C	Avg Temp, degrees C	(Avg Temp + 10)Δt, degrees C	TTF, C-Hrs	Compressive Strength, PSI
0	22				
2	22	22.0	64.0	64.0	
4	25	23.5	67.0	131.0	411
6	27	26.0	72.0	203.0	780
8	29	28.0	76.0	279.0	1178
10	33	31.0	82.0	361.0	1475
12	36	34.5	89.0	450.0	1781
14	37	36.5	93.0	543.0	1920
16	37	37.0	94.0	637.0	2049



Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4	780
8	84.2	82.4	136.8	502.2	1178
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12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4	1920
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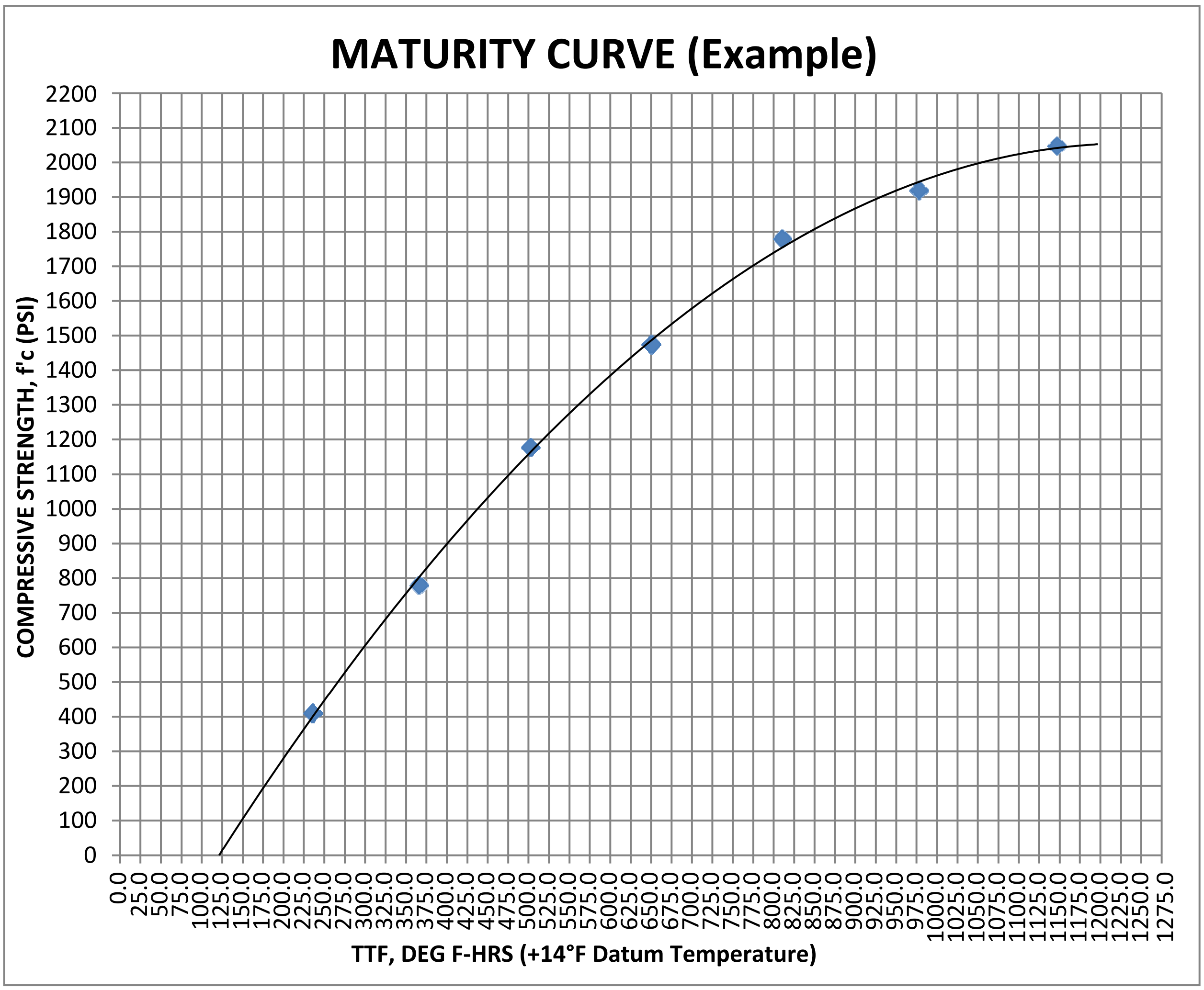

KT-49: Method for Obtaining and Testing Drilled Cores from PCCP and Precast Girders

Coring in-situ concrete

1

Scope

- Provide standardized procedures for obtaining and testing specimens to determine compressive strength and depth of in-place concrete in pavement and precast girders
- Sampling and sample preparation requirements are given to ensure the dimensional requirements are met and that the specimens are made of intact, sound concrete and are as free of flaws as the concrete will allow

2

Significance and Use

- The strength of concrete measured by tested core samples is affected by the distribution and amount of moisture in the specimen
- There is no standard procedure to condition a specimen that ensures it will be in the identical moisture condition as the in-situ concrete during all times of testing
- The moisture conditioning procedures in this test method are intended to provide reproducible moisture conditions that minimize within laboratory and between laboratory variations and to reduce the effects of moisture introduced during specimen preparation

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3

Apparatus (1/4)

- Testing machine shall comply with AASHTO T 22
  - Have sufficient capacity and capable to provide rates of loading corresponding to a stress rate on the specimen of 35 +/- 7 psi/sec
  - The rate of movement should be maintained at least during the second half of the anticipated loading phase
  - Should be capable of testing cores up to and including 12 inches in length

The faces of the bearing blocks need to be checked for planeness every 12 months, repairing or replacing if needed

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4

Apparatus (2/4)

- The bearing block faces should not depart from plane by more than 0.001 inches (0.02 mm) along any 6 inches in length for bearing blocks that have a diameter of 6 inches or larger
- For smaller bearing blocks, the faces should not depart from plane by more than 0.001 inches (0.02 mm) in any direction
- New bearing blocks need to be manufactured within ½ of this tolerance

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Apparatus (3/4)

- Clean and lubricate the curved surfaces of the socket and spherical portion of the upper bearing block every 6 months
- Check for any visible wear on the spherical portion of the upper bearing block during the cleaning and lubrication
- Any noticeable wear is cause for replacement of the upper bearing block
- Conventional motor oil should be used for the lubricant

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Apparatus (4/4)

- Core Drill – a diamond drill should be used to obtain the cylindrical core specimens
- Calipers
- Steel ruler – 12 inches long and graduated in 0.01 inches

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Sampling

- Core should be from a bed of concrete that is not near joints or obvious edges. Cores should be taken from near the middle of the placed concrete when possible
- All cores for the purpose of determining compressive strength must be taken a minimum of 21 days after the pavement has been placed and in time to determine the 28-day compressive strength

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8

Determining the Length

- Cores used as specimens for length measurements should be in every way representative of the concrete in the structure from which it was removed
- If particles are bonded to the bottom of the core, use a chisel and hammer to remove the particles in order to expose the lower surface of the core
- Take three caliper measurements at 120-degree intervals along the circumference of the circle to the nearest 0.01 inches to determine the average length

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Specimen (1/4)

- For concrete greater than or equal to 8 inches thick, the diameter of the core should be at least 3.75 inches
- Cores less than 3.75 inches are permitted when it is impossible to obtain cores with length-to-diameter (L/D) ratio ≥ 1 for compressive strength evaluations
- For concrete thickness of less than 8 inches, the diameter should preferably be at least 3 times the nominal maximum size of the coarse aggregate

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Specimen (2/4)

- Moisture Conditioning
  - Procedure specified to preserve the moisture of drilled cores and to provide a reproducible moisture condition that minimizes the effects of moisture induced by wetting during drilling and preparation
  - After coring, wipe off the surface drill water and allow remaining surface moisture to evaporate. When surface appears dry, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss within an hour of drilling
  - Transport cores to the testing lab as soon as possible

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Specimen (3/4)

- Always keep the cores in sealed plastic bags or containers except during end preparation and for a maximum time of 2 hrs. to permit capping before testing
- If water is used during end preparation, complete the operation asap but not later than 2 days after obtaining the cores
- After end preparation, wipe off the surface moisture and allow the surface to dry. Then place the cores back in the bags or containers to minimize the exposure to water

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Specimen (4/4)

- End preparation should make the cores smooth and perpendicular to the longitudinal axis
- Saw or grind no more than 0.375 inches from the top to remove the tining or roughness
- Saw or grind the bottom only the amount that is required for the core to fit into the testing machine
- At no point should either end protrude by more than 0.125 inches from plane before capping with sulfur

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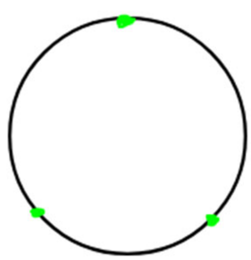
Capping

- Cap according to KT-77
- Measure the diameter and length prior to testing to compute the length to diameter ratio (L/D)
- All measurements are taken to the nearest 0.01 inches
- Take the length measurement at 120-degree increments (3 measurements)



Approximate locations for length measurements

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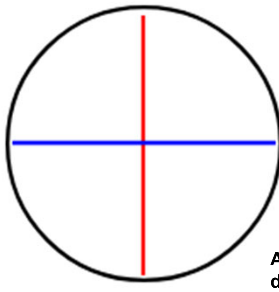
Capping (cont.)

- Take the width measurements perpendicular to each other at 90-degree increments (2 measurements)
- Do not test the core if the difference between the largest and smallest diameter exceeds 5% of their average



Approximate locations for diameter measurements

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Testing (1/6)

- Testing of the cores for compressive strength should be done within 7 days after coring when determining the 28-day strength
- Specimens should be tested at the age required by the applicable specification within the time tolerances shown in Table 1

Table 1: Permissible Time Tolerances	
12 h	±0.25 h
24 h	±0.5 h
3 days	± 2 h
7 days	± 6 h
28 days	± 20 h
56 days	± 40 h
90 days	± 2 days

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Testing (2/6)

- Place the lower bearing block with the hardened face up on the table or directly under the upper bearing block
- Wipe clean the upper and lower bearing blocks before placing the core in the testing machine
- Prior to testing, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator
- As the top bearing block is brought near the specimen, rotate its movable portion gently by hand so that uniform seating is obtained

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Testing (3/6)

- The technique used to verify and adjust the load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.
- The load should be applied at a rate of movement corresponding to a stress rate on the specimen of 35 ± 7 psi/s. The designated rate of movement should be maintained at least during the latter half of the anticipated loading phase

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Testing (4/6)

- During the application of the first half of the anticipated loading phase, a higher rate of loading is permitted. Apply the higher loading rate in a controlled manner so that the specimen is not subjected to shock loading
- Do not adjust the rate of movement as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen

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Testing (5/6)

- Apply the compressive load until the load indicator shows that the load is decreasing steadily, and the specimen displays a well-defined fracture pattern
- For testing machines equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95% of the peak load (recommended setting is 60% of peak load)

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Testing (6/6)

- Record the maximum load carried by the specimen during the testing
- Note the type of fracture pattern. If the fracture pattern is not one of the typical patterns, sketch and describe briefly the fracture pattern.
- If the measured strength is lower than expected, examine the fractured concrete and note the presence of larger air voids, evidence of segregation, whether the fractures pass predominantly around or through the coarse aggregate particles and verify the end preparations were done correctly

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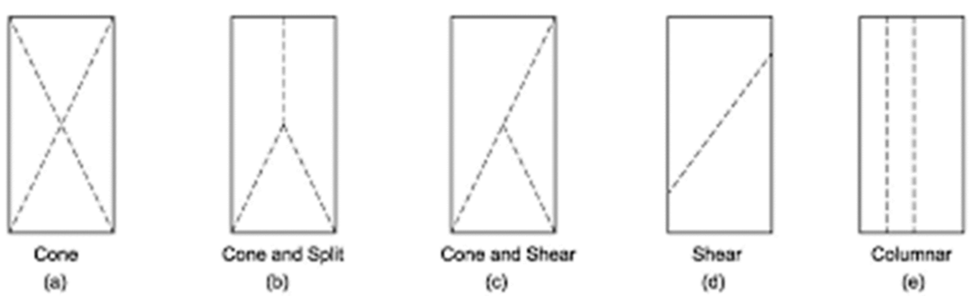
Fracture Pattern



Types of Fracture Patterns

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Calculations

- Calculate the compressive strength of each core using the computed cross-sectional area based on the average diameter
- $A = \pi r^2$.
- Determine the L/D ratio to the nearest 0.01 inches
- Determine a correction factor using the appropriate formula in Table 2
- Use Table 3 to obtain the correction factor
- Multiply the compressive strength by the correction factor to determine the corrected PSI of the core

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L/D Ratio, Conversion Factors, and You

TABLE 2: COMPRESSIVE STRENGTH CORRECTION	
FACTOR FORMULAS	LD Correction Factor
LD < 2	$\frac{100}{95 + 0.2 (1 / LD) + 19.5 (1 / LD)^2}$
LD = 2	1.00
LD >2	$\frac{100}{110 - 5(LD)}$

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Table 3 – Compressive Strength Correction Factor			
LD	Correction Factor	LD	Correction Factor
1.00	0.872	2.60	1.031
1.10	0.898	2.70	1.036
1.20	0.920	2.80	1.042
1.30	0.937	2.90	1.047
1.40	0.952	3.00	1.053
1.50	0.963	3.10	1.058
1.60	0.973	3.20	1.064
1.70	0.982	3.30	1.070
1.80	0.989	3.40	1.075
1.90	0.995	3.50	1.081
2.00	1.000	3.60	1.087
2.10	1.005	3.70	1.093
2.20	1.010	3.80	1.099
2.30	1.015	3.90	1.105
2.40	1.020	4.00	1.111
2.50	1.026		

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Reporting (1/3)

- Report the following information:
  - Identification of the core
  - Diameter and length
  - Cross sectional area
  - Maximum load
  - Corrected compressive strength to the nearest 1psi
  - Defect in either the cores or caps
  - Age of the cores

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Reporting (2/3)

- Length of core as drilled to the nearest 0.01 inches
- Length of test specimen before and after capping or end grinding to the nearest 0.01 inches and the average diameter of the core to the nearest 0.01 inches
- Direction of application of the load on the specimen with respect to the horizontal plane of the concrete as placed
- If water was used during end preparation, the date and time end preparation was completed and when the core is placed in a sealed bag or nonabsorbent container

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Reporting (3/3)

- The date and time when tested
- If determined, the density
- If applicable, description of defects in cores that could not be tested
- If any deviation from this test method was required, describe the deviation and explain why it was necessary

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Questions?

