KANSAS STATE UNIVERSITY | Salina

BASIC LAB COURSE WORKBOOK

CIT Program

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Kansas Department of Transportation

BASIC LAB COURSE
CIT PROGRAM

Written Test: Open book – 20 multiple choice questions

Grading: Must score at least 70% on the written exam.

Exam Results: Exams results will be emailed to the student within 2 weeks of class. Exam results are not given over the phone.

Exam Re-takes: Students who need to re-take the written 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. The student will be emailed 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 CIT^2 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.

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Click on the section name below to be taken to the correct page.

Basic Laboratory Soils Section

Isaac M Ferguson

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Sample Preparation

- We recommend a minimum of 100 lb sample for testing soils.
- We recommend a minimum 150 lb sample for testing aggregate, MSE Wall, Relative Density, or treated subgrade/base testing.

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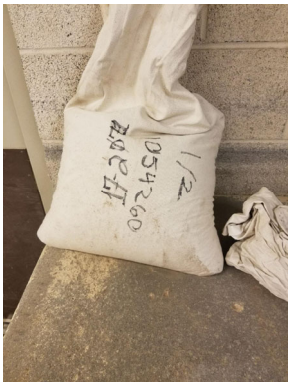
Sample Preparation

- It takes about 2 days to prepare the sample before testing starts
- This is why not having a large enough sample initially could delay test results.

Routine Testing

- Routine tests can be performed using disturbed sample



Routine Tests

- Standard Compaction KT-12
- Atterberg Limits KT-10
- Grain Size Analysis
- Specific Gravity

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Strength Testing

- Strength testing are typically performed from an undisturbed sample collected by a Shelby Tube.

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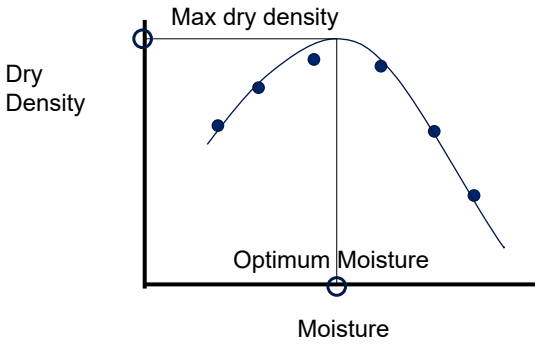
Strength Tests

- Unconfined Compression
- Direct Shear
- Ring Shear
- Triaxial
- Consolidation

Standard Compaction

Standard Compaction (KT-12)

- Maximum Dry Density
- Optimum Moisture



Standard Compaction

- Standard Compaction uses a 5.5 lb hammer with a 12-inch drop
- Soils typically use a 4 inch mold with 25 blows to 3 lifts
- Aggregate typically uses a 6-inch mold with 56 blow to 3 lifts.
- Note: The 4-inch and 6-inch molds are both approx. 4.584-inch tall.

Standard Compaction (KT-12)

- Performed on fine grained material
  - 1. The material has less than 10% retained on the No. 4 sieve or
  - 2. The material has more than 10% but less than 30% retained on the No 4 sieve and the fraction passing the No. 40 sieve has a plasticity index greater than 8
- Coarse grained (Aggregate)
  - Typically this material will have sufficient fines to hold moisture.
  - If “too clean” then a Relative Density would be more suitable.

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Relative Density

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Relative Density (KT-69)

- Uses a Vibrating Table
- For testing free draining, cohesionless material containing a maximum of 15% fines and 100% passing the 3” sieve
- The minimum density is determined when the material is in its uncompacted state
- The maximum density is determined after being loaded and vibrated

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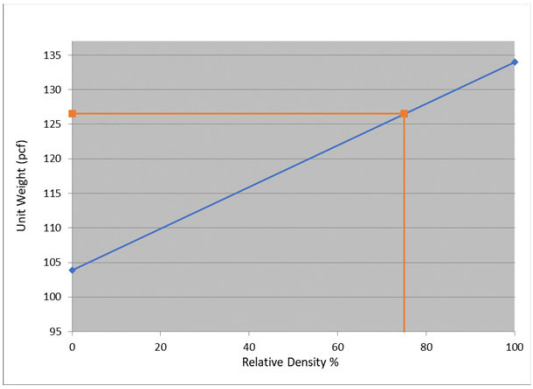
Relative Density (KT-69)

ρ_{dmax} = 134.0pcf ρ_{dmin} = 103.9pcf 75% Relative Density: 126.5 pcf



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Atterberg Limits

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Atterberg Limits

- Liquid Limit
- Plastic Limit
- Plasticity Index

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Atterberg Limits

- Liquid Limit: LL
- Plastic Limit
- Plasticity Index

Atterberg Limits

- Liquid Limit: this test determines the water content at which the soil passes from a plastic to a liquid state.

Atterberg Limits

- Liquid Limit: LL
- Plastic Limit: PL
- Plasticity Index

Atterberg Limits

- Plastic Limit: this is the lowest water content of the soil at which the soil remains plastic

Atterberg Limits

- Liquid Limit: LL
- Plastic Limit: PL
- Plasticity Index: PI

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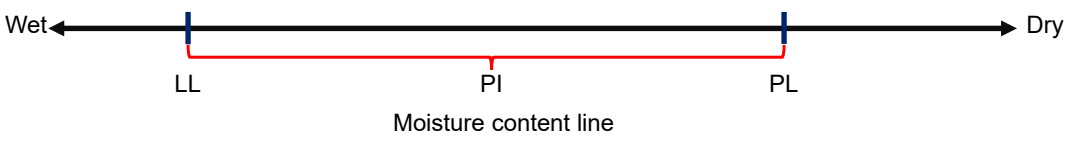
Atterberg Limits

- Plasticity Index of a soil is the range in water content within which the material is in a plastic state.
- PI = LL-PL



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Sieve Analysis/Gradation

Sieve Analysis/Gradation

- Sieves are used for determining the distribution of particle sizes in soils/aggregates
- Aggregate is washed to determine material passing #200 sieve

Hydrometer

- Analysis of particle size distribution of material passing a #200 Sieve
- Silts
- Clays

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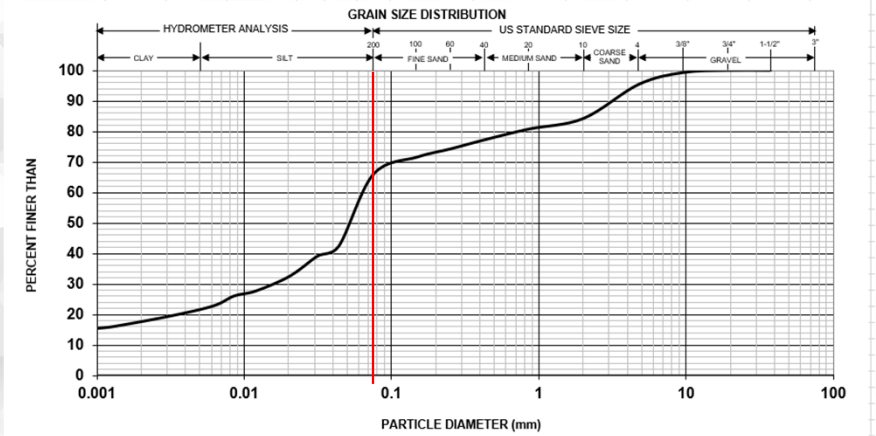
Gradation Curve



PHYSICAL PROPERTIES

SAMPLE NUMBER	STATION	CL DIST.	DEPTH (ft)	L.L.	P.L.	P.I.	% RET. ON 10 SEIVE	SPEC. GRAV. (PASS NO. 10)	CLASSIFICATIONS KANSAS	CLASSIFICATIONS USCS
1A-1	762+00	85'RT	0-2.0'	37	22	15	15.8	2.65	CL	CL

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Classification of Soils

- AASHTO-uses a classification system based on laboratory determination of particle size distribution, liquid limit, and plasticity index.