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5.9.49 METHOD FOR OBTAINING AND TESTING DRILLED CORES FROM PCCP AND PRECAST GIRDERS (Kansas Test Method KT-49)

1. SCOPE

1.1. This test method provides standardized procedures for obtaining and testing specimens to determine the compressive strength and depth of in-place concrete in pavement and precast girders. Sampling and sample preparation requirements are given to ensure that dimensional requirements are met and that the specimens are made of intact, sound concrete, and are as free of flaws as the particular pavement or precast girder will allow.

2. REFERENCED DOCUMENTS

2.1. AASHTO T 22; Compressive Strength of Cylindrical Concrete Specimens

2.2. AASHTO T 148; Measuring Length of Drilled Concrete Cores

2.3. AASHTO T 24; Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

2.4. KT-77; Method for Capping Cylindrical Concrete Specimens

3. SIGNIFICANCE AND USE

3.1. The strength of concrete measured by tests of cores is affected by the amount and distribution of moisture in the specimen at the time of test. There is no standard procedure to condition a specimen that will ensure that, at the time of test, it will be in the identical moisture condition as concrete in the pavement or precast girder. The moisture conditioning procedures in this test method are intended to provide reproducible moisture conditions that minimize within-laboratory and between-laboratory variations and to reduce the effects of moisture introduced during specimen preparation. See AASHTO T 24 for additional information on the significance and use of obtaining concrete cores.

4. APPARATUS

4.1. Testing Machine – The testing machine shall comply with requirements set forth in **AASHTO T 22**. The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading corresponding to a stress rate on the specimen of 35 ± 7 psi/s (0.25 ± 0.05 MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase. The testing machine shall be capable of testing cores up to and including 12 in (300 mm) in length.

4.1.1. Verify that the faces of the bearing blocks are plane every 12 months.

Except for the concentric circles described in AASHTO T 22, Section 5.2., the bearing block faces shall not depart from a plane by more than 0.001 in. (0.02 mm) along any 6 in. (150mm) length for bearing blocks with a diameter of 6 in. (150mm) or larger, or by more than 0.001 in. (0.02 mm) in any direction for smaller bearing blocks. New bearing blocks shall be manufactured within one half of this tolerance.

4.1.2. Clean and lubricate the curved surfaces of the socket and spherical portion of the upper bearing block every six months. Check for any visible wear on the spherical portion of the upper bearing block during the cleaning and lubrication. Any noticeable wear is cause for replacement of the upper bearing block. The lubricant shall be conventional motor oil.
4.2. Core Drill - For obtaining cylindrical core specimens, a diamond drill shall be used.

4.3. Caliper and a 12 in (300 mm) steel rule graduated in 0.01 in (0.25 mm).

5. SAMPLING

5.1. Core Drilling - A core specimen taken perpendicular to a horizontal surface shall be located, when possible, so that its axis is perpendicular to the bed of the concrete as originally placed and not near formed joints or obvious edges of a concrete pour. A specimen taken perpendicular to a vertical surface, or perpendicular to a surface with a batter, shall be taken from near the middle of a concrete pour when possible and not near formed joints or obvious edges of a concrete pour.

NOTE: All coring for the purpose of determining compressive strength must be performed a minimum of 21 days after the pavement has been placed, and in time to determine the 28-day compressive strengths.

6. DETERMINING LENGTH OF DRILLED CORE SPECIMENS

6.1. A core specimen for the determination of length shall have a minimum diameter as stated in the applicable specification.

6.2. Determining Length of Core using Calipers.

6.2.1. Cores used as specimens for length measurement shall be in every way representative of the concrete in the structure from which they are removed. The specimen shall be drilled with the axis normal to the surface of the structure, and the ends shall be free from all conditions not typical of the surfaces of the structure. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used. If a core drilled from a pavement or structure placed on dense-graded aggregate base course includes particles of the aggregate bonded to the bottom surface of the concrete, the bonded particles shall be removed by wedging or by chisel and hammer applied so as to expose the lower surface of the concrete. If the concrete is placed on an open-graded aggregate base course, the mortar in the concrete may penetrate into the base and surround some particles. Use sufficient force with a wedge or chisel and hammer to remove bonded particles but not such force as to fracture particles substantially surrounded by mortar. If during the removal of bonded aggregate the concrete is broken so that the instructions of **section 6.2.3** of this test method cannot be followed, the core shall not be used for length measurement[1]

6.2.2. Take three caliper measurements at 120 degree intervals along the circumference of the circle of measurement to the nearest 0.01 in (0.25 mm), to determine the average length.

6.2.3. If, in the course of the measuring operation, it is discovered that at one or more of the measuring points the surface of the specimen is not representative of the general plane of the core end because of a small projection or depression, the specimen shall be rotated slightly about its axis and a complete set of three measurements made with the specimen in the new position.

7. SPECIMENS

7.1. Test Specimens – For concrete greater than or equal to 8 inches in thickness the nominal diameter of core specimens for the determination of compressive strength shall be at least 3.75 in (95 mm). Core diameters less than 3.75” are permitted when it is impossible to obtain cores with length-to-diameter (L/D) ratio ≥ 1 for compressive strength evaluations. For concrete with a thickness of less than 8 inches the

[1] AASHTO T 148

nominal core diameter should preferably be at least three times the nominal maximum size of the coarse aggregate and must be at least twice the nominal maximum size of the coarse aggregate.

7.2. Moisture Conditioning - Test cores after moisture conditioning as specified in this test method. The moisture conditioning procedures specified in this test method are intended to preserve the moisture of the drilled core and to provide a reproducible moisture condition that minimizes the effects of moisture gradients introduced by wetting during drilling and specimen preparation.

7.2.1. After cores have been drilled, wipe off surface drill water and allow remaining surface moisture to evaporate. When surfaces appear dry, but not later than one hour after drilling, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss. Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as practical. Keep cores in the sealed plastic bags or nonabsorbent containers at all times except during end preparation and for a maximum time of two hours to permit capping before testing.

7.2.2. If water is used during sawing or grinding of core ends, complete these operations as soon as practicable, but no later than two days after drilling of cores. After completing end preparation, wipe off surface moisture, allow the surfaces to dry, and place the cores in sealed plastic bags or nonabsorbent containers. Minimize the duration of exposure to water during end preparation.

7.2.3. When direction is given to test cores in a moisture condition other than achieved by conditioning according to s**ections 7.2.1.** and **7.2.2** of this test method, report the alternative procedure.

7.3. End Preparation Prior to Capping - The ends of specimens to be tested in compression shall be essentially smooth, perpendicular to the longitudinal axis, and of the same diameter as the body of the specimen. Saw or grind the top of the specimen no more than 0.375 inches (10 mm) to remove surface tining or roughness. Saw or grind the bottom of the specimen only the amount that is required for the specimen to fit into the testing machine. No point on either end of compressive test specimens shall protrude by more than 0.125 inches (3 mm) from a plane perpendicular to the axis of the specimen at the lowest point of the surface *prior to capping with sulfur*.

NOTE: Prior to capping, the density of a core may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

8. CAPPING

8.1. Cap the specimen according to the procedures contained in **KT-77**.

8.2. Measurement - Prior to testing, measure the length of the capped specimen to the nearest 0.01 inch (0.25 mm) and use this length to compute the length-diameter ratio. Take three caliper measurements at 120 degree intervals along the circumference of the circle to determine the average length. Determine the average diameter by averaging two measurements taken at right angles to each other about the mid-height of the specimen. Measure core diameters to the nearest 0.01 inch (0.25 mm). Do not test cores if the difference between the largest and smallest diameter exceeds five percent of their average.

9. TESTING

9.1. Test the specimens for the 28th day compression strength within seven days after coring, unless specified otherwise.

9.2. Specimens shall be tested at the age required by the applicable specification within the time tolerances shown in **Table 1**.

Table 1 Permissible Time Tolerances

Test Age	Permissible Tolerance
12 h	± 0.25 h
24 h	± 0.5 h
3 days	± 2 h
7 days	± 6 h
28 days	± 20 h
56 days	± 40 h
90 days	± 2 days

9.3. Placing the Specimen - Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically-seated (upper) bearing block. Wipe clean the bearing faces of the upper- and lower-bearing blocks and of the test specimen and place the test specimen on the lower bearing block.

9.4. Zero Verification and Block Seating - Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator. As the spherically-seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

NOTE: The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

9.5. Rate of Loading - Apply the load continuously and without shock.

9.5.1. The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of 35 ± 7 psi/s (0.25 ± 0.05 MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

NOTE: For a screw driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

9.5.2. During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. Apply the higher loading rate in a controlled manner so that the specimen is not subjected to shock loading.

9.5.3. Do not adjust the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

9.5.4. Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (See **Figure 1**). For a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95% of the peak load. A setting of 60% of peak is recommended. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained and a clear fracture pattern is discernable. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern according to **Figure 1**. If the fracture pattern is not one of the typical patterns shown in **Figure 1**, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete, and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with **section 8.1** of this test method**.**

10. CALCULATIONS

10.1. Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen as follows:

Compressive strength=peak load/area

$Area = \pi r^2$

10.2. Determine the length/diameter ratio (LD), and round the result to the nearest hundredth using the following formula:

LD = Length / Diameter

Determine a correction factor to the nearest thousandth by using the appropriate formula in **TABLE 2**. Correct the compressive strength by multiplying the compressive strength determined in **10.1** by the correction factor.

TABLE 2: COMPRESSIVE STRENGTH CORRECTION FACTOR FORMULAS	
LD	**Correction Factor**
LD < 2	$\frac{100}{95 + 0.2\left(\frac{1}{LD}\right) + 19.5\left(\frac{1}{LD}\right)^2}$
LD = 2	1.00
LD >2	$\frac{100}{110 - 5(LD)}$

The compressive strength correction factor may also be obtained by using TABLE 3 below. If a discrepancy should arise due to rounding numbers or the appropriate value is not shown in the table, the value determined by the above formulas shall govern.

Correct the compressive strength determined during testing by multiplying that amount by the compressive strength correction factor.

Table 3 – COMPRESSIVE STRENGTH CORRECTION FACTOR			
LD	Compressive Strength Correction Factor	LD	Compressive Strength Correction Factor
1.00	0.872	2.60	1.031
1.10	0.898	2.70	1.036
1.20	0.920	2.80	1.042
1.30	0.937	2.90	1.047
1.40	0.952	3.00	1.053
1.50	0.963	3.10	1.058
1.60	0.973	3.20	1.064
1.70	0.982	3.30	1.070
1.80	0.989	3.40	1.075
1.90	0.995	3.50	1.081
2.00	1.000	3.60	1.087
2.10	1.005	3.70	1.093
2.20	1.010	3.80	1.099
2.30	1.015	3.90	1.105
2.40	1.020	4.00	1.111
2.50	1.026		

11. REPORT

11.1. Report the results as required by the Contract Document with the addition of the following information:

11.1.1. Identification number.

11.1.2. Diameter and length, inch (mm).

11.1.3. Cross-sectional area, in^2 (cm^2).

11.1.4. Maximum load, lbf (kN).

11.1.5. Compressive strength (corrected) calculated to the nearest 1 psi (0.01 MPa).

11.1.6. Type of fracture, if other than the usual cone. (See **Figure 1**)

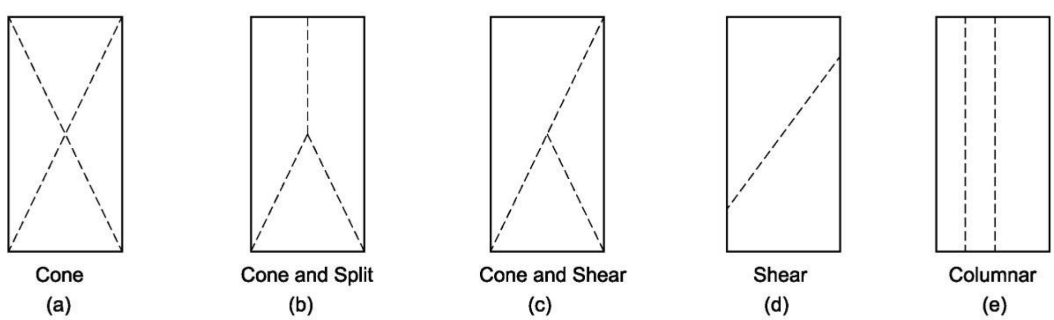

Figure 1 - Sketches of Types of Fracture

11.1.7. Defects in either specimen or caps.

11.1.8. Age of specimen.

11.1.9. Length of core as drilled to the nearest 0.01 inch (0.25 mm).

11.1.10. Length of test specimen before and after capping or end grinding to the nearest 0.01 inch (0.25 mm), and average diameter of core to the nearest 0.01 inch (0.25 mm).