Table 1—Classification of Soils and Soil–Aggregate Mixtures

General Classification	Granular Materials (35 Percent or Less Passing 75 μm)			Silt–Clay Materials (More Than 35 Percent Passing 75 μm)			
Group Classification	A-1	A-3[a]	A-2	A-4	A-5	A-6	A-7
Sieve analysis, percent passing:							
2.00 mm (No. 10)	—	—	—	—	—	—	—
0.425 mm (No. 40)	50 max	51 min	—	—	—	—	—
75 μm (No. 200)	25 max	10 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40):							
Liquid limit	—			40 max	41 min	40 max	41 min
Plasticity index	6 max	Nonplastic (NP)	[b]	10 max	10 max	11 min	11 min
General rating as subgrade	Excellent to Good			Fair to Poor			

[a] The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.
[b] See Table 2 for values.

Classification of Soils

- Unified Soil Classification System

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
COARSE-GRAINED SOILS	Gravels (More than 50 % of coarse fraction retained on No. 4 sieve)	Clean Gravels (Less than 5 % fines[C])	Cu ≥ 4.0 and 1 ≤ Cc ≤ 3.0[D]	GW	Well-graded gravel[E]
			Cu < 4.0 and/or [Cc < 1 or Cc > 3.0][D]	GP	Poorly graded gravel[E]
		Gravels with Fines (More than 12 % fines[C])	Fines classify as ML or MH	GM	Silty gravel[E,F,G]
			Fines classify as CL or CH	GC	Clayey gravel[E,F,G]
More than 50 % retained on No. 200 sieve	Sands (50 % or more of coarse fraction passes No. 4 sieve)	Clean Sands (Less than 5 % fines[H])	Cu ≥ 6.0 and 1.0 ≤ Cc ≤ 3.0[D]	SW	Well-graded sand[I]
			Cu < 6.0 and/or [Cc < 1.0 or Cc > 3.0][D]	SP	Poorly graded sand[I]
		Sands with Fines (More than 12 % fines[H])	Fines classify as ML or MH	SM	Silty sand[F,G,I]
			Fines classify as CL or CH	SC	Clayey sand[F,G,I]
FINE-GRAINED SOILS	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic clay[K,L,M,N] Organic silt[K,L,M,O]
50 % or more passes the No. 200 sieve	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
			PI plots below "A" line	MH	Elastic silt[K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic clay[K,L,M,P] Organic silt[K,L,M,Q]
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor			PT	Peat

Classification of Soils

- KDOT Classification System

TABLE I

CLASS NAME	PERCENTAGE OF SOIL FRACTIONS PRESENT SAND	SILT	CLAY
Sand	80-100	0-20	0-20
Sandy Loam	50-80	0-50	0-20
Sandy Clay Loam	50-80	0-30	20-30
Sandy Clay	50-70	0-20	30-50
Silt	0-20	80-100	0-20
Silty Loam	0-50	50-80	0-20
Silty Clay Loam	0-30	50-80	20-30
Silty Clay	0-20	50-70	30-50
Clay	0-50	0-50	30-100
Clay Loam	20-50	20-50	20-30
Loam	30-50	30-50	0-20

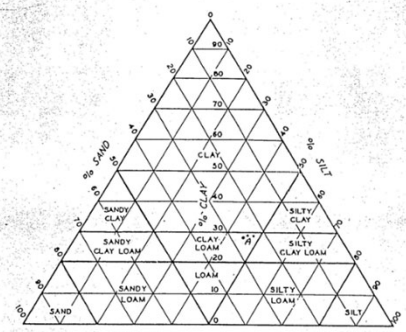


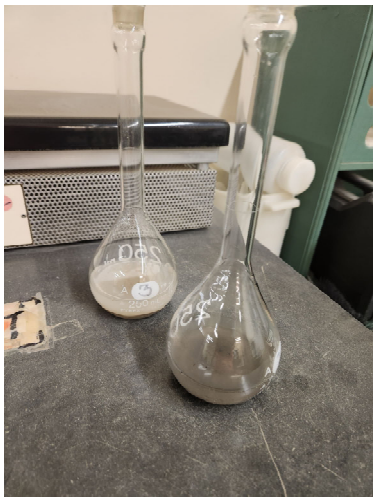
CHART FOR TEXTURAL CLASSIFICATION OF SOILS

Classification of Soils

- KDOT Classification System

Specific Gravity

Specific Gravity



- The ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.
- Soils determines specific gravity by means of a pycnometer.

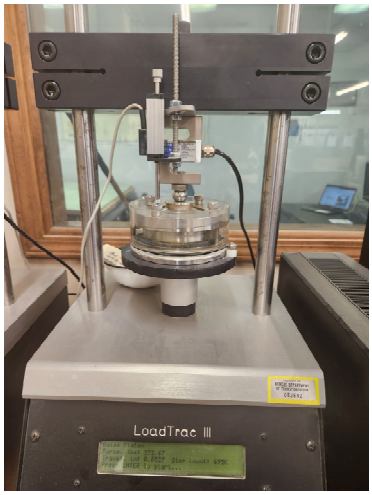
Soil Swell Test Checks

- Soils with 2% or greater swelling potential beneath pavement is not good.
- We can check swelling potential by using Oedometer or Atterberg test results

Soil Stabilization

- Examples are: Hydrated Lime, Type “C” Fly Ash, Portland Cement

Consolidometer (Oedometer)



- Predicts settlement
- Predicts swell potential

Strength Testing

Strength Tests

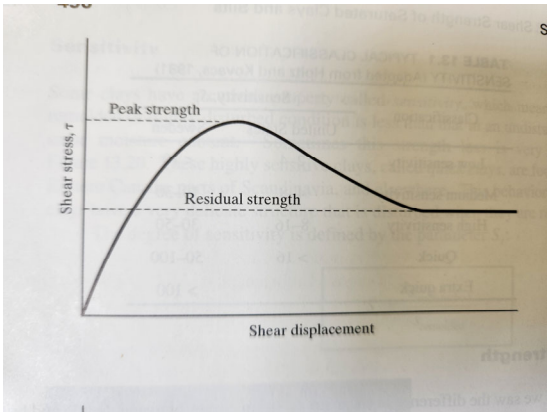
- Direct Shear
- Ring Shear
- Triaxial
- Unconfined Compression

Direct Shear

- Calculates shear strength of soil as internal angle of friction = ϕ'

Ring Shear Test

- Used to calculate the residual strength of soils
- Information is useful for landslide/slope failure analysis.