11.1.11. Direction of application of the load on the specimen with respect to the horizontal plane of the concrete as placed.

11.1.12. The moisture conditioning history.

11.1.12.1. The date and the time core was obtained and first placed in sealed bag or nonabsorbent container.

11.1.12.2. If water was used during end preparation, the date and time end preparation was completed and the core placed in sealed bag or nonabsorbent container.

11.1.13. The date and time when tested.

11.1.14. If determined, the density.

11.1.15. If applicable, description of defects in cores that could not be tested.

11.1.16. If any deviation from this test method was required, describe the deviation and explain why it was necessary.

12. PRECISION AND BIAS

12.1. From AASHTO T 24, the single-operator coefficient of variation on cores has been found to be 3.2% for a range of compressive strength between 4500 psi (32.0 MPa) and 7000 psi (48.3 MPa). Therefore, results of two properly conducted tests of single cores by the same operator on the same sample of material should not differ from each other by more than nine percent of their average.

12.2. From AASHTO T 24, the multi-laboratory coefficient of variation on cores has been found to be 4.7% for range of compressive strength between 4500 psi (32.0 MPa) and 7000 psi (48.3 MPa). Therefore results on two properly conducted tests on cores sampled from the same hardened concrete (where a single test is defined as the average of two observations (cores), each made on separate adjacent drilled 4 in (100 mm) diameter cores), and tested by two different laboratories should not differ from each other by more than 13 percent of their average.

12.3. From AASHTO T 24, since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

KT -73

Density, Absorption and Volume of Permeable Voids in Hardened Concrete

1

Apparatus

- Balance that conforms to Part V, 5.9.3: Sampling and Testing Methods. Needs to be equipped with a suitable apparatus for suspending the sample in water
- Forced draft oven capable of maintaining a temperature of **230°F +/- 9°F** (110+/- 5°C)
- Container suitable for boiling with a rack to support specimens ¼ inch from the bottom and can hold enough water to boil for 5 hours
- Hot plate or stove capable of maintaining boiling water

2

Test Specimens

- Prepare 3 specimens per sample, testing each separately
- Specimens should consist of a 4” diameter puck that is 2” thick and was taken from the top portion of the cast cylinders or cores
- Remove no more than 3/8” from the top of the cylinder first
- Should be free from observable cracks, fissures or shattered edges
- Cylinders should be molded and cured according to KT-22
- Used for mix design approval and most verification samples

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3

Test Cylinders

Concrete cylinder prior to cutting

Specimens from cylinder after cutting

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4

Procedure (1/4)

- Determine the mass of each sample
- Dry the samples on their edge in the oven
- Cool samples to a constant mass before weighing at a temperature of **72°F +/- 5 °F**
- Weigh the samples every 24 hours until the loss of moisture is less than 0.5%
- When comparing dry weights, only compare weights that are taken 24 hours apart
- This will be value **A**

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Procedure (2/4)

- Once cores have been determined to be dried, submerge the samples in water at **72°F +/- 5°F** (22°C +/- 3°C)
- Weights need to be taken at an SSD state
- Take first weight after soaking for 24 hours
- Take additional weights in 24-hour increments until the samples have shown a mass increase of less than 0.5%
- This will be value **B**

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6

Boiling Pot

Test Specimens boiling

Hot Plate

7

Procedure (3/4)

- Once it is determined that the samples are completely saturated, it is time to place them in the boiling water
- Water should come to a boil prior to samples being placed in water
- The boiling process needs to be maintained for no less than 5 hours
- No additional water may be added once the samples are added
- After boiling, turn off heat to pot and leave the samples submerged for at least 14 hours to bring them back to room temperature

8

Procedure (4/4)

- After the samples are back at room temperature, suspend them in a water bath to determine the apparent mass in **77°+/- 2°F**
- This will be value **D**
- Remove specimens from water bath and damp dry to determine the SSD mass of each sample
- This will be value **C**

9

Formulas

- Use the following formulas to calculate the following:
  - Absorption after immersion, % = [(B-A)/A] x 100
  - Absorption after immersion and boiling, % = [(C-A)/A] x 100
  - Bulk density, dry = [A/(C-D)] = g_1
  - Bulk density after immersion, = [B/(C-D)]
  - Bulk density after immersion and boiling = [C/(C-D)]
  - Apparent density = [A/(A-D)] = g_2
  - Volume of permeable voids (pore space), % = [(C-A)/(C-D)] x 100

10

Formulas (Cont.)

- Where: A = Mass of oven dried specimen in air
- B = Mass of surface-dry specimen in air after immersion
- C = Mass of surface-dry specimen in air after immersion and boiling
- D = Apparent mass of specimen in water after immersion and boiling
- g_1 = Bulk density, dry
- g_2 = Apparent density

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11

Reporting

- Record absorption to the nearest 0.01%
- Record densities to the nearest 0.1 lb/ft^3
- Record the volume of permeable voids (pore space) to the nearest 0.01% and report to the nearest 0.1%

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12

Questions?

13

5.9.73 DENSITY, ABSORPTION AND VOLUME OF PERMEABLE VOIDS IN HARDENED CONCRETE (Kansas Test Method KT-73)

1. SCOPE

This method covers the determinations of density, percent absorption and percent volume of permeable voids in hardened concrete. **KT-73** reflects testing procedures found in **ASTM C642**.

2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

2.3. KT-49; Method for Obtaining and Testing Drilled Cores

2.4. ASTM C642; Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

3. APPARATUS

3.1. The balance shall conform to the requirements of **Part V, 5.9.3; Sampling and Test Methods Foreword**, Class G5. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of weighing platform or pan of the balance into a bucket with an overflow device to maintain a constant water level.

3.2. Forced draft oven capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C).

3.3. Container suitable for boiling the immersed specimens with a rack suitable for supporting the specimens a minimum of ¼” above the bottom of the container. The container must be large enough to keep the specimens covered with boiling water for a period of 5 hours.

3.4. Hot plate, stove or other heat source capable of maintaining the water at boiling for 5 hours.

4. TEST SPECIMENS

4.1. Prepare 3 specimens per sample, each to be tested separately. Each specimen shall consist of a 2” thick by 4” diameter piece taken from the top portion of a cast concrete cylinder or core. Remove not more than 3/8” from the top of the cylinder or core and obtain the specimen from the next 2”. Each specimen shall be free from observable cracks, fissures, or shattered edges. Cylinders molded and cured in accordance with **KT-22** of this manual shall be used for mix design approval and most verification samples. Cores obtained in accordance with **KT-49** of this manual may be used for verifications on PCCP.

5. PROCEDURE

5.1. Determine the mass of each specimen. Place each specimen on its edge in a forced draft oven directly on the oven rack and dry the specimens at a temperature of 230 ± 9°F (110 ± 5°C) for not less than 24 hours. Do not place the specimens inside a pan or any other container. Do not place the specimens on the flat surface of the cylinder. Allow enough room between specimens for complete airflow around each specimen. After removing each specimen from the oven, allow it to cool in dry air (preferably in a desiccator) to a temperature of 72 ± 5°F (22 ± 3°C) and determine the mass. If the specimen was comparatively dry when its mass was first determined, and the second mass agrees with the first within

0.5%, consider it dry. If the specimen was wet when its mass was first determined, place it in the oven for a second drying treatment of 24 hours and again determine the mass. In case of any doubt, redry the specimen for 24 hour periods until check values of mass are obtained. If the difference between values obtained from two successive values of mass exceeds 0.5% of the lesser value, return the specimens to the oven for an additional 24 hour drying period. Repeat this procedure until the difference between any two successive values is less than 0.5 % of the lowest value obtained. Designate this final mass value **A**.

5.2. Immerse the specimen on its edge in water at 72 ± 5°F (22 ±3°C). Do not place the specimen on the flat surface of the cylinder. Continue soaking the specimen in water for not less than 48 hours and until two successive values of mass of the surface-dried sample at intervals of 24 hours show an increase in mass of less than 0.5% of the larger value. Surface-dry the specimen by removing surface moisture with a towel, and determine the mass. Designate the final surface-dry mass after immersion **B**.

5.3. Begin boiling tap water in a suitable container. Verify that the water is rapidly boiling prior to placing the specimens in the water for testing. Place the specimen on its edge on a rack in the boiling water a minimum of 1/4" from the bottom of the container. The water must return to boiling in less than 1 hour. Boil the specimens completely submersed for a minimum of 5 hours. Do not add additional water during boiling. Allow the specimens and water to cool by natural loss of heat for not less than 14 hours to a final temperature of 72 ± 5°F (22 ± 3°C). Continue to store the specimens on their edges in the boiled water until the final two steps are completed.

5.4. Suspend the specimen in the bucket at a constant water level by the suitable apparatus and determine the apparent mass of the specimen in water at 77 ± 2°F (25 ± 1°C). Designate this apparent mass **D**.

5.5. Remove the specimen from the water. Quickly damp-dry the specimen with a damp absorbent cloth and determine the mass of the specimen. Designate the boiled surface-dried mass **C**.

6. CALCULATION

6.1. Using the values for mass determined in accordance with the procedures described in **Section 5** of this test method make the following calculations:

Absorption after immersion, % = $[(B-A)/A] \times 100$

Absorption after immersion and boiling, % = $[(C-A)/A] \times 100$

Bulk density, dry = $[A/(C-D)] = g_1$

Bulk density after immersion, = $[B/(C-D)]$

Bulk density after immersion and boiling = $[C/(C-D)]$

Apparent density = $[A/(A-D)] = g_2$

Volume of permeable voids (pore space), % = $[(C-A)/(C-D)] \times 100$

Where:
A = Mass of oven dried specimen in air
B = Mass of surface-dry specimen in air after immersion
C = Mass of surface-dry specimen in air after immersion and boiling
D = Apparent mass of specimen in water after immersion and boiling
g_1 = Bulk density, dry

g_2 = Apparent density

7. REPORT

7.1. Record absorption to the nearest 0.01 %.

7.2. Record densities to the nearest 0.1 lb/ ft^3 (1 kg/m^3).

7.3. Record the volume of permeable voids (pore space) to the nearest 0.01 % and report to the nearest 0.1%.

Hardened Concrete Properties

KT-76: Method for Testing the Compressive Strength of Molded Cylindrical Concrete Specimens

1

Scope

- This method provides standardized procedures for determining the compressive strength of molded cylindrical concrete specimens.
- This method **does not** cover drilled cores (KT-49)
- Only applies to concrete having a unit weight greater than 50lbs/ft^3 (800 kg/m^3)
- Cylinders need to be prepared and cured according to KT-22

2

Apparatus (1/4)

- Testing machine shall comply with AASHTO T 22
  - Have sufficient capacity and capable to provide rates of loading corresponding to a stress rate on the specimen of 35 +/- 7 psi
  - The rate of movement should be maintained at least during the second half of the anticipated loading phase
  - Should be capable of testing cores up to and including 12 inches in length

The faces of the bearing blocks need to be checked for planeness every 12 months, repairing or replacing if needed

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3

Apparatus (2/4)

- The bearing block faces should not depart from plane by more than 0.001 inches (0.02 mm) along any 6 inches in length for bearing blocks that have a diameter of 6 inches or longer
- For smaller bearing blocks, 0.001 inches (0.02 mm) in any direction
- New bearing blocks need to be manufactured within ½ of this tolerance

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4

Apparatus (3/4)

- Clean and lubricate the curved surfaces of the socket and spherical portion of the upper bearing block every 6 months
- Check for any visible wear on the spherical portion of the upper bearing block during the cleaning and lubrication
- Any noticeable wear is cause for replacement of the upper bearing block
- Conventional motor oil should be used as the lubricant

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Apparatus (4/4)

- Calipers graduated in 0.01 inches (0.25mm)
- Steel ruler graduated to 0.01 inches (0.25 mm)
- Metal square to determine the perpendicularity of the ends to the sides of the specimens

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Determining the Diameter

- Using calipers, take 2 measurements of the diameter to the nearest 0.01 in. (0.25 mm)
- The measurements need to be taken at right angles to each other near mid-height of the specimens
- Average the two measurements to determine the cross-sectional area of the specimen
- Cylinders should not be tested if any individual diameter of the cylinder varies by more than 2% on the same cylinder

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7

End Preparation

- The ends should be essentially smooth, perpendicular to the longitudinal axis and of the same diameter as the body of the cylinder
- No point at either end should protrude by more than 0.125 inches from plane prior to capping
- If the end exceeds this limit, either saw or grind the end no more than the amount that is required

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8

Capping

- Cap the cylinder according to KT-77
- Maintain free moisture on the surface after capping
- Return to standard curing once the cap has hardened
- Always maintain the cylinders in a moist condition until testing

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9

Measuring

- Prior to testing, measure the length of the capped specimen
  - Measure to the nearest 0.01 inches
  - Take 3 caliper measurements at 120-degree intervals along the circumference of the circle
  - Take the average length to use in the L/D ratio

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Testing (1/4)

- Test the cylinders at the age using the time tolerance table

Table 1: Permissible Time Tolerances	
12 h	±0.25 h
24 h	±0.5 h
3 days	± 2 h
7 days	± 6 h
28 days	± 20 h
56 days	± 40 h
90 days	± 2 days

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Testing (2/4)

- Wipe clean the upper and lower bearing blocks before placing the cylinder in the testing machine
- Make sure that the machine has no pressure recorded upon starting to breaking the specimen
- Apply a constant load without shocking the cylinder

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Testing (3/4)

- The load shall be applied at a rate of movement corresponding to a stress rate on the specimen of 35 +/- 7 psi/sec
- The designated rate of movement should be maintained at least during the latter half of the anticipated loading phase
- Do not adjust the rate of movement as the ultimate load is being approached and the stress rate decreases due to cracking in the cylinder

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Testing (4/4)

- Apply the load until the load indicator shows that the load is decreasing steadily, and the specimen displays a well-defined fracture pattern
- Record the maximum load and fracture pattern for each cylinder

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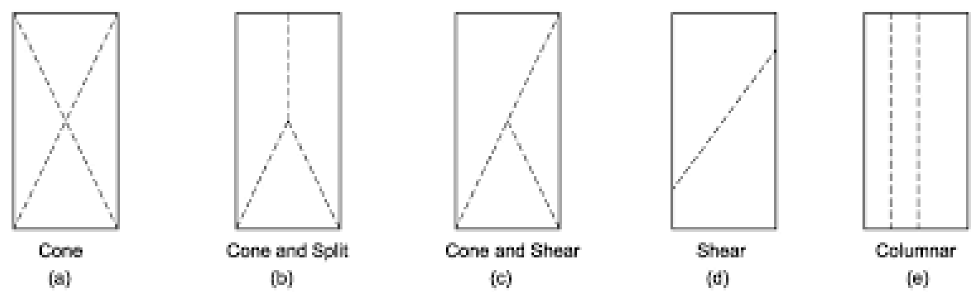
Fracture Pattern



Types of Fracture Patterns

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Calculations

- Calculate the compressive strength of each core using the computed cross-sectional area based on the average diameter
- $A = \pi r^2$
- Determine the L/D ratio to the nearest 0.01 inches
- Determine a correction factor using the appropriate formula in Table 2
- Multiply the compressive strength by the correction factor to determine the corrected PSI if the diameter ratio is 1.75 or less

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Calculations (Cont.)

- To calculate the compressive strength use:

$$f'c = \frac{P}{A}$$

f'c ≡ Compressive Strength (PSI)

P ≡ Maximum applied load (lb_f)

A ≡ Cross Sectional Area (in^2)

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L/D Ratio

Table 2				
L/D Ratio	1.75	1.50	1.25	1.00
Factor	0.98	0.96	0.93	0.87

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Report

- AWP Sample Record SID
- Diameter and length, in inches
- Cross sectional area, in^2
- Maximum load, lb_f
- Compressive strength (corrected) calculated to the nearest 10 psi
- Type of fracture

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Report (Cont.)

- Defects in either the specimen or caps
- Age of specimen
- The moisture conditioning history
- The date and time when tested
- If determined, the density to the nearest 1 lb/ft^3 (10 kg/m^3)
- If any deviation from this test method was required, describe the deviation and explain why it was necessary

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Example 1

- Maximum applied load = 56,024 lb_f
- Diameter of Cylinder = 4 inches
- Length of Cylinder = 8 inches

L/D = 8 / 4 = 2 > 1.75 ∴ No Correction Factor Needed

$$f'c = \frac{56{,}024}{\pi(2)^2} = \frac{56{,}024}{\pi \times 4} = 4{,}460.51 \text{ PSI} \rightarrow 4{,}460 \text{ PSI}$$

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Example 2

- Maximum applied load = 56,024 lb_f
- Diameter of Cylinder = 4 inches
- Length of Cylinder = 6 inches

L/D = 6 / 4 = 1.5 ∴ Correction Factor = 0.96 (Table 2)

$$f'c = \frac{56{,}024}{\pi(2)^2} = \frac{56{,}024}{\pi \times 4} = 4{,}460.51 \text{ PSI} \times 0.96 = 4{,}282.09 \text{ PSI} \rightarrow 4{,}280 \text{ PSI}$$

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Questions?

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5.9.76 METHOD FOR TESTING THE COMPRESSIVE STRENGTH OF MOLDED CYLINDRICAL CONCRETE SPECIMENS (Kansas Test Method KT-76)

1. SCOPE

1.1. This test method provides standardized procedures for determining the compressive strength of molded cylindrical concrete specimens. This method is not used for testing drilled cores. See **KT-49** of this manual for testing of drilled cores. This method only applies to concrete having a unit weight greater than 50 lb/ft^3 (800 kg/m^3).

2. REFERENCED DOCUMENTS

2.1. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

2.2. KT-49; Method for Obtaining and Testing Drilled Cores From PCCP and Precast Girders

2.3. KT-77; Method for Capping Cylindrical Concrete Specimens

2.4. AASHTO T 22; Compressive Strength of Cylindrical Concrete Specimens

2.5. AASHTO T 231; Capping Cylindrical Concrete Specimens

3. SIGNIFICANCE AND USE

3.1. This method may be used to determine the compressive strength of molded cylindrical concrete specimens prepared and cured in accordance with **KT-22** of this manual.

4. APPARATUS

4.1. Testing Machine- The testing machine shall comply with requirements set forth in **AASHTO T 22**. The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading corresponding to a stress rate on the specimen of 35 ± 7 psi/s (0.25 ± 0.05 MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase. The testing machine shall be capable of testing specimens up to and including 12 in (300 mm) in length.

4.1.1. Verify that the faces of the bearing blocks are plane every 12 months.

Except for the concentric circles described in AASHTO T 22, Section 5.2., the bearing block faces shall not depart from a plane by more than 0.001 in (0.02 mm) along any 6 in (150mm) length for bearing blocks with a diameter of 6 in (150mm) or larger, or by more than 0.001 in (0.02 mm) in any direction for smaller bearing blocks. New bearing blocks shall be manufactured within one half of this tolerance.

4.1.2. Clean and lubricate the curved surfaces of the socket and spherical portion of the upper bearing block every six months. Check for any visible wear on the spherical portion of the upper bearing block during the cleaning and lubrication. Any noticeable wear is cause for replacement of the upper bearing block. The lubricant shall be conventional motor oil.

4.2. Caliper and a 12 in (300 mm) steel rule graduated in 0.01 in (0.25 mm).

4.3. Metal square to determine the perpendicularity of the ends to the side.

5. DETERMINING THE DIAMETER OF SPECIMENS

5.1 Determining the Diameter of Specimens.

5.1.1 Using calipers, take two measurements of the diameter to the nearest 0.01 in (0.25 mm). The measurements are taken at right angles to each other at about mid-height of the specimen.

5.1.2 The two measurements taken in **Section 5.1.1** of this test method are averaged for determining the cross-sectional area of the specimen.

5.1.3 Specimens shall not be tested if any individual diameter of a cylinder varies from any other diameter of the same specimen by more than 2%.

6. END PREPARATION

6.1. End Preparation Prior to Capping - The ends of specimens to be tested in compression shall be essentially smooth, perpendicular to the longitudinal axis, and of the same diameter as the body of the specimen. No point on either end of compressive test specimens shall protrude by more than 0.125 inches (3 mm) from a plane perpendicular to the axis of the specimen at the lowest point of the surface *prior to capping*. If the end exceeds this limit, saw or grind the end of the specimen no more than the amount that is required to correct the condition.

NOTE: Prior to capping, the density of a specimen may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

7. CAPPING

7.1 Cap the specimen according to the procedures contained in **KT-77**. Maintain free moisture on the surface of the specimen after capping. The specimen may be returned to standard curing as soon as the cap has hardened. Maintain the specimen in a moist condition at all times until testing.

7.2. Measurement - Prior to testing, measure the length of the capped specimen to the nearest 0.01 inch (0.25 mm) and use this length to compute the length-diameter ratio. Take three caliper measurements at 120 degree intervals along the circumference of the circle to determine the average length.

8. TESTING

8.1 Test the specimens for the compression strength at a given age within the time tolerances shown in **Table 1**.

Table 1 Permissible Time Tolerances

Test Age	Permissible Tolerance
12 h	± 0.25 h
24 h	± 0. 5 h
3 days	± 2 h
7 days	± 6 h
28 days	± 20 h
56 days	± 40 h
90 days	± 2 days

8.2. Placing the Specimen - Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically-seated (upper) bearing block. Wipe clean the bearing faces of the upper- and lower-bearing blocks and of the test specimen and place the test specimen on the lower bearing block.

8.3. Zero Verification and Block Seating - Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator. As the spherically-seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

NOTE: The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

8.4. Rate of Loading - Apply the load continuously and without shock.

8.4.1. The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of 35 ± 7 psi/s (0.25 ± 0.05 MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

NOTE: For a screw driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

8.4.2. During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. Apply the higher loading rate in a controlled manner so that the specimen is not subjected to shock loading.

8.4.3. Do not adjust the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

8.4.4. Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (See **Figure 1.** For a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95% of the peak load. A setting of 60% of peak is recommended. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained and a clear fracture pattern is discernible. Record the maximum load carried by the specimen during the test and note the type of fracture pattern according to **Figure 1**. If the fracture pattern is not one of the typical patterns shown in **Figure 1**, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with **Section 7** of this test method**.**

9. CALCULATIONS

9.1. Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen as follows:

Compressive strength=peak load/area

$Area = \pi r^2$

.

9.2. Determine the length to diameter ratio (L/D), and round the result to the nearest hundredth using the following formula:

LD = Length / Diameter

9.3. If the specimen length to diameter ratio is 1.75 or less, correct compressive strength obtained in Section 9.1 by multiplying by the correction factor shown in Table 2. Interpolate to determine correction factors between the L/D ratios shown.

Table 2

L/D Ratio:	1.75	1.50	1.25	1.00
Factor:	0.98	0.96	0.93	0.87

10. REPORT

10.1. Report the results as required by the Contract Documents with the addition of the following information:

10.1.1. Identification number.

10.1.2. Diameter and length, inch (mm).

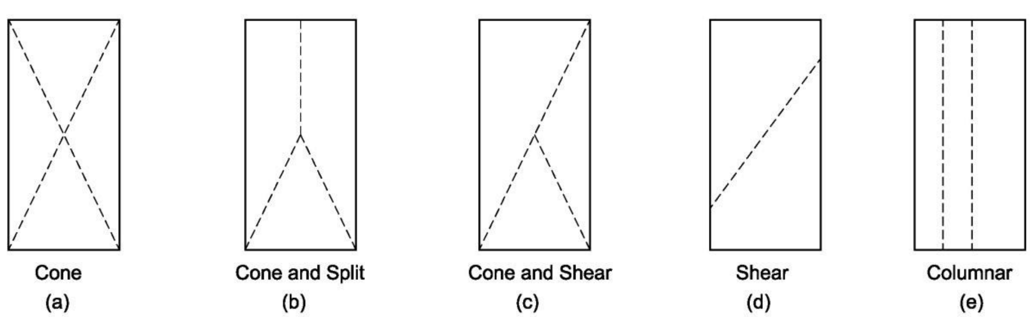
10.1.3. Cross-sectional area, in^2 (cm^2).

10.1.4. Maximum load, lbf (kN).

10.1.5. Compressive strength (corrected) calculated to the nearest 10 psi (0.1 MPa).

10.1.6. Type of fracture, if other than the usual cone. (See **Figure 1**)

Figure 1 - Sketches of Types of Fracture



10.1.7. Defects in either specimen or caps.

10.1.8. Age of specimen.

10.1.9. The moisture conditioning history.

10.1.10. The date and time when tested.

10.1.11. If determined, the density to the nearest 1 lb/ ft^3 (10 kg/m^3).

10.1.12. If any deviation from this test method was required, describe the deviation and explain why it was necessary.

11. PRECISION AND BIAS

11.1. Precision

11.1.1. Within–Test Precision- The acceptable range of individual cylinder strengths between two cylinders under laboratory conditions is 9.0% and 6.6% for 4x8 inch and 6x12 inch cylinders respectively. The acceptable range of individual cylinder strengths between three cylinders under laboratory conditions is 10.6% and 7.8% for 4x8 inch and 6x12 inch cylinders respectively.

11.1.2. Multilaboratory Precision- The difference between properly conducted compressive strength tests between two laboratories on 6x12 inch cylinders is not expected to exceed 14% of the average. This does not include variations associated with different operators preparing specimens from split samples. These variations are expected to increase the multilaboratory coefficient of variation.