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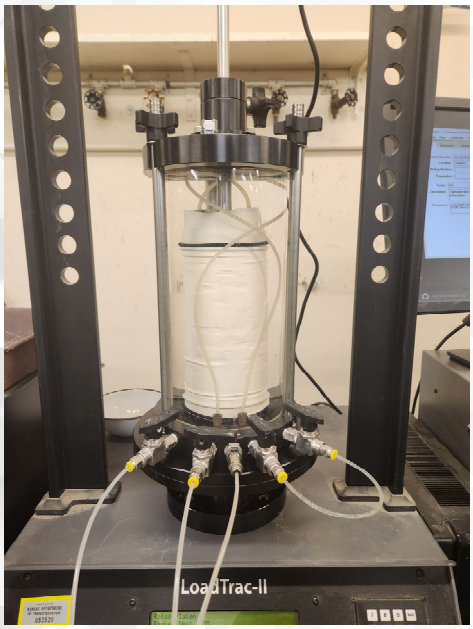
Triaxial Testing



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Unconfined Compression Test

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Unconfined Compression Test

- Similar to the Triaxial Test, but does not have a confining pressure.
- This test is used for analysis of cohesion = c

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Permeability Test

- This test is used to predict the hydraulic conductivity of soil.

Requesting Testing

Requesting Testing

- Proctor- This is the standard compaction test. KT-12
- Atterberg Limits- this is KT-10
- Note: currently both of these tests can be found in AASHTOWare under the name **Routine Tests**

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Materials and Research Center

Basic Laboratory Course

1

Overview of the Duties of the Research Asphalt Section

- Investigate the use of recyclable materials proposed to be used in Asphalt Pavement mixtures, (Tire rubber, coal fly ash, broken glass, steel slag, steel staples, lignin, asphalt roofing shingles, sulphur, FRAP and high percentages of RAP).
- Learn the use of new technology test equipment (Auto Rice, CoreLok, CoreDry, Bulk Specific Gravity Tester SG-4, MIST Tester, SSD Detech, Raveling and Brush Tester, Thermal Stress Restrained Specimen Tester (TSRST), Air and Water Permeability Testers, Linear Asphalt Compactor, Asphalt Beam Fatigue Tester, Pull-Off Test for HMA, Asphalt Mixture Pavement Tester (AMPT), Interlaken and DTS-30 Universal testing Machines, Smart-Jig and Smart Loader).

2

Overview of the Duties of the Research Asphalt Section

- Develop Test Sections relating to new treatment mixes (map out a **1000-foot test** section of the pavement, by recording all existing distresses on the pavement prior to the new treatment), then every Spring of the following year, observe and record the distresses of the designated test section.
- Perform lab testing on HMA in use now or new treatment mixes (Asphalt Rubber, Cold-In-Place-Recycling (CIR), Micro-Surfacing, Asphalt Treated Base, Reflective Crack Inner-Layer (RCI), Stone Matrix, Sulphur Mix, Open-Friction Graded Course, High % RAP mixes, Spray Paver, Warm Mix Asphalt, and Recycled Asphalt Shingle Mixes).

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Overview of the Duties of Research Asphalt

- Superpave Field (SF) CIT course,(Obtain 4000 pounds of HMA from a plant, print/edit manuals in-house, weigh out test procedure samples for each session and deliver to the university, be an Instructor for the course and as a Supplement Examiner on the day of test method demonstrations).
- Investigate premature HMA pavement failures, (Obtain field cores from the distressed area, perform lab testing to determine problem).
- Referee testing of active HMA projects (If any District Material Lab's has a dispute with an Asphalt Contractor) over Lot/Sublot test results and cannot be solved at the district lab. A split sample of the dispute is giving to our lab, we perform same tests, to compare all results.

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Overview of the duties of Research Asphalt

- AASHTO Accreditation Laboratory, (familiarize ourselves and become proficient in performing HMA AASHTO test procedures similar like Kansas Test Methods Part V. Verify our test equipment used for any HMA test procedure, done every 6 months or annually. Keep documentation on all equipment verified, perform proficiency samples provided by AASHTO re:Source yearly, and every 18 months be available to be witnessed on site by federal inspectors, on the HMA test procedures we are accredited to perform in our lab).

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Overview of latest Testing in Research Asphalt

- IDEAL CRACKING TEST (CT) & IDEAL RUTTING TEST (RT) are what we are focusing on in the lab. The test method for cracking test is **ASTM D-8225, Standard Test Method for Determination of Cracking Tolerance Index of Asphalt Mixture Using the Indirect Tensile Cracking Test at Intermediate Temperature.**
- IDEAL RUTTING TEST (RT) test method is **ASTM D-8360, Standard Test Method for Determination of Rutting Tolerance Index of Asphalt Mixture Using the Ideal Rutting Test.**
- Both methods calculate the CT or RT Index from the load-displacement curves that are used to evaluate HMA for cracking and rutting.

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Overview of latest Testing in Research Asphalt

- To perform these two new tests, equipment needed are the same for Volumetric testing (SGC, Gmm, KT-15 Proc. III, Stability machine, jigs for the IDEAL CT & RT, that have adapted using the Lottman breaking head. A stability machine can be used with the **Smart-Jig** or what we are using is the **Smart-Loader** testing machine, which has the following test methods installed, (Stability & Flow, TSR, IDEAL CT and SCB (Semi-Circular Bend). After two construction years of testing mixtures from mobile plants, Headquarters is now going to have the same **Smart-Loader** test frames placed in all 6 district labs, which will assist in analyzing test results, HMA contractors will follow also.

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Overview of latest Testing in Research Asphalt

- In July of 2023, we are purchasing a Hamburg Rut Testing machine, the product is coming for InstroTek which is named **SmarTracker Hamburg Wheel Tester**, the test method to use is AASHTO T-324.
- We will evaluate mixes for rutting, then can compare results from the HWT to our Corp of Engineer Gyratory Compactor and IDEAL RT.
- The C of E Gyratory has ben is existence since 1940's, during the 1990's, the gyratory was used to predict rutting of surface mixes by testing different percents of asphalt binder, when KDOT did mix designs, now we allow HMA Contractors to do mix designs.

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Overview of latest Testing in Research Asphalt

- **Hamburg Rut Tester or Hamburg Wheel Tester** is used for testing the rutting and moisture-susceptibility of asphalt mixture pavement samples. Specimens are either compacted by a slab compactor or by Superpave Gyratory Compactor. Compacted slab specimens are to be 12.5”L X 10.25”W X 1.5 – 4” thick. For the SGC, compact two 150mm diameter X 38 – 100mm thick specimens , using a HDPE (high-density polyethene) mold, to secure the specimens for testing. The test will stop after 20,000 passes has occurred or to a maximum impression depth established by KDOT.

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Overview of latest Testing in Research Asphalt

- **IDEAL – RT (Rutting Test)** the test method we follow is ASTM D-8360.
- Specimens are compacted on the SGC to a height of 62 ± 1 mm by 150mm diameter and 7 ± 0.5% air void content.
- Test specimens are preconditioned to a temperature of 50 ± 1.0 ^{o}C, in environmental cabinet 150 ± 10 min or 45 ± 5 min in a water bath, testing with a Lottman breaking head and cradle 19.05 ± 0.3mm inserted on to the bottom loading strip of the Lottman breaking head.
- Using our Smart-Loader that has the software to obtain the maximum load for the IDEAL-RT, test is run using the IDEAL-CT software, but the RT value is calculated in Excel on a form developed in-house.