11.1.3. See **AASHTO T-22** for further information on precision.

11.2. Bias- Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

KT-77

Capping Cylindrical Concrete Specimens

Scope

- This method provides standardized procedures for the capping of cylindrical concrete specimens prior to testing for compressive strength
- Intended to comply with AASHTO T 231

Significance and Use

- To describe the procedure for providing plane surfaces on the end surfaces of molded concrete cylinders or drilled cores
- The ends must comply with planeness and perpendicularity requirements

3

Tools (1/3)

- Metal square – determine the perpendicularity of the ends
- Straight edge and feeler gauges – determine planeness
- Metal Thermometer – verify temperature of capping material
- Melting Pot- equipped with automatic temperature control
  - Made of metal or lined with nonreactive material to molten sulfer

4

Tools (2/3)

- Capping Plates
  - Machined metal plane at least 0.45 inches (11mm) thick
  - Polished plate of granite or diabase at least 3 inches thick
    - Plates shall be at least 1 inch (25mm) greater in diameter than the test specimen
    - Working surface shall not depart from plane by more than 0.002 inches (0.05 mm)
    - Surface roughness on newly finished metal plates shall not exceed 0.003 mm
    - Surface shall be free of gorges, groves and indentions greater than 0.010 inches (0.25 mm) deep or greater than 0.05 inches squared (32 mm) in surface area
    - If recessed into a metal plate, the thickness below shall be at least 0.5 inches (13mm)
    - The recessed area should not be deeper than 0.5 inches (13 mm)

5

Tools (3/3)

- Alignment Devices
  - Either guide bars or bulls-eye level should be used
  - No single cap should depart from perpendicularity to the axis of a cylindrical specimen by more than 0.5 degrees
    - Approximately 0.125 in 12 inches
    - Approximately 0.070 in 8 inches

6

Capping Devices with Guide Bars

7

Specimen End Preparation

- Prepare the ends of the specimen according to the requirements in the applicable test method
  - KT-49 for drilled cores
  - KT-76 for molded cylinders

8

Capping Material

- Shall be a sulfur mortar that has been tested for compressive strength in accordance with AASHTO T-231 Section 5.4.2
- Shall have a minimum compressive strength of at least 5,000 psi
  - But not less than the compressive strength of the concrete being tested except for concrete strength greater than 7,000 psi when comparison tests of capped and ground specimens have been made

9

Capping (1/6)

- Maintain free moisture on the surface of cylinders after capping
- Specimen may be returned to standard curing as soon as the cap has hardened
- Specimen may also be wrapped with a moist towel if testing will occur in 2 hours
- Place cores in plastic container and reseal until tested

10

Capping (2/6)

- Sulfur mortar should be heated to approximately 265°F (130°C)
- Make sure to empty the pot so that the oldest material has not been heated more than 5 times
- Check the temperature periodically by inserting the metal thermometer near the center of the mass
- Make sure the ends of the specimens are free of oil, wax or other contaminants prior to capping

11

Capping (3/6)

- Moist cured specimens should be maintained in a moist condition between the completion of capping and the time of testing
- The capping plate or device should be slightly warmed before use to reduce the rate of hardening and allow for thin caps
- Oil the plate slightly, stir the mortar prior to capping
- Use enough sulfur to cover the cylinder end

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Capping (4/6)

- Take the cylinder and push tight to the capping guides keeping constant contact
- Slowly lower the cylinder into the sulfur that was placed in the capping plate
- Once cylinder is starting to hit the sulfur, turn the cylinder a quarter of a turn to release trapped air while placing the cylinder in the sulfur
- Leave the cylinder in the capping plate until the sulfur has hardened

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Capping (5/6)

- After capping, make sure that the cap is within specifications
  - The cap surface should not depart from perpendicular to the axis of the specimen by more than 0.5 degrees (0.070 inches in 8 inches or 0.125 inches in 12 inches). This can be checked with a notched square
  - The surface of the cap should not depart from plane by more than 0.002 inches and should be approximately 0.125 inches thick
  - Tap the cap with a metal implement to check for hollow areas under the cap.
  - The cap will need to be removed/replaced if out of spec

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Capping (6/7)

- Upon removal from the capping device caps shall be allowed to cure:
  - A minimum of 2 hours for cylinders with a design compressive strength less than 5,000 psi
  - A minimum of 16 hours for cylinders with a design compressive strength greater than 5,000 psi.

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Capping (7/7)

- https://www.youtube.com/watch?v=UIn0q8AScB0

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Cap Thicknesses

- Caps shall be no thicker than 0.31 inches thick for cylinders with a design compressive strength up to 7,000 psi.
- Cylinders with a very high design compressive strength (7,000 psi – 19,000 psi) may require caps to be less than 0.080 in to produce accurate test results.
- Cylinders with a design compressive strength greater than 19,000 psi may not produce valid test results if sulfur caps are used.

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Questions?

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18

5.9.77 METHOD FOR CAPPING CYLINDRICAL CONCRETE SPECIMENS
(Kansas Test Method KT-77)

1. SCOPE

1.1. This test method provides standardized procedures for the capping of cylindrical concrete specimens prior to test for compressive strength. It is intended that capping procedures comply with the applicable sections of **AASHTO T 231.**

2. REFERENCED DOCUMENTS

2.1. KT-49; Method for Obtaining and Testing Drilled Cores From PCCP and Precast Girders

2.2. KT-76; Method For Testing The Compressive Strength of Molded Cylindrical Concrete Specimens

2.3. AASHTO T 231; Capping Cylindrical Concrete Specimens

2.4. ANSI/ASME B46.1; Surface Texture (Surface Roughness, Waviness and Lay)

3. SIGNIFICANCE AND USE

3.1. This method describes procedures for providing plane surfaces on the end surfaces of molded concrete cylinders or drilled cores when the end surfaces do not conform to the planeness and perpendicularity requirements of the applicable standards.

4. APPARATUS

4.1. Metal square to determine the perpendicularity of the ends to the side.

4.2. Straight edge and feeler gauges for determining planeness.

4.3. Metal Thermometer.

4.4. Capping Plates- Sulfur mortar caps shall be formed against a machined metal plate at least 0.45 in (11 mm) thick or a polished plate of granite or diabase at least 3 in (76 mm) thick. In all cases, plates shall be at least 1 in. (25 mm) greater in diameter than the test specimen and the working surfaces shall not depart from a plane by more than 0.002 in (0.05 mm). The surface roughness of newly finished metal plates shall not exceed that set forth in **Table 4 of ANSI B46.1**, or 125 μ in (0.003 mm) for any type of surface and direction of lay. The surface, when new, shall be free of gouges, grooves, or indentations beyond those caused by the finishing operation. Metal plates that have been in use shall be free of gouges, grooves, and indentations greater than 0.010 in (0.25 mm) deep or greater than 0.05 in^2 (32 mm^2) in surface area. If a recess is machined into the metal plate, the thickness of the plate beneath the recessed area shall be at least 0.5 in (13 mm). In no case shall the recess in the plate be deeper than 0.5 in (13 mm).

4.5. Alignment Devices- Suitable alignment devices, such as guide bars or bull's-eye levels, shall be used in conjunction with capping plates to ensure that no single cap will depart from perpendicularity to the axis of a cylindrical specimen by more than 0.5 degrees (approximately equivalent to 0.125 inches in 12 in. (3.2 mm in 305 mm)). The same requirement is applicable to the relationship between the axis of the alignment device and the surface of a capping plate when guide bars are used. In addition, the location of each bar with respect to its plate must be such that no cap will be off-centered on a test specimen by more than 0.06 in (1.6 mm).

4.6. Melting Pots for Sulfur Mortars-Pots used for melting sulfur mortars shall be equipped with automatic temperature controls and shall be made of metal or lined with a material that is nonreactive with molten sulfur.

5. END PREPARATION

5.1. End Preparation Prior to Capping – Prepare the ends of the specimen according to the requirements stated in applicable test method, **KT-49** for drilled cores or **KT-76** for molded cylinders.

NOTE: Prior to capping, the density of a specimen may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

6. CAPPING MATERIAL

6.1 The capping material shall be a sulfur mortar that has been tested for compressive strength in accordance with **AASHTO T 231 Section 5.4.2.**

6.2 Capping material shall have a minimum compressive strength of at least 5000 psi (35 MPa) and not less than the compressive strength of the concrete being tested except as allowed in **AASHTO T 231, Section 5.1.1**for concrete strengths greater than 7000 psi when comparison tests of capped and ground specimens have been made.

7. CAPPING

Maintain free moisture on the surface of cylinders after capping. The specimen may be returned to standard curing as soon as the cap has hardened. Cylinders maybe wrapped with a moist towel if testing is to occur in 2 hours.

Return cores to the plastic container and reseal until testing.

7.1 Prepare sulfur mortar for use by heating to about 265°F (130°C). Determine the temperature of the material periodically by inserting a metal thermometer inserted near the center of the mass. Empty the pot and recharge with fresh material at frequent enough intervals to ensure that the oldest material has not been heated more than five times.

7.2 The ends of the specimen shall be free of oil, wax or other contaminants prior to capping. The ends shall be dry enough to preclude the formation of steam or foam pockets under the cap larger than 0.25 in (6 mm). Moist cured specimens shall be maintained in a moist condition between the completion of capping and the time of testing by returning them to moist storage consistent with the requirements for the type of specimen, cylinders or cores.

7.3 The capping plate or device should be warmed slightly before use to slow the rate of hardening and permit the production of thin caps. Oil the capping plate lightly and stir the molten sulfur mortar immediately prior to capping. Pour the mortar onto the surface of the capping plate. Use sufficient material to cover the cylinder end after the sulfur mortar solidifies. Lift the cylinder above the plate and contact the cylinder sides with the guides. While keeping the cylinder sides in constant contact with the guides, slide the cylinder down the guides onto the capping plate. The cylinder end should continue to rest on the capping plate while maintaining positive contact with guides until the mortar has hardened.

7.4 The capped surfaces of the specimens shall not depart from perpendicular to the axis of the specimen by more than 0.5 degrees; i.e. 0.125 inches in 12 inches (3.2 mm in 305 mm), 0.070 inches in 8 inches (1.8 mm in 200 mm). Perpendicularity may be checked by placing one leg of a notched square on the cap and checking for any clearance between the other leg and side of the cylinder. The surface of the cap shall not depart from plane by more than .002 in (0.05 mm). Caps should be about 0.125 in (3 mm) thick. For specimens with compressive strengths up to 7000 psi (50 MPa), caps shall be no more than 0.31 in (8 mm) thick at any point. For specimens with compressive strengths over 7000 psi (50 MPa), caps shall be no more than 0.20 in (5 mm) thick at any point. Tap the cap with a metal implement after hardening to check for hollow areas under the cap. Remove and replace any cap not meeting these requirements.

NOTE: Very high compressive strengths may require caps to be less than 0.080 in (2 mm) to produce accurate test results. Test results may not be valid when using sulfur capping compound on specimens with compressive strengths above 19,000 psi (130 MPa).[1]

7.5. Compressive strengths above 7000 psi (50 MPa) require testing of the capping compound as specified in **AASHTO T 231, Section 5.1.1** or grinding so that each end surface is perpendicular to the axis of the specimen within 0.5 degrees or 0.125 inches in 12 inches (3.2 mm in 305 mm) and that the surface does not depart from plane by more than .002 in (0.05 mm). *Testing of the capping compound according to **AASHTO T 231 Section 5.1.1,** is not required if routine testing of the capping compound indicates that the compound has as high or higher compressive strength than the concrete being tested.*

For specimens with compressive strengths of less than 5000 psi (35 MPa), allow the caps to cure a minimum of two hours prior to testing. For specimens with compressive strengths of greater than 5000 psi (35 MPa), allow the caps to cure for a minimum of 16 hours.

[1] Acïtcin, P.-C., High-Performance Concrete (1998)

Hardened Concrete Properties

KT-79: Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration

1

Scope

- This method covers the determination of the electrical resistivity of concrete to provide a rapid indication of its resistance to the penetration of chloride ions
- Based on procedures found in test method AASHTO T 358

2

Terminology

- Sample: Set of three cylinders taken from the same concrete batch at the same time
- Specimen: One cylinder of the set of cylinders to be tested

3

Apparatus

- Specimen holder: prevents specimen rotation during testing, should be non-conductive
- Surface Resistivity meter with a Wenner Linear four-probe array
  - Should have a range of 0 to 100 kΩ-cm
  - Resolution of 0.1 kΩ-cm
  - Accuracy of ± 2% of reading
  - Spaced at least 1.5 inches apart
  - Meter should be a single, self-contained handheld unit

4

Surface Resistivity Meter

Kansas Department of Transportation

5

Test Specimen

- Prepare 3 specimens per sample per mix design
- Each specimen is to be tested separately
- 4” x 8” cylinders
- Should be molded in accordance with KT-22

Kansas Department of Transportation

6

Curing and Conditioning (1/4)

- Initial curing of cast samples
  - Undergo initial curing procedures according to KT-22
  - Samples are to be submitted to the testing facility within 48 hours of casting
  - The samples must be demolded at 24 ± 8 hours

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7

Curing and Conditioning (2/4)

- Make 4 marks on the finished top of the specimen marking the 0°, 90°, 180°, 270° points
- Randomly assign one of the marks as 0°
- Extend the marks onto the longitudinal sides of the specimens
- Mark center on the longitudinal length in order to use as a visual reference during testing

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8

Specimen Marking

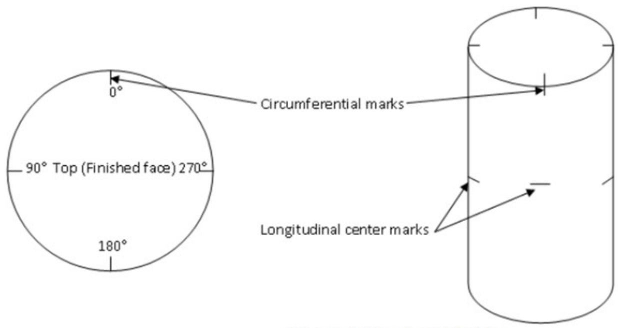

Figure 1: Specimen Marking

9

Curing and Conditioning (3/4)

- Cure samples with standard curing, KT-22
- Samples must remain in the curing environment until ready to be tested
- If transporting cylinders after demolding:
  - Wrap in saturated towels, place in sealed plastic bags and deliver to destination lab
  - Samples should be removed and placed in suitable curing environment within 30 minutes of arrival to destination

10

Curing and Conditioning (4/4)

- If samples are demolded at a location other than the testing facility, samples must be demolded and transported to the testing facility
- Placed back in curing environment within 48 hours of casting
- If these procedures are not followed and samples are allowed to dry out at any point during the curing process, this can result in an invalid test

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11

Procedure (1/7)

- Testing is typically performed at 28 days
- Due to this being a nondestructive test, these cylinders are likely to be run on samples cast for other testing purposes
- Resistivity readings could occur on day 27 or 28 before being altered in any way for a different test (strength)
- Cannot be tested more than 1 day before or no later than 4 days after the specified test date

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12

Procedure (2/7)