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Overview of the duties of Research Asphalt

- Other unique testing devices for HMA, which our group will analyze to see if they would be better and accurate ways to test HMA.
- CoreDry – used to dry cores or mix that needs to be @ constant mass.
- CoreLok – used for permeable mixes, greater than 2% absorption, which vacuum seals the HMA specimen in plastic bag, then bulk specific gravity can be determined.
- MIST (Moisture Induced Sensitivity Testing) – used as an accelerated conditioning device to determine the resistance of the asphalt mixture to adhesion and cohesion problems generally know as stripping.

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Sampling of HMA Materials in the Field.

- Aggregate sampling (It is important that we obtain a representative sample from the material by following KT Method KT-1).
- Sampling of HMA for QC/QA testing (Sampling is done behind the paving machine, the KT Method to follow is KT-25).
- Sampling of HMA for IDEAL Cracking test (Sampling is done by the auger of the paving machine, typically 150 pounds, once bagged, on the bag information needed is, Mix design, Date of sampling and **ONLY** 50 pounds per bag/container).

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Unique & HMA Test Methods used in Lab

- AASHTO R-30 - Laboratory Conditioning of HMA
- AASHTO T-324 - Hamburg Wheel-Track Testing
- AASHTO TP-10 - Thermal Stress Restrained Specimen Test (TSRST)
- AASHTO T-312 – Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- ASTM D-8225 – Standard Test Method for Determining of Cracking Index of Asphalt Mixtures (IDEAL-CT/RT)
- ASTM D-8360 – Standard Test Method for Determination of Rutting Tolerance of HMA, using the IDEAL Rutting Test.

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Materials Test Unit/ Physical Test Unit

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1

2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION

- **Link to Standards:**
  - KDOT: 2015 Standard Specifications for State Road and Bridge Construction (ksdot.gov)
- **DIVISION 400 – Concrete**
  - **General concrete, structural concrete, general on grade, on grade for prestressed members,**
    - **Teste performed in concrete:**
      - **Freeze and thawing of concrete beams**
      - **Wetting and drying of concrete beams**

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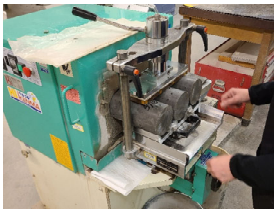
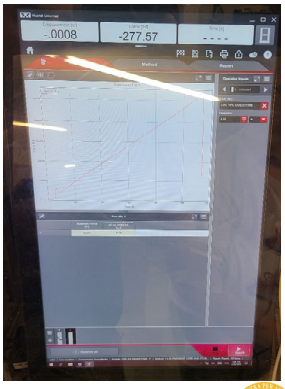
2

2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION cont.

- **DIVISION 400 – Concrete cont.**
  - **Compressive strength of cylinders and pavers**





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2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION cont.

DIVISION 1100 – AGGREGATES

- **Aggregates for Concrete, Asphalt, Base, Backfill, Micro surfacing, Rock Shoulders, etc.**
- **Tests performed in aggregates:**
  - **LA wear and micro deval**

LA Wear testing machine

Micro Deval Testing Machine

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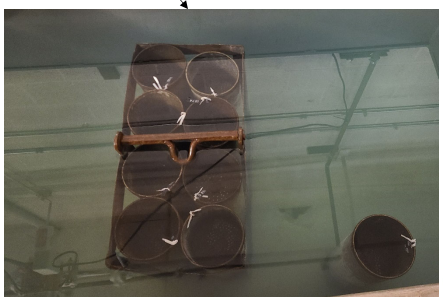
2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION cont.

- Tests performed in aggregates cont.:
- Gradation
- Soundness (Freeze and Thaw)
- Specific gravity 1 and 2



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2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION cont.

- DIVISION 1300 - **BRICK AND CONCRETE MASONRY UNITS**
- DIVISION 1400 - **CONCRETE ADMIXTURES AND CURING MATERIALS**
  - **Admixtures, Liquid Membrane forming compounds,**
- DIVISION 1500 - **JOINT SEALING AND JOINT FILLER MATERIAL**

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2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION cont.

- **DIVISION 1600 - FERROUS AND NON-FERROUS METALS**
  - **Steel Reinforcing Bars, Wire Fabric for Concrete Reinforcement, Strand for Prestressed Concrete, Structural Steel, Steel Pile, Steel Plate Shear Connectors, Anchor Bolts, Zinc coating, cast Bronze, Steel Posts, etc.**
    - **Tests performed on metals:**
      - **Tensile testing of rebar, bolts and cable**
        - **Only A325 and A490 structural bolts are tested**
      - **Rotational capacity testing of bolt assemblies**
      - **Chemical testing of bolt assemblies and rebar**

Rotational capacity testing

Tensile testing of Rebar

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2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION cont.

- **DIVISION 1700 - MISCELLANEOUS MATERIALS**
  - **Manholes, Gabions, Rapid-set Concrete Patching Material, Detectable Warning Surface Panels for Curb Ramps and Medians**
- **DIVISION 1900 -CULVERT, SEWER AND UNDERDRAIN PIPE**
  - **Quality control Program for Precast concrete Products, Corrugated Metal Pipe and End Sections**
- **DIVISION 2600 - MATERIALS CERTIFICATIONS**
  - **Material Certifications**

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2015 KDOT STANDARD SPECIFICATIONS SECTIONS APPLICABLE TO THE PHYSICAL TEST UNIT* MATERIALS DIVISION cont.

- DIVISION 2000 - PORTLAND CEMENT, LIME AND FLY ASH
  - Cement, Fly Ash, Silica Fume, Slag
    - Testing performed on cement::
      - Cubes for compressive strength
      - Chemical testing of cement and water
      - Time of set, permeability, air content, normal consistency, …etc
- DIVISION 2400 – WATER (Water for use in Concrete)
- DIVISION 2500 - MISCELLANEOUS METHODS OF TEST
  - Part V

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MATERIALS AND RESEARCH (MR) CENTER TEST PROCEDURES APPLICABLE TO PTU

SECTION

- MR-11 ROTATIONAL CAPACITY TESTING OF HIGH STRENGTH FASTNERS-FHWA SUPPLEMENTAL SPECIFICATION (RE: 1616)
- MR-16 TESTING OF DOWEL BARS PLACED IN CONCRETE FOR RESISTANCE TO REMOVAL (PULL OUT)
- MR-21 SOUNDNESS AND MODIFIED SOUNDNESS OF AGGREGATES BY FREEZING AND THAWING
- MR-22 RESISTANCE OF CONCRETE TO RAPID FREEZING AND THAWING
- MR-23 WETTING AND DRYING TEST OF SAND-GRAVEL AGGREGATE FOR CONCRETE
- MR-24 PROCEDURES FOR TESTING LIGHTWEIGHT AGGREGATES
- MR-26 TEST METHOD FOR COMPRESSIVE STRENGTH OF HYDRAULIC CEMENT MORTARS (USING 2 in. OR [50 mm] CUBE SPECIMENS)
- MR-27 MODIFIED SPECIFIC GRAVITY AND ABSOPRTION OF AGGREGATE
- MR-28 DETERMINATION OF TOTAL ACID INSOLUBLE RESIDUE
- MR-29 WETTING AND DRYING TEST OF STEAM CURED REINFORCED CONCRETE PIPE WITH FLY ASH

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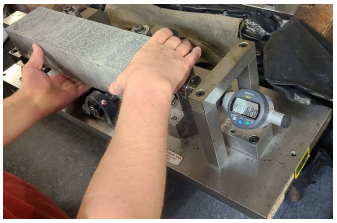
Testing Purposes and Sample Sizes
2015 Standard Specifications w/o Special Provisions

400: concrete

Production: For monitoring the quality of OGCA aggregate that is being used in concrete pavement production. Sampled from quarry production and consists of 80# each of material between -3/4+1/2 sieves and -1/2 +3/8 inch sieves. RE: most current version of Part V for sampling frequency. Productions typically consist of aggregate from multiple beds. Nominal test time is 140 days (beam test) unless MF&T fails radically. Failure for any reason will result in a follow up sample or a quarry inspection by Geologists depending on degree of failure. Use of material failing production testing can also result in premature pavement failure. RE: Note above regarding test time.