- At the beginning of each testing day, calibrate the unit using the test strip provided by the manufacturer
- The foam pads located on each probe tip must be saturated before and during calibration and testing
- If unit doesn't display correct value during the calibration check:
  - Ensure foam pads are saturated (over-saturation can occur)
  - Turn off unit and restart

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13

Procedure (3/7)

- The air temperature should be maintained at 68°F to 77°F (20°C to 25°C)
- If possible, test in the same room where specimens are stored

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14

Procedure (4/7)

- Remove specimens from curing environment and blot off excess water with a damp towel/sponge to SSD condition
- If cured in lime-saturated water, clean off excess lime residue from specimens prior to testing
- If several samples are to be tested, be sure that the specimens are not allowed to dry out excessively before completing testing
- Recommended to remove only one set of 3 specimens at a time from the curing environment

Kansas Department of Transportation

15

Procedure (5/7)

- Place the meter longitudinally on the side of the specimen at the 0° mark
- Center the meter on the specimen by making sure the longitudinal center mark on the specimen is equidistant between the two inner probes
- Make sure all the points of the array probe are in contact with the concrete

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16

Procedure (6/7)

- Contact with the specimen will automatically induce a reading on the display screen
- Wait until a stable reading is obtained and record the resistivity measurement of the testing from to the nearest 0.1 kΩ-cm
- A reading is considered unstable if it drifts by more than 1 kΩ-cm

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17

Procedure (7/7)

- Negative, unstable or obviously erroneous readings are indicative of problems with the instrument, the probe array or specimen and should be addressed before proceeding
- Repeat these steps for the 90°, 180°, and 270° marks
- Each specimen should have a total of 8 readings
- Make sure to test all 3 cylinders in the sample

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18

Testing of Specimen

Testing Specimen using a Specimen Holder

Kansas Department of Transportation

19

Calculations (1/3)

- Calculate the average resistivity for each specimen
- Calculate the coefficient of variation (COV) for each specimen
  - If the COV is above 7.5%, fully immerse the specimen in a water bath (68°F to 77°F) for 2 hours, then repeat the test
  - If the COV is below 7.5% on the second test, use the second test to calculate the specimen average
  - If the COV is greater than 7.5%, use all 16 readings to calculate the specimen average

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20

Calculations (2/3)

- Calculate an average resistivity for the sample by averaging the average resistivity between the three specimens tested
- If specimens were cured in lime-saturated water, multiply the set average by 1.1
- Report the final resistivity to the nearest 0.1 kΩ-cm

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21

Calculations (3/3)

- Factors that are known to affect chloride ion penetration include:
  - Water-cement ratio
  - Pozzolans (fly ash, silica fume, slag, etc.)
  - The presence of plyometric admixtures
  - Sample age
  - Air-void system
  - Aggregate type
  - Degree of consolidation
  - Type of curing

Kansas Department of Transportation

22

Report

- Report the results as required by the contract documents:
  - Source of cylinder
  - AWP Sample Record SID or equivalent identification number
  - AWP or equivalent mix design number
  - Date cast
  - Date of testing

Kansas Department of Transportation

23

Questions?

Kansas Department of Transportation

24

5.9.79 SURFACE RESISTIVITY INDICATION OF CONCRETE’S ABILITY TO RESIST CHLORIDE ION PENETRATION (Kansas Test Method KT-79)

1. SCOPE

This test method covers the determination of the electrical resistivity of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. This test method is based on procedures found in AASHTO T 358.

2. REFERENCED DOCUMENTS

2.1. KDOT Construction Manual, Part V, Section, 5.9; Sampling and Test Methods Forward

2.2. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

2.3. AASHTO T 358; Surface Resistivity Indication of Concrete’s Ability to Resist Chloride Ion Penetration

3. TERMINOLOGY

3.1. Sample: Set of three cylinders taken from the same concrete batch at the same time.

3.2. Specimen: One cylinder of the set of cylinders to be tested.

4. APPARATUS

4.1. Surface Resistivity meter with a Wenner linear four-probe array. The meter should have a range of 0 to 100 kΩ-cm, with a resolution of 0.1 kΩ-cm and an accuracy of ± 2% of reading. The Wenner probe array spacing should be set at 1.5 inches (38.1 mm). The meter should be a single, self-contained handheld unit.

4.2. Specimen holder. Specimen holder to prevent specimen rotation during testing. Holder should be non-conductive.

5. TEST SPECIMEN

5.1. Prepare 3 specimens per sample per mix design. Each specimen is to be tested separately. The specimens shall be 4” x 8” (100 mm x 200 mm) cylinders cast at time of mixing. Cylinders shall be molded in accordance with **KT-22** of this manual.

6. CURING AND CONDITIONING

6.1. Initial curing of cast samples: Cast samples must undergo initial curing procedures according to **KT-22** with the requirement that samples are to be submitted to the testing facility within 48 hours of casting. Therefore, the samples must be demolded at 24 ± 8 hours. See **6.4.** for transportation requirements.

6.2. Make four indelible marks on the top (finished) circular face of the specimen marking the 0, 90, 180, and 270 degree points of the circumference of the circle. Randomly assign one of the marks as 0°, then rotate either clockwise or counterclockwise and assign the next mark 90°, and so on. Extend the marks into the longitudinal sides of the specimens. On the longitudinal sides mark the center of the longitudinal length of the specimen in order to use as a visual reference during testing. (Figure 1)

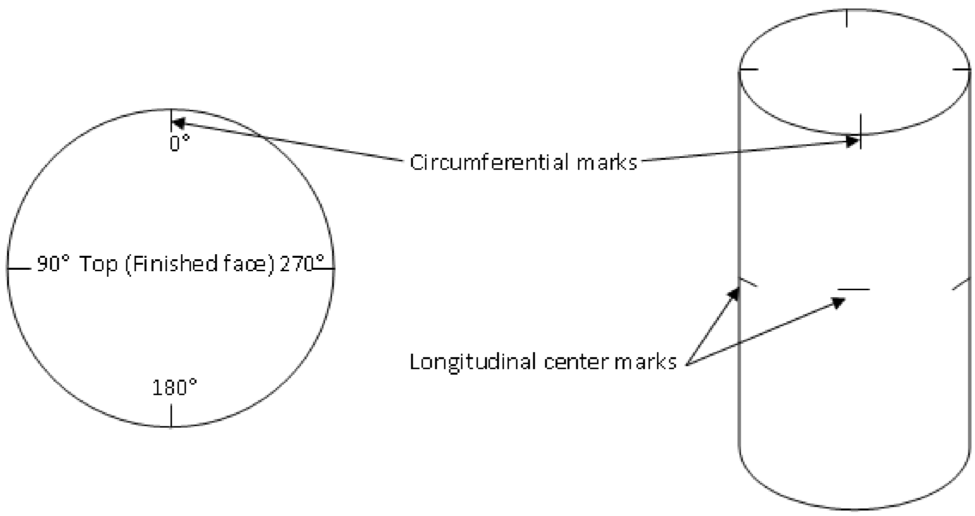

Figure 1: Specimen Marking

6.3. Standard Curing: Samples will undergo standard curing according to **KT-22**. Samples are to remain in the curing environment until specified in section **7.3.** of this test method.

6.4. Transporting samples: Whenever samples are to be transported at any time after demolding, they are to be wrapped in saturated towels, placed in sealed plastic bags and delivered to their destination. Upon arrival at destination, samples are to be removed from bags and placed back in suitable curing environment within 30 minutes of arrival. Alternatively to saturated towels and plastic bags, samples may be fully submerged in water in a suitable water-tight container during transport.

If samples are demolded at a location other than the testing facility, samples must be demolded and transported to the testing facility and placed back in the curing environment within 48 hours of casting. If samples are to be moved a second time after 28 day testing has occurred, samples must be transported within 72 hours from when they were removed from the curing environment.

NOTE: If these procedures are not followed and samples are allowed to dry out at any point during the curing process, this can result in an invalid test.

7. PROCEDURE

NOTE: Testing is typically scheduled at 28 days. However, as this is a nondestructive test and is likely to be run on samples cast for other testing purposes, resistivity testing shall occur as close to the specified test date as possible before the sample is altered in any way for a different test; i.e., resistivity testing will occur on day 27 or 28 before the samples are tested for strength, KT-76. The samples are to be tested no earlier than 1 day before, or no later than 4 days after the specified test date. Therefore, samples tested for KT-73 cannot be used for surface resistivity testing.

7.1. At the beginning of each day of testing, calibrate the unit using the test strip provided by the manufacturer. Foam pads located on each probe tip must be saturated before and during calibration and testing. If unit does not display correct values during calibration check the following: ensure foam pads are saturated (over-saturation can occur), turn off and restart the unit. If issues persist, contact KDOT Research personnel for further assistance.

7.2. During the test, the air temperature around the specimens shall be maintained in the range of 68 to 77ºF (20 to 25ºC). As the unit is portable, testing the specimens in the room they are stored in is ideal.

7.3. Remove the specimens from curing environment, blot off excess water with damp towel/sponge to SSD condition, and transfer specimen to specimen holder. If specimens are stored in lime-saturated water storage tanks, clean off excess lime residue from specimens prior to testing. If several samples are to be tested, be sure that the specimens are not allowed to dry out excessively before completion of the testing. It is recommended that only one set of three specimens are removed from the curing environment at any given time.

7.4. Place the meter longitudinally on the side of the specimen at the 0 degree mark. Center the meter longitudinally on the specimen by making sure the longitudinal center mark on the specimen is equidistant between the two inner probes (Figure 2). Make sure all the points of the array probe are in contact with the concrete. Contact with the specimen will automatically induce a reading on the display screen. Wait until a stable reading is obtained (usually 3 to 5 seconds), and record the resistivity measurement on the testing form to the nearest 0.1 kΩ-cm. A reading is considered unstable if it drifts by more than 1 kΩ-cm. Negative, unstable or obviously erroneous readings are indicative of problems with the instrument, the probe array, or specimen, and need to be addressed before proceeding.

Figure 2: Location of unit during testing

7.5. Repeat step **7.4** for the 90, 180, and 270 degree marks.

7.6. Repeat steps **7.4** and **7.5** for the same specimen for a total of eight readings.

7.7. Repeat steps **7.4** to **7.6** for the remaining two specimens in the sample set.

8. CALCULATION

8.1. Calculate an average resistivity for each specimen. Calculate the coefficient of variation (COV) for each specimen. If the COV is above 7.5%, fully immerse the specimen in a water bath 68 to 77ºF (20 to 25ºC) for two (2) hours, then repeat the test. If the COV on second test is below 7.5%, use second test to calculate specimen average and complete **8.2** and **8.3**. If the COV on second test is greater than 7.5%, use all 16 readings for the specimens to calculate specimen average.

8.2. Calculate an average resistivity for the sample by averaging the average resistivity **(8.1)** of the three specimens tested.

8.3. If specimens were cured in lime-saturated water, multiply set average by 1.1. Report the final resistivity to the nearest 0.1 kΩ-cm.

8.4. Factors which are known to affect chloride ion penetration include: water-cement ratio, pozzolans, the presence of polymeric admixtures, sample age, air-void system, aggregate type, degree of consolidation, and type of curing.

9. REPORT

9.1. Report the results as required by the Contract Documents with the addition of the following information:

9.1.1. Source of cylinder, in terms of the particular station the cylinder represents.

9.1.2. AWP or equivalent identification number of cylinder.

9.1.3. AWP or equivalent mix design number.

9.1.4. Date cast.

9.1.5. Date samples were demolded.

9.1.6. Min/Max temperature during first 24 hrs (if known).

9.1.7. Date of surface resistivity testing.

9.1. 8. Description of specimen, including presence and location of reinforcing steel, presence and thickness of overlay, and presence and thickness of surface treatment.

9.1.9. Curing history of specimen.

9.1.10. Unusual specimen preparation, for example, removal of surface treatment or sulfur capping.

9.1.11. Test results, reported as the surface resistivity measured from **8.2** or **8.3** if a correction factor is applied.

Hardened Concrete Properties

Review Questions

Kansas Department of Transportation

1

Questions for KT-23

Kansas Department of Transportation

2

The size of the leather shims are:

A. 152.4 mm x 152.4 mm x 530 mm
B. 1ft x 1 ft x 2 ft
C. 0.25 in. x 1.5 in by 6.0 in.
D. 0.5 in. x 5.0 in by 5.0 in.
E. I don't know

Kansas Department of Transportation

3

Draw lines on the beam at _____ intervals equally spaced from the end of the beam to align the beam in the test fixture.

A. 21 inches
B. 6 inch
C. 3 to 6 %
D. 6 mm
E. I don't know

Kansas Department of Transportation

4

For each dimension of the beam, ______ measurements must be taken.

A. 2
B. 5
C. Don’t need to measure
D. 3
E. I don’t know

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5

When there is no gap longer than 1 in. or the gap is less than 0.004 in. deep, test the specimen without further preparation.

A. True
B. False
C.
D.
E. I don’t know

Kansas Department of Transportation

6

If the gap is more than 0.015 inches, grind the contact surfaces until it complies.

A. True
B. False
C.
D.
E. I don't know

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7

How many contact points are made with the beam?

A. 2
B. 4
C. 6
D. 3
E. I don't know

Kansas Department of Transportation

8

The beam is to be kept ______ until the time of testing.

A. Dry
B. Field Cured
C. Saturated Surface Dry
D. Moist
E. I don't know

9

If the beam is twisted or warped 1/16 inch or more in any plane, discard the beam.

A. True
B. False
C.
D.
E. I don't know

10

The rate of loading affects the maximum load the specimen will withstand. Therefore, the loading rate after approximately 50% of the final load must not increase the extreme fiber stress by less than 125 psi/minute nor more than _____ until the specimen breaks.