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Testing Purposes and Sample Sizes
2015 Standard Specifications w/o Special Provisions

1100: Aggregates

Official Quality: To determine what specifications an aggregate is compliant with. One per source per product per process per year for crushed stone, one per source per product at least every five years for sand/sand gravel (siliceous). Failure to complete an OFQ could result in structure/pavement degradation and/or failure. Sample sizes vary per material, refer to the most current version of Part V of the C&M Manual, READ CAREFULLY. Nominal test time is 2-3 weeks.

Ledge: To determine if limestone from an open quarry qualifies for use in on grade concrete. Sampled by Geologists.

Verifications and Information's: these tests are performed much the same as an official quality but often the materials are pulled directly off of projects to verify against the OFQ results or to ensure the product meets the requirements for the intended use. Information's are performed as a means to check different labs results or purely as an informational test to see what a product is.

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Testing Purposes and Sample Sizes
2015 Standard Specifications w/o Special Provisions

1600: Ferrous and Non-Ferrous Metals

Several materials/products governed by this division are structure critical and failure could result in catastrophic failure of a bridge or other structure.

Prequalification*: Steel reinforcing bars (uncoated)-30 samples per mill of representative sizes and heats,* mill tests half of each sample, KDOT tests remaining half, test for tensile and bend properties and compare to mill data and specifications, one, two, three year repetition cycle barring problems, sample bar lengths tentatively differ from Part V. Welded wire fabric-30 per mill of fabric (and wire if available) representative of sizes, combinations, and heats, mill tests half of each sample, KDOT tests remaining half, test for tensile and weld properties and compare to mill data and specifications, one initially then Type C certification barring problems. Reinforcing steel splices-3 fully assembled splices of sizes #4, 6, 8, bars tested for tensile properties, one initially then Type C certification and testing on lot by lot basis for spec. compliance.

Acceptance: High strength fasteners for structural applications-lot by lot basis for overhead structures, signing and lighting, tested for tensile and rotational capacity properties as an assembly that includes the bolt, nut, and washer(s) by lot, only to be used as tested and not intermixed in the field unless tested as a different combination, 6 each bolt, nut, washer, a lot is size as well as heat dependent, one heat can have several lots but not conversely. Anchor bolts-when certifications are not available-tested on a lot by lot basis for tensile properties. Nuts and washers typically tested for dimensions, hardness, composition, and coating thickness, due to their size. Prestressing strand for concrete beams and post tensioning for slabs-weight basis involving specific heats and lots.

Information: Can be taken on any material at any time for any credible reason.

Verification: As prescribed by the applicable subsection, such as for rebar and splices, or at any time as deemed necessary in order to ascertain that the product being purchased is essentially the same as that prequalified and/or is compliant with the applicable specifications. Steel reinforcing bar-RE: 1601, verification samples are mandatory and will normally be obtained by the Regional Materials Laboratories. Splices-prequalified sources-tested for specification compliance on a lot by lot basis from jobsite, prefabricated splices have different sampling requirements than those requiring operator prequalification.

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Testing Purposes and Sample Sizes
2015 Standard Specifications w/o Special Provisions

2000: Portland Cement, Lime, and Fly Ash Cementitious Materials

Prequalification: Portland and blended hydraulic cement- prequalification by testing of one gallon sample per source to determine compliance with applicable specs., also must submit required documentation which is to include an acceptable quality control program. Fly ash for use in concrete-test one gallon pql sample for specification compliance, also submit required documentation, including QC program. Fly ash for stabilization, mod., and cold recycle asphalt-test a two quart pql sample for specification compliance, also submit required documentation including quality control data. Fly ash for concrete pipe-test one gallon pql sample for specification compliance, also submit required documentation, including analytical test data, in addition (re: 1902) the fly ash, as utilized in the precast design mix it is intended for must have modified wetting and drying test requirements for precast products. Ground granulated blast furnace slag for use in concrete and mortars-test one gallon pql sample for specification compliance, also submit required documentation, including analytical test data.

Information: Can be taken on any material at any time for any credible reason.

Verification: Required for all of the above, random samples and typically at least one per year.

2400: Water

Acceptance: All water for use with cement in prestressed concrete products will be based on M&R Center sample test results, acceptance based on compliance with the applicable specifications.

KDHE Approval for Domestic Use: Water for use with cement in other applications accepted if from a city water source and approved for domestic use by KDHE, otherwise acceptance is based on M&R Center sample test results being compliant with the applicable specifications.

Note: Verification and Information samples can be taken for any material at any time if someone is concerned about the material quality.

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Questions?

Email me at zachary.katzer@ks.gov

Basic Laboratory Course

Materials Quality Management Section

aka, Quality Assurance and Quality Control

Tabitha Taylor

Kansas Department of Transportation

1

Quality Assurance Responsibilities

- Part V of the Construction Manual
- District laboratory inspections
- Laboratory certification under the AASHTO Accreditation Program
- Review of Type A & B materials certifications
- Asphalt Aggregate Specific Gravity List, also known as The SpG List

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Title 23, Chapter 1, Subchapter G, Part 637, Subpart B of the Code of Federal Regulations

- Title 23 covers highways
- Chapter 1 covers the Federal Highway Administration, FHWA, requirements that must be met by each State Department of Transportation or STD
- Subchapter G covers Engineering and Traffic Operations
- Part 637 covers Construction Inspection and Approval
- Subpart B covers Quality Assurance Procedures for Construction

Note: The Code of Federal Regulations sets the requirements for a lot of what KDOT does in terms of materials testing and personnel performing the testing and inspections.

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Title 23, Chapter 1, Subchapter G, Part 637, Subpart B

Some aspects of 637

- Quality Assurance
- Qualified laboratories/lab inspections
- Independent Assurance program
- Random sampling
- Qualified sampling and testing personnel/CIT^2 Program
- Proficiency Sample Testing

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Purpose of Title 23, Chapter 1, Subchapter G, Part 637, Subpart B – Quality Assurance Procedures for Construction

- To prescribe policies, procedures, and guidelines to assure the quality of materials and construction in all Federal-Aid Highway projects on the National Highway System.

Which in turn will ensure us that we …

"get what we pay for!"

5

Quality Assurance Program

The Quality Assurance program is a requirement of part 637.205.(a)

- Each STD shall develop a quality assurance program which will ensure that the materials and workmanship incorporated into each Federal-Aid Highway construction project on the National Highway System are in conformity with the requirements of the approved plans and specifications, including approved changes.
- The program must meet the criteria in 637.207 and be approved by the FHWA.