A. 225 psi/minute
B. 275 psi/minute
C. 175 psi/minute
D. 325 psi/minute
E. I don't know

Kansas Department of Transportation

11

Maximum allowable rate of increase in extreme fiber stress S=150 psi/min
Average width of the specimen b=5.95 inches
Average depth of the specimen d=6.05 inches
Span Length L=18.00 inches
Maximum Load Applied P=6,500 lb_f

Calculate and report the modulus of rupture in the beam is broken within the middle 1/3 of the span.

A. 450 psi
B. 635 psi
C. 535 psi
D. 600 psi
E. I don't know

Kansas Department of Transportation

12

Maximum allowable rate of increase in extreme fiber stress S=150 psi/min
Average width of the specimen b=5.95 inches
Average depth of the specimen d=6.05 inches
Span Length L=18.00 inches
Maximum Load Applied P=7,200 lb_f

Calculate and report the modulus of rupture if the beam broke outside the middle 1/3 of the span but not by more than 5%. a = 5.85

A. 580 psi
B. 625 psi
C. 605 psi
D. 585 psi
E. I don't know

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13

Maximum allowable rate of increase in extreme fiber stress S=150 psi/min
Average width of the specimen b=6.05 inches
Average depth of the specimen d=6.25 inches
Span Length L=18.00 inches
Maximum Load Applied P=4,500 lb_f

Calculate and record the modulus of rupture if the beam is broken within the middle 1/3 of the span.

A. 434 psi
B. 343 psi
C. 334 psi
D. 443 psi
E. I don't know

Kansas Department of Transportation

14

Maximum allowable rate of increase in extreme fiber stress S=150 psi/min
Average width of the specimen b=5.97 inches
Average depth of the specimen d=5.95 inches
Span Length L=18.00 inches
Maximum Load Applied P=8,700 lb_f

Calculate and report the modulus of rupture if the beam is broken outside the middle 1/3 by no more than 5%.
a = 5.72 inches

A. 612
B. 706
C. 705
D. 610
E. I don't know

15

Questions for KT-44

16

When maturity testing is used, the Contractor and KDOT shall jointly develop a plan.

A. True
B. False
C.
D.
E. I don't know

Kansas
Department of Transportation

17

Test specimens shall be cast with concrete made from:

A. From the same plant to produce the mix for the project
B. From the closest concrete plant not being used for the project
C. From another district
D. Concrete mixed in a laboratory
E. I don't know

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Department of Transportation

18

A validation test shall be conducted to determine if concrete strength is being accurately represented by the current maturity curve how many times per month?

A. Four
B. Six
C. One
D. Twelve
E. I don't know

Kansas Department of Transportation

19

The contractor shall develop the maturity curve and KDOT shall develop a secondary maturity curve.

A. True
B. False
C.
D.
E. I don't know

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20

The maturity values and strength for a minimum of _____ cylinders must be calculated at each age of concrete.

A. 12
B. 3
C. 1
D. 6
E. I don't know

21

Maturity values should be recorded at a minimum of _____different ages.

A. 1
B. 2
C. 3
D. 4
E. I don't know

22

Each concrete mix will have the same maturity rates.

A. True
B. False
C.
D.
E. I don't know

23

A minimum of how many specimens must be cast?

A. 6
B. 12
C. 18
D. 24
E. I don't know

24

A plot of the concrete strength vs the maturity number shall be made in the middle of testing.

A. True

B. False

C.

D.

E. I don't know

25

This procedure is based on the premise that

A. Concrete doesn't gain strength over time

B. The contractor knows more about concrete than KDOT

C. The strength gain of concrete is dependent of curing time and temperature

D. Asphalt is immoral and disgusting

E. I don't know

26

Questions for KT - 49

27

What is the recommended end of testing automatic shut-off peak load for the break machine?

A. 95% of the peak load
B. 10% of the peak load
C. 75% of the peak load
D. 60% of the peak load
E. I don’t know

28

The fracture pattern of the broken cylinder doesn't need to be recorded.

A. True
B. False
C.
D.
E. I don't know

29

What needs to be recorded at the conclusion of testing.

A. Wind speed
B. Cloud Coverage
C. Entrapped Air Voids
D. Moisture Conditioning History
E. I don't know

30

A faster loading rate during the first half of testing is permitted.

A. True
B. False
C.
D.
E. I don't know

31

The increased rate of loading can be applied in any manner.

A. True
B. False
C.
D.
E. I don't know

32

Core diameters should be recorded to the nearest _____ inches

A. 12
B. 0.1
C. 0.01
D. 0.001
E. I don't know

Kansas Department of Transportation

33

The load indicator should be set at 3 - 6% of the expected load at the beginning of the test.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

34

The cores should be tested ______ days after the samples are cored.

A. 3
B. 5
C. 28
D. 7
E. I don't know

Kansas Department of Transportation

35

When breaking 28 day cores for strength, the cores can be broken by a variance of +/-__________.

A. 2 days
B. 20 hours
C. 20 minutes
D. 20 days
E. I don't know

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36

Questions for KT-73

37

Specimens should be placed on their edge only during the boiling process.

A. True
B. False
C.
D.
E. I don't know

38

Record the volume of permeable voids to the nearest _____.

A. 0.01%
B. 0.1%
C. 0.001%
D. 1%
E. I don't know

Kansas Department of Transportation

39

What is not calculated using the measured mass values?

A. Apparent density
B. Bulk density of water
C. Bulk density after immersion
D. Dry bulk density
E. I don't know

Kansas Department of Transportation

40

Report the volume of permeable voids to the nearest ______.

A. 0.01%
B. 0.1%
C. 0.001%
D. 1%
E. I don't know

Kansas Department of Transportation

41

The specimens need to be oven dried for a minimum of 12 hours.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

42

The specimens should be allowed to cool to 77 +/- 2 °F after oven drying.

A. True

B. False

C.

D.

E. I don't know

Kansas Department of Transportation

43

If an increase in mass of 0.6% is not observed, the specimen should be immersed again

A. True

B. False

C.

D.

E. I don't know

Kansas Department of Transportation

44

When boiling, the specimens should sit off the bottom of the pot a minimum of _____inches.

A. 2.5
B. 0.5
C. 0.25
D. 25
E. I don't know

Kansas Department of Transportation

45

The temperature of the oven should be 230 +/- 6 °F.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

46

Mass of oven dried sample in air A=930.7
Mass of surface-dry sample in air after immersion B=981.5
Mass of surface-dry sample in water after immersion and boiling C=982.9
Apparent mass of sample in water after immersion and boiling D=572.3

Calculate the Volume of permeable pore space

A. 11.0
B. 17.2
C. 13.0
D. 12.7
E. I don't know

Kansas Department of Transportation

47

Mass of oven dried sample in air A=885.0
Mass of surface-dry sample in air after immersion B=931.1
Mass of surface-dry sample in water after immersion and boiling C=932.7
Apparent mass of sample in water after immersion and boiling D=529.9

Calculate the bulk density, dry:

A. 2.194
B. 2.197
C. 2.205
D. 2.179
E. I don't know

Kansas Department of Transportation

48

Mass of oven dried sample in air A=890.5
Mass of surface-dry sample in air after immersion B=939.0
Mass of surface-dry sample in water after immersion and boiling C=941.0
Apparent mass of sample in water after immersion and boiling D=535.1

Calculate the bulk density after immersion and boiling

A. 2.318
B. 2.320
C. 2.312
D. 2.331
E. I don't know

Kansas Department of Transportation

49

Mass of oven dried sample in air A=876.8
Mass of surface-dry sample in air after immersion B=926.3
Mass of surface-dry sample in water after immersion and boiling C=927.0
Apparent mass of sample in water after immersion and boiling D=521.6

Calculate the apparent density

A. 2.458
B. 2.479
C. 2.468
D. 2.471
E. I don't know

Kansas Department of Transportation

50

Questions for KT - 76

Kansas
Department of Transportation

51

The rate of loading may be decreased towards the end of testing.

A. True
B. False
C.
D.
E. I don't know

Kansas
Department of Transportation

52

Calculate the compressive strength and report it to the nearest _____.

A. 5 psi
B. 7 psi
C. 20 psi
D. 10 psi
E. I don't know

Kansas Department of Transportation

53

The compressive strength is computed by dividing the maximum load by the _____.

A. Square footage
B. Volume
C. Cross Sectional Area
D. Thickness of Pavement
E. I don't know

Kansas Department of Transportation

54

This test is limited to concrete having a unit weight of at least 25 pcf

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

55

The diameter of an individual cylinder may vary by up to 5%.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

56

The bearing surface of the testing apparatus may have debris and imperfections.

A. True

B. False

C.

D.

E. I don't know

Kansas Department of Transportation

57

The initial reading on the testing apparatus should read:

A. 0 psi

B. 10 psi

C. 25 psi

D. 100 psi

E. I don't know

Kansas Department of Transportation

58

Rotate the spherically-seated block as it is brought to bear on the specimen so that a uniform seating is obtained.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

59

If the maximum load of compression test is 120,325 pounds, and the average cross-sectional area of a cylinder is 28.26 square inches then the compressive strength of that cylinder is reported to

A. 3,575 psi
B. 3,750 psi
C. 4,260 psi
D. 4,440 psi
E. I don't know

Kansas Department of Transportation

60

If the maximum load of compression test is 118,357 pounds, and the average cross-sectional area of a cylinder is 28.26 square inches then the compressive strength of that cylinder is reported to

A. 4,185 psi
B. 4,190 psi
C. 4,941 psi
D. 5,287 psi
E. I don't know

Kansas Department of Transportation

61

If the maximum load of compression test is 141,211 pounds, and the average cross-sectional area of a cylinder is 28.26 square inches then the compressive strength of that cylinder is reported to

A. 4,990 psi
B. 5,000 psi
C. 4,996 psi
D. 4,728 psi
E. I don't know

Kansas Department of Transportation

62

Questions for KT - 77

63

For cylinders with compressive strengths up to 7,000 psi, caps shall be no more than 0.31 inches thick at any point.

A. True
B. False
C.
D.
E. I don't know

64

For cylinders with compressive strengths of less than 5,000 psi, allow the caps to cure a minimum of 2 hours prior to testing

A. True
B. False
C.
D.
E. I don't know

65

For cylinders with compressive strengths of greater than 5,000 psi, allow the caps to cure for a minimum of 16 hours.

A. True
B. False
C.
D.
E. I don't know

66

Maintain free moisture on the surface of cylinders after capping

A. True
B. False
C.
D.
E. I don't know

67

The capping plate should be heavily oiled before the molten sulfur is added

A. True
B. False
C.
D.
E. I don't know

68

The cylinder may be removed from the plate once the sulfur has hardened

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

69

Prior to capping, the density of a specimen may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

70

The cylinder should be placed in the molten sulfur and then pushed against the guides.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

71

No single cap will depart from perpendicularity to the axis of a cylindrical specimen by more than 0.5 degrees (approximately equivalent to 0.125 inches in 12 inches).

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

72

This method is used to cap both concrete cores and concrete cylinders.

A. True
B. False
C.
D.
E. I don't know

73

Questions for KT - 79

74

Record the resistivity measurements on each reading to the nearest?

A. 1.0 Kilo-ohm
B. 0.1 Kilo-ohm
C. 1.0 Kilo-ohm cm
D. 0.1 Kilo-ohm cm
E. I don’t know

Kansas Department of Transportation

75

The average resistivity for each specimen is the average of how many readings?

A. 4
B. 8
C. 12
D. 24
E. I don’t know

Kansas Department of Transportation

76

This test method is for both 4” x 8” and 6” x 12” cylinders.

A. True
B. False
C.
D.
E. I don’t know

Kansas Department of Transportation

77

Whenever samples are transported after demolding, they must be

A. Placed in a bucket of water
B. Left out dry until they arrive at the lab
C. Wrapped in saturated towels and placed in sealed plastic bags
D. Placed in a mobile curing environment
E. I don’t know

Kansas Department of Transportation

78

How often must the Surface Resistivity Meter be calibrated?

A. Yearly
B. Monthly
C. Quarterly
D. Daily
E. I don't know

Kansas Department of Transportation

79

Specimens must be demolded and transported to testing facility and placed back in the curing environment within 48 hours of casting.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

80

What other test can the surface resistivity cylinders be used for?

A. Boil Test
B. Strength Test
C. Checking for pavement depth
D. Crushed for a gradation test
E. I don't know

Kansas Department of Transportation

81

The cylinders must be tested in a saturated surface dry (SSD) condition.

A. True
B. False
C.
D.
E. I don't know

Kansas Department of Transportation

82

The spacing between the probes on the Surface Resistivity Meter should be

A. 1.0”
B. 2.5”
C. 3.5”
D. 1.5”
E. I don’t know

Kansas Department of Transportation

83

Hardened Concrete Properties
KT-23 Flexural Strength Of Concrete (Third-Point Loading Method)

Revised July 2023

Two attempts may be made by the applicant. The applicant may stop themselves once and not have that count as one of the two attempts. If the applicant stops voluntarily, draw a line at that point and note that the applicant stopped themselves then restart at the top of the next attempt.