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Part 637.207 Quality Assurance Program

Requires each STD to have an acceptance program that covers such things as:

- Frequency guide schedules for verification sampling and testing which give general guidance to personnel responsible for the program.
- That sampling and testing is performed by qualified laboratories and personnel.
- Quality control sampling and testing is evaluated by an Independent Assurance program, IA. The samples used for quality control and verification sampling and testing shall be random samples.
- Identification of the specific location in the construction or production operation at which the verification samples and testing is to be accomplished.

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Part 637.207 Quality Assurance program

The STD's Independent Assurance program shall cover sampling procedures, testing procedures and testing equipment and each IA program shall include such things as:

- Frequency schedules for IA evaluation
- Evaluation of test equipment by using one or more of the following; calibration checks, split samples or proficiency samples
- Evaluation of qualified sampling and testing personnel shall be evaluated by using observations and split samples or proficiency samples
- Evaluation of sampling and testing procedures
- Annual reporting of IA results to the FHWA when using a system approach, as opposed to a project basis system

Note: The system that the State of Kansas uses is the system approach. This requires us to provide an annual report to the FHWA summarizing the results of the IA program.

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District Laboratories and Lab Inspections

637.209 Laboratory and sampling and testing personnel qualifications

(a)**Laboratories**.

- (1) After June 29, 2000, all contractor, vendor and STD testing used in the acceptance decision shall be performed by qualified laboratories.

(b) **Sampling & testing personnel**.

- After June 29, 2000, all sampling and testing data to be used in the acceptance decision or the IA program shall be executed by qualified sampling & testing personnel.

Note: District labs must be "qualified labs "and the Materials and Research Center is the State central laboratory and as such must be Accredited by the AASHTO AAP.

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637.203 Definitions of Qualified Laboratory

Qualified Laboratories.

- Laboratories that are capable as defined by appropriate programs established by each STD.
- As a minimum, the qualification program shall include provisions for checking test equipment and the laboratory shall keep records of calibration checks.

Note: District Lab inspections are a part of KDOT's qualification program.

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District Laboratory Inspections

The following are performed annually:

- Witnessing of test procedures performed by the lab
- Inspection of testing equipment and calibration reports

Note: The selection of the presenter is random.

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District Lab Inspection Process

- An excel spread sheet, otherwise known as the Grid Sheet, is sent to each District Materials Lab Specialist to select the test methods that are either performed or witnessed by each technician. Once the grid sheet is returned, a formula will select each test method at random.
  - During the inspection, each technician must successfully demonstrate the test methods assigned to them. The results are entered into AWP as a Witness Report.
- The Quality Manual is reviewed to make sure it is kept up to date and contains all verification, calibration and maintenance reports for all testing equipment.
- Testing equipment will be inspected to verify its performance.
- A memo is written summarizing the inspection findings.

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District Laboratory Inspections

Contractor Quality Manuals

The Contractor Quality Manual is to include calibration & verification documents of equipment and should be reviewed regularly. Particularly if a problem or question arises concerning test results.

- Examples of contractor's quality manuals in 5.2.7. "Contractors Quality Control Plan"
  - HMA 5.2.7.3.
  - Concrete 5.2.7.5.

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Hot Mix Aggregate Specific Gravity List

- Samples are taken by District Materials and the contractor or producer.
- Split samples are run by the District Materials Laboratory, Materials & Research Center's Aggregate Laboratory and the contractor/producer Materials Lab.
- Results are used to establish the specific gravity and absorption values per 5.6.5.7. The Asphalt Aggregate Specific Gravity List, otherwise known as the SpG List, which is conceived as a bidding aid for contractors.
  - This list is updated monthly and published by the Bureau of Construction and Materials on the KDOT internet web pages, https://www.ksdot.org/htmxAggravValu.asp

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The SpG List consist of 2 sections

- Coarse aggregate, **Procedure 1**, is aggregate that is retained on the No. 4 (4.75mm sieve).
- Fine aggregate, **Procedure II**, is aggregate that passes the No. 4 (4.75mm sieve).
  - **Part V, 5.7.2.** Sand Sand-Gravel must be verified every 5 years to remain on the SpG List.
  - **Part V, 5.7.3.** Chat and Crushed-Stone must be verified every 2 years to remain on the SpG List.

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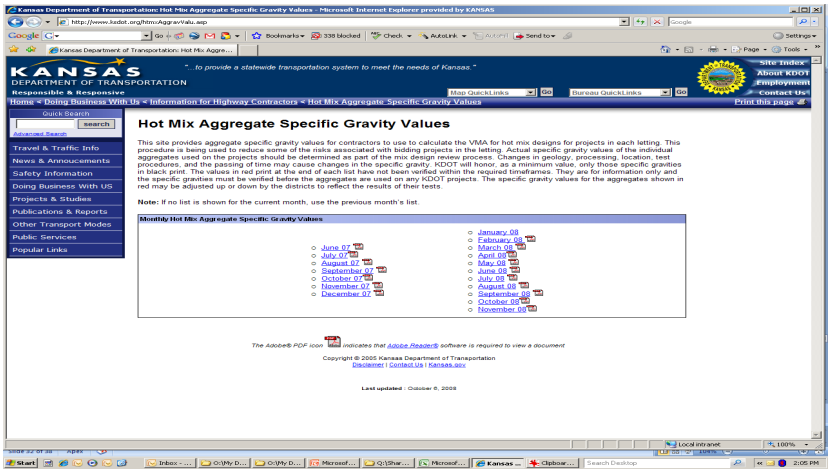
Example of the Hot Mix Aggregate Specific Gravity Values List



http://www.ksdot.org/htmxAggravValu.asp

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2015 KDOT Special Provision to the Standard Specification Section 2601 Materials Certifications 15-26001-R10

SP Specification Section 2601 governs the requirements for the content and distribution of certifications when dictated. In part or in whole, as the basis of acceptance for a material.

What is a certification?

- A certification, or materials certification, is a paper validation of confirmation of the authenticity of a material. It's a guarantee that the material meets a given specification. In other words, if we were to test it, we would get the same results.
- This comes from the manufacturer or qualified lab. We , KDOT, do not write Certifications.
  - We create a report based on the certification(s).

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Does a Material need a certification?

SP 2601 MATERIALS CERTIFICATIONS; TABLE 2601-1:

- Reference Chart for Material Related Specifications. This lists what KDOT Specification governs the material, if the material is required to be on a PQL List and the list number, if the material is covered under a "Blanket Cert" and what type of cert is required for that material.
  - The Basis of Acceptance located within a specification lists the requirements and the type of certification needed.

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KDOT Standard Specifications, 2015, section 2601.2a(2) Provide the following information on all certifications regardless of the type:

- Identification of the organization submitting the certification.
- KDOT project number and KDOT contract number.
- Name of contractor.
- Identification markings on the shipment. As a minimum, this must include the name of the manufacturer. Also include the lot or heat number referenced in the certification, the serial number if applicable, and the date of manufacture if available. This information is not required for Type "F" and "G" certifications.
- Quantity of material represented by the certification. If multiple lot/heat numbers are submitted, the quantity should be listed per lot/heat number.
- KDOT Contract line number (bid item) and item code number of the material represented by the certification.
- Statement that all material complies with the applicable specifications. List the specifications by responsible organization, number, section reference or other appropriate identification.
- Additional information as required in the specification for the material, or as added requirements for the various types of certifications in subsection 26012b.
- "Buy America" statement on domestic iron & steel products and "Buy America, Build America" (BABA) on construction materials and manufactured products as required in section 106.