Applicant: ______________________ **CIT #:** ______________

Employer: ______________________

		1st Test	Stopped Test	Re-Test
	Test Specimen			
1.	A nominal 6 by 6 by 21 in (152.4 by 152.4 by 530 mm) concrete beam, molded and cured according to KT-22. The beam must be kept moist until time of test. (4.1)	PASS FAIL	PASS FAIL	PASS FAIL
2.	Draw lines on the beam 6" intervals equally spaced from the end of the beam representing the support and load applying block locations. Use these marks when installing the beam in the test fixture. (4.2)	PASS FAIL	PASS FAIL	PASS FAIL
	Test Procedure			
3.	Place the specimen on its side in the machine in such a manner that a minimum of 1 in of the beam extends outside the support rollers. (5.2.1.)	PASS FAIL	PASS FAIL	PASS FAIL
4.	Apply a load of between 3 and 6% of the expected ultimate load.	PASS FAIL	PASS FAIL	PASS FAIL
5.	If there is a 1 in or longer gap in excess of 0.004 in, grind the contact surfaces of the specimen, or shim with leather strips. (5.2.1.)	PASS FAIL	PASS FAIL	PASS FAIL
6.	If full contact is not obtained between the specimen and the load-applying blocks and the supports so that there is a 1 in (25 mm) or longer gap in excess of 0.015 in (0.38 mm), grind the surfaces of the specimen as stated above. (5.2.1.1.)	PASS FAIL	PASS FAIL	PASS FAIL

Hardened Concrete Properties
KT-23 Flexural Strength Of Concrete (Third-Point Loading Method)
Revised July 2023

		1st Test	Stopped Test	Re-Test
7.	If specimen is twisted or warped 1/8" (3.2 mm) or more in any plane, discard the specimen and repair or replace the mold. (5.2.1.2)	PASS FAIL	PASS FAIL	PASS FAIL
8.	Load the specimen continuously and without shock.	PASS FAIL	PASS FAIL	PASS FAIL
9.	Note and record the total load required to break the beam. (5.3.1.1.)	PASS FAIL	PASS FAIL	PASS FAIL
10.	Take three measurements at the fractured face across each dimension to the nearest 0.05 in to determine the average width, average depth and line of fracture location of the specimen at the section of failure. (5.4.1.)	PASS FAIL	PASS FAIL	PASS FAIL

Overall Score

Circle One

1st Test	Stopped Test	Re-Test
PASS	PASS	PASS
FAIL	FAIL	FAIL

Witness Examiner: ______________________ ______________________
(First Try) Signature Date

Witness Examiner: ______________________ ______________________
(Stopped Try) Signature Date

Witness Examiner: ______________________ ______________________
(Re-Test) Signature Date

KT-49 Drilled Cores From PCCP and Precast Girders

Revised July 2023

Two attempts may be made by the applicant. The applicant may stop themselves once and not have that count as one of the two attempts. If the applicant stops voluntarily, draw a line at that point and note that the applicant stopped themselves then restart at the top of the next attempt.

Applicant: ______________________ **CIT #:** ______________

Employer: ______________________

		1st Test	2nd Test	Re-Test
	Determining Length of Drilled Core Specimens			
1.	Take three caliper measurements at 120 degree intervals along the circumference of the circle of measurement to the nearest 0.01 in (0.25 mm), to determine the average length. (6.2.2.)	PASS FAIL	PASS FAIL	PASS FAIL
	Specimens			
2.	Wipe off surface drill water and allow remaining surface moisture to evaporate. (7.2.1)	PASS FAIL	PASS FAIL	PASS FAIL
3.	When surface appears dry, but not later than one hour after drilling, place cores in separate plastic bags and seal to prevent moisture loss. (7.2.1)	PASS FAIL	PASS FAIL	PASS FAIL
4.	Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as practical. (7.2.1.)	PASS FAIL	PASS FAIL	PASS FAIL
5.	Saw or grind the top and bottom of the specimen. Remove no more than 0.375 in from the top. Remove only the amount required for the specimen to fit in the testing machine from the bottom. (7.3)	PASS FAIL	PASS FAIL	PASS FAIL
6.	No point on either end of the specimen shall protrude by more than 0.125 in from a plane perpendicular to the axis of the specimen at the lowest point of the surface. (7.3)	PASS FAIL	PASS FAIL	PASS FAIL
7.	Prior to capping, determine the density of a core. (Note)	PASS FAIL	PASS FAIL	PASS FAIL
	Capping			
8.	Cap the specimen according to the procedures contained in **KT-77.** (8.1)	PASS FAIL	PASS FAIL	PASS FAIL
9.	Measure and break the cores according to **KT - 76**	PASS FAIL	PASS FAIL	PASS FAIL

KT-49 Drilled Cores From PCCP and Precast Girders
Revised July 2023

Overall Score

Circle One

1st Test	**2nd Test**	**Re-Test**
PASS	PASS	PASS
FAIL	FAIL	FAIL

IA Witness Examiner: ______________________ ______________________
(First Try) Signature Date

IA Witness Examiner: ______________________ ______________________
(Second Try) Signature Date

IA Witness Examiner: ______________________ ______________________
(Re-Test) Signature Date

Comments:

Hardened Concrete Properties
KT-76 Method For Testing The Compressive Strength Of Molded Cylindrical Concrete Specimens
Revised July 2023

Two attempts may be made by the applicant. The applicant may stop themselves once and not have that count as one of the two attempts. If the applicant stops voluntarily, draw a line at that point and note that the applicant stopped themselves then restart at the top of the next attempt.

Applicant: ______________________ **CIT #:** ______________

Employer: ______________________

		1st Test	Stopped Test	Re-Test
	Scope			
	Capping			
1.	Cap the specimen according to the procedures contained in **KT-77**. (7.1.)	PASS FAIL	PASS FAIL	PASS FAIL
	Determining the Size of the Specimen			
2.	Take two measurements of the diameter at right angles to the nearest 0.01 in. Average the two measurements (5.1)(5.2)	PASS FAIL	PASS FAIL	PASS FAIL
3.	Take three measurements of the length at 3 intervals. Average the three measurements. (7.2.)	PASS FAIL	PASS FAIL	PASS FAIL
	Testing			
4.	Wipe clean the bearing faces of the upper- and lower-bearing blocks and of the test specimen and place the test specimen on the lower bearing block. (8.2)	PASS FAIL	PASS FAIL	PASS FAIL
5.	As the spherically-seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.	PASS FAIL	PASS FAIL	PASS FAIL
6.	Prior to testing the specimen, verify that the load indicator is set to zero. (8.3)	PASS FAIL	PASS FAIL	PASS FAIL

		1st Test	Stopped Test	Re-Test
7.	Rate of Loading - Apply the load continuously and without shock. Apply the compressive load at a rate of 35 +/- 7 psi/s until the specimen displays a well-defined fracture pattern. Record the maximum load carried by the specimen during the test and note the type of fracture pattern. (8.4., 8.4.4.)	PASS FAIL	PASS FAIL	PASS FAIL

Overall Score

Circle One

1st Test	**Stopped Test**	**Re-Test**
PASS	PASS	PASS
FAIL	FAIL	FAIL

Witness Examiner:
(First Try) ______________________ Signature ______________________ Date

Witness Examiner:
(Stopped Try) ______________________ Signature ______________________ Date

Witness Examiner:
(Re-Test) ______________________ Signature ______________________ Date

Hardened Concrete Properties
KT-77 Method For Capping Cylindrical Concrete Specimens

Revised July 2023

Two attempts may be made by the applicant. The applicant may stop themselves once and not have that count as one of the two attempts. If the applicant stops voluntarily, draw a line at that point and note that the applicant stopped themselves then restart at the top of the next attempt.

Applicant: ______________________________ **CIT #:** ____________________

Employer: ____

		1st Test	Stopped Test	Re-Test
	End Preparation			
1.	No point on either end of compressive test specimens shall protrude by more than 0.125 inches (3 mm) from a plane perpendicular to the axis of the specimen at the lowest point of the surface *prior to capping with sulfur*. If the end exceeds this limit, saw or grind the end of the specimen no more than the amount that is required to correct the condition. (Sec. 5.1, refers to KT-76.)	PASS FAIL	PASS FAIL	PASS FAIL
	Capping			
2.	Prepare sulfur mortar for use by heating to about 265°F (130°C). (Sec. 7.1.)	PASS FAIL	PASS FAIL	PASS FAIL
3.	Remove any excess moisture, oil, wax or other contaminants from the ends of the specimen prior to capping. (Sec. 7.2.)	PASS FAIL	PASS FAIL	PASS FAIL
4.	Check the capping plate and guide device to ensure it is warmed slightly. Oil capping plate lightly. (Sec. 7.3)	PASS FAIL	PASS FAIL	PASS FAIL
5.	Stir the molten sulfur mortar immediately prior to capping. (Sec. 7.3.)	PASS FAIL	PASS FAIL	PASS FAIL
6.	Pour the mortar onto the surface of the capping plate. Use sufficient material to cover the cylinder end after the sulfur mortar solidifies. (Sec. 7.3)	PASS FAIL	PASS FAIL	PASS FAIL

		1st Test	Stopped Test	Re-Test
7.	Lift the cylinder above the plate and contact the cylinder sides with the guides. While keeping the cylinder sides in constant contact with the guides, slide the cylinder down the guides onto the capping plate. The cylinder end should continue to rest on the capping plate while maintaining positive contact with guides until the mortar has hardened. (Sec. 7.3)	PASS FAIL	PASS FAIL	PASS FAIL
8.	The capped surfaces of the specimens shall not depart from perpendicular to the axis of the specimen by more than 0.5 degrees; i.e. 0.125 in in 12 in (3.2 mm in 305 mm), 0.070 in in 8 in (1.8 mm in 200mm). The surface of the cap shall not depart from plane by more than 0.002 in (0.05 mm). Caps should be about 0.125 in (3 mm) thick. (Sec. 7.4)	PASS FAIL	PASS FAIL	PASS FAIL
9.	Tap the cap with a metal implement after hardening to check for hollow areas under the cap. Remove and replace any cap not meeting these requirements. (Sec. 7.4)	PASS FAIL	PASS FAIL	PASS FAIL
10.	For specimens with compressive strengths up to 7000 psi (50MPa), caps shall be no more than 0.31 in (8 mm) thick at any point. For specimens with compressive strengths over 7000 psi (50MPa) but less than 8,000 psi (55 MPa), caps shall be no more than 0.20 in (5 mm) thick at any point. (Sec. 7.4)	PASS FAIL	PASS FAIL	PASS FAIL
	Curing			
11.	**After Capping** Specimens shall be maintained in a moist condition consistent with the requirements for the type of specimen, cylinders or cores. (Sec. 7.2.)	PASS FAIL	PASS FAIL	PASS FAIL

KT-77 Method For Capping Cylindrical Concrete Specimens

Revised July 2023

Overall Score

Circle One

1st Test	**Stopped Test**	**Re-Test**
PASS	PASS	PASS
FAIL	FAIL	FAIL

Witness Examiner:
(First Try) ______________________ Signature ______________________ Date

Witness Examiner:
(Stopped Try) ______________________ Signature ______________________ Date

Witness Examiner:
(Re-Test) ______________________ Signature ______________________ Date

Hardened Concrete Properties
KT-79 Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration

Revised July 2018

Two attempts may be made by the applicant. The applicant may stop themselves once and not have that count as one of the two attempts. If the applicant stops voluntarily, draw a line at that point and note that the applicant stopped themselves then restart at the top of the next attempt.

Applicant: ______________________________ **CIT #:** ____________________

Employer: ____

		1st Test	Stopped Test	Re-Test
	Test Specimen			
1.	Prepare 3 specimens per mix design. The specimens shall be 4" x 8" (100mm X 200mm) cylinders cast at time of mixing. (4.1)	PASS FAIL	PASS FAIL	PASS FAIL
2.	Cast samples must undergo initial curing procedures according to KT-22 with the requirements that samples are to be submitted to the testing facility within 48 hours of casting.(5.1)	PASS FAIL	PASS FAIL	PASS FAIL
3.	Make four marks on the top circular face of the specimen marking the 0, 90, 180, 270 degree points of the circumference of the circle. On the longitudinal sides mark the center of the longitudinal length of the specimen in order to use as a visual reference during testing.(5.2)	PASS FAIL	PASS FAIL	PASS FAIL
	Procedure			
4.	Specimens are to be tested no earlier than 1 day before, or no later than 4 days after the specified test date. (Note)	PASS FAIL	PASS FAIL	PASS FAIL
5.	Calibrate the unit using the test strip provided by the manufacturer each day of testing.(6.1)	PASS FAIL	PASS FAIL	PASS FAIL
6.	Remove the specimen from water, blot off excess water to SSD condition, and transfer specimen to specimen holder. (6.3)	PASS FAIL	PASS FAIL	PASS FAIL

KT-79 Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration

Revised July 2018

		1st Test	Stopped Test	Re-Test
7.	Place the meter longitudinally on the side of the specimen at the 0 degree mark. Center the meter longitudinally on the specimen. (6.4)	PASS FAIL	PASS FAIL	PASS FAIL
8.	Make sure all the points of the array probe are in contact with the concrete. (6.4)	PASS FAIL	PASS FAIL	PASS FAIL
9.	Wait until a stable reading is obtained, and record the resistivity measurement on the testing form to the nearest 0.1 kΩ-cm. (6.4)	PASS FAIL	PASS FAIL	PASS FAIL
10.	Repeat step **6.4** for the 90, 180, and 270 degree marks. (6.5)	PASS FAIL	PASS FAIL	PASS FAIL
11.	Repeat steps **6.4** and **6.5** for the same specimen for a total of eight readings. (6.6)	PASS FAIL	PASS FAIL	PASS FAIL
12.	Repeat steps **6.4** to **6.6** for the remaining two specimens in the sample set. (6.8)	PASS FAIL	PASS FAIL	PASS FAIL

Overall Score

Circle One

1st Test	Stopped Test	Re-Test
PASS	PASS	PASS
FAIL	FAIL	FAIL

Witness Examiner:
(First Try) ______________________ Signature ______________________ Date

Witness Examiner:
(StoppedTry) ______________________ Signature ______________________ Date

Witness Examiner:
(Re-Test) ______________________ Signature ______________________ Date