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2601.2a(3) The general information outlined in 2601.2a(2) must be provided by the material supplier on a cover sheet to the manufacture's certification(s). Verify that the cover sheet & certification(s) are so well cross referenced & identified as a unit that they can be reunited if accidently separated.

The example, below, is located at the end of SP 2015, section 2601

Date: _____

Submitted by: _____

Kansas Department of Transportation
Materials Certifications
2300 Van Buren
Topeka, Kansas

Project Number: _____

Contract Number: _____

Line Number: _____ Item Code: _____

Contractor Name: _____

ID Markings on Shipment: _____

Additional Information: _____

This is to certify that the following items furnished by our firm for use on the reference project meet or exceed the requirements of section _____ of the _____ edition of the Kansas Department of Transportation Standard Specification.

Quantity	Description	Heat	Lot	Manufacturer

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Type “A” Certification

This certification is to include a copy of the results of tests conducted by the manufacturer or other qualified laboratory on samples obtained from the lot or lots of material in the shipment.

When a mill test report is submitted as the laboratory report, the quantity in the shipment does not need to be included on the report, provided that the identifying heat or lot numbers involved are roll stamped, embossed, or durably affixed to each item of material in the shipment represented by the report.

In this case, provide the necessary quantity information on a cover sheet, clearly identifying the quantity of each heat or lot in the shipment.

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Type “B” Certification

This certification is to include a current summary of the maximum to minimum range of the manufacturer’s quality control test results as determined by the manufacturer or other qualified laboratory.

These summaries must provide data on all major specification requirements and include the range of lots and manufacture dates represented by the data.

When combining multiple components into a single item, submit a detailed parts summary indicating the lot/heat number, part description and quantity for each part. Summary reports dated more than six months prior to the date of manufacture or shipment of the product will not be accepted.

The Engineer of Tests may also request copies of detailed test reports for material produced during a specified time interval for verification of the certification.

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Type "C" and "D" Certifications

Type "C" Certification

This certification is to include a statement certifying that the material in the shipment is essentially the same as material that is prequalified.

Type "D" Certification

This certification is to include a statement certifying that the material in the shipment is essentially the same as material that is specified.

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Type “E” Certification

This certification applies to assemblies or structures that are composed of two or more components or materials.

These components or materials have been approved previously on an individual basis for KDOT projects but lose their identity when they are incorporated into an assembly or structure.

This certification would apply to signs, overhead signs and lighting structures, etc.

The certification is to state that all the components or materials used in the fabrication of the represented assembly or structure were previously approved for KDOT use.

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Type “F” and “G” Certification

These certifications are referred to as “blanket certifications”. As permitted by Table 2601-1, submit Type “F” and “G” certifications covering material provided throughout the present calendar year. Clearly denote the covering year. Submit “F” or “G” for each manufacturer, producer, fabricator, plant, production facility, or supplier; and for each unique product, design, model, mix design, or formulation. If the previous criteria is satisfied, multiple pipe sizes of the same type can be covered by one certification, but each size must be clearly listed. Certification may cover multiple contracts and identical materials supplied under multiple line-items, provided the contracts and associated line-items are clearly listed. For multi-year contracts submit blanket certifications for each calendar year that material is supplied. Submit the certification in the covering year prior to the material’s first use, not in advance of the covering year. Unanticipated changes in any of the criteria listed above during the course of a year requires submittal of an additional blanket certification.

Type “F” certifications. This certifications is to include a statement certifying that the material supplied during the covering calendar year is essentially the same as material that is prequalified.

Type “G” certifications. This certification is to comply with subsections 2601.2a. This is stated on slide 19.

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Responsibility for preparation of certifications?

- **2601.2.a.(1)**. The contractor is responsible for obtaining all certifications and arranging for their delivery to the proper destination prior to use of the material and allowing sufficient time for review as stated herein.
- **2601.2.c.** The manufacturer of the individual item is responsible for preparing certifications of Type “A”, “B”, “C”, “D”, “F” and “G” certifications.
- **2601.2.c.** The fabricator or assembler of individual items is responsible for preparing a Type “E” certifications.
- **2601.2d**. The Engineer reserves the right to sample and test any material or product that is governed by a certification. If deviations from the applicable specifications are found, the results will be reviewed by the Engineer to determine the final disposition of the material or product. Serious deviations may cause for removal from prequalification status.

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Who Gets Them?

2601.2e(1) Types “A” and “B” certifications. Submit one copy of the certification via hard mail or e-mail to:

Materials and Research Center, Materials Certifications, 2300 Van Buren, Topeka, KS, 66611

E-mail address: KDOT#CM.TypeABCerts@ks.gov

2601.2e(2) Types “C”, “D”, “E”, “F” and “G” certifications. Issue one copy to the Field Engineer(s) responsible for the project(s) construction.

Note: Epoxy Coated Materials (reinforcing, dowels, tie bars), A325 & A490 Nuts, Bolts, Washers, DTIs are handled by our Regional Labs.

Special Note: A325 & A490 bolts used for structural uses are to be tested by the MRC Metals Lab.
*Contact Susan Barker for information regarding certifications for the materials listed in this note.

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Geology Research Section

KDOT IKE THE EISENHOWER LEGACY TRANSPORTATION PROGRAM

1

Geology Research Section

Tasks Include

- Air System Analysis of Hardened Concrete
- Microscopy/Petrographic/Forensic Analysis
- Alkali-Aggregate Reactivity (AAR)
  - Alkali-Silica Reaction (ASR)
  - Alkali-Carbonate Reaction (ACR)
- Aggregate Studies
  - Resistance of aggregate to D-cracking
  - Resistance of aggregate to internal reactions
  - Resistance of aggregate to chlorides
- Assist in any other study

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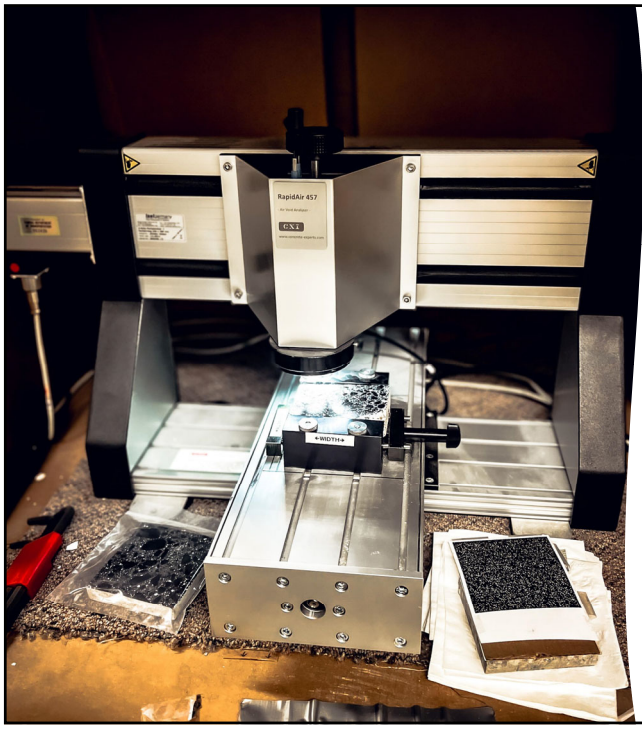
2

ASTM Standard C 457

- **Standard test method for microscopical determination of parameters of the air-void system in hardened concrete**
- **We use the Linear Traverse Method**



RapidAir 457 Automated System

- Analyzes air content in hardened concrete
- Cuts the analysis time from 4-6 hours per samples to under 10 minutes per sample
- Replaces the manual test performed as described in ASTM C457

Evaluation of the Air Void System in Hardened Concrete Samples

Importance of the Air Void System in Concrete

- Air in the concrete helps protect the paste from cracking during freezing weather
- Critical in environments where freeze-thaw cycles are prevalent
- Measure total air, size of air voids, and distribution of air voids

What Do We Want To Know From The Linear Traverse Test

- **Total Percent Air in the sample**
  - Generally accepted range of 5% to 8% in hardened samples
  - Most KDOT designs call for 6.5% +/- 1.5 %
- **Spacing Factor---**how the voids are distributed in the paste
  - Generally accepted range in hardened samples is 0.004 to 0.008 inch
- **Specific Surface Value**
  - How fine or coarse the air void system is
  - Generally accepted range 600 to 1100
  - Higher numbers mean a finer air void system (smaller air voids)
- **Amount of the type of air**
  - Entrained Air vs. Entrapped Air

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Two Types of Air Voids

- **Entrained Air**
- Usually spherical
- Very small in size
  - 5 to 500 micrometers (1/2 mm)
  - ASTM states 1000 micrometers (1 mm)
- **Entrapped Air**
- Usually odd shaped
- Usually larger in size
  - >1000 micrometers (1 mm)
  - But can be of any size

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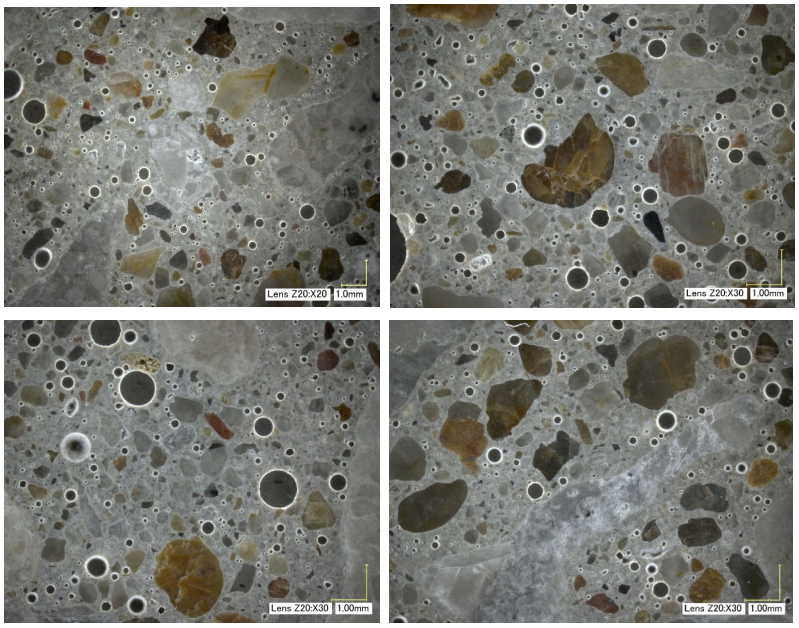
Entrained Air



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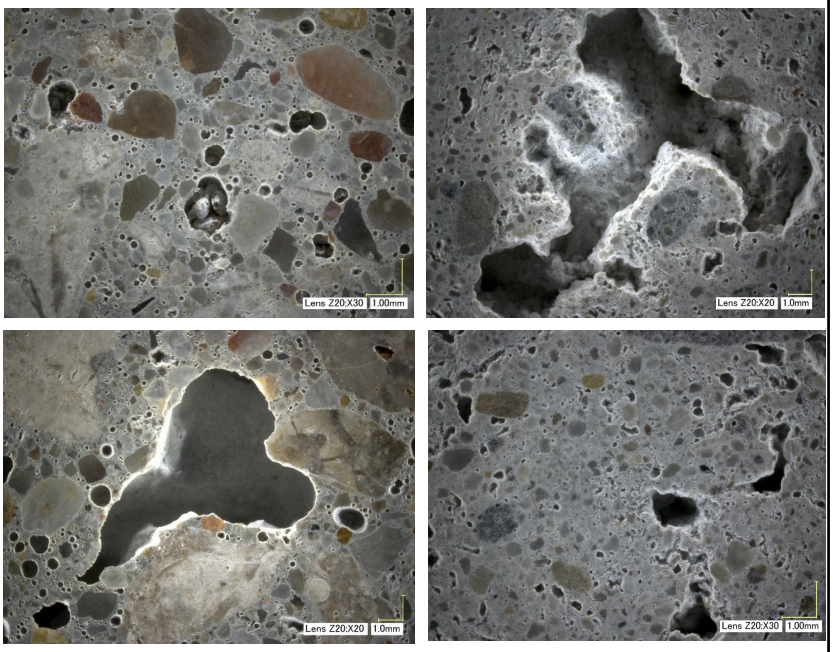
Entrapped Air



10

ASTM C457 Test

- There is a minimum length of traverse required for ASTM C457 Test
- Dependent on maximum aggregate size
- If the maximum aggregate size is:
  - 3/4-inch aggregate----90 linear inch traverse
  - 1/2-inch aggregate----80 linear inch traverse
  - 3/8-inch aggregate----75 linear inch traverse

  These are listed in the ASTM C457 Standard

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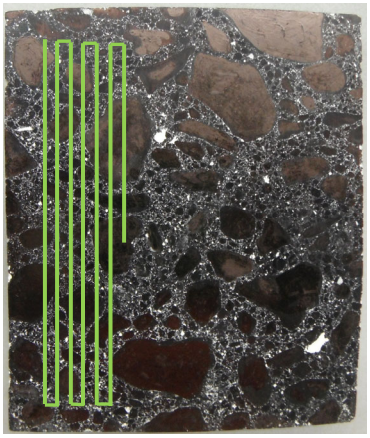
Liner Traverse Example



- 4 X 8-inch cylinder/core
- Sample size 4.0 X 4.25 inch
- Area Traversed approximately
  3.1 X 3.1 inches (80x80mm)
- 3/4-inch maximum aggregate size (most common)
- Requires 90 linear inches of traverse
- We input the length of traverse we want completed
  (always a little more than required)

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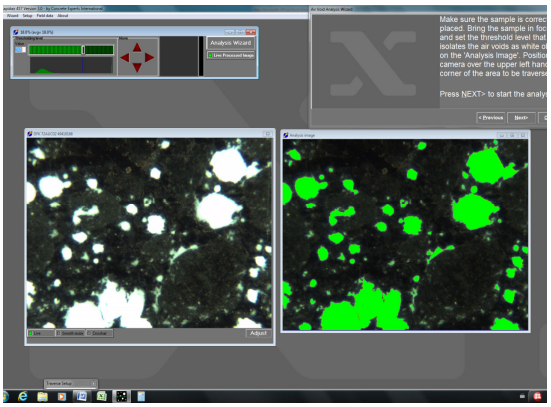
ASTM C457 Test

- Test is run at 100 x magnification
- ASTM requires at least a 50x magnification
- Only count the voids that intersect the reference line



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Linear Traverse Report

Sample ID:	17-0294 10		
Sample Size (in x in):	4.4 x 4.0	Length Traversed (in):	92.94
Paste Content (%):	24.40	Area Traversed (in):	3.1 x 3.1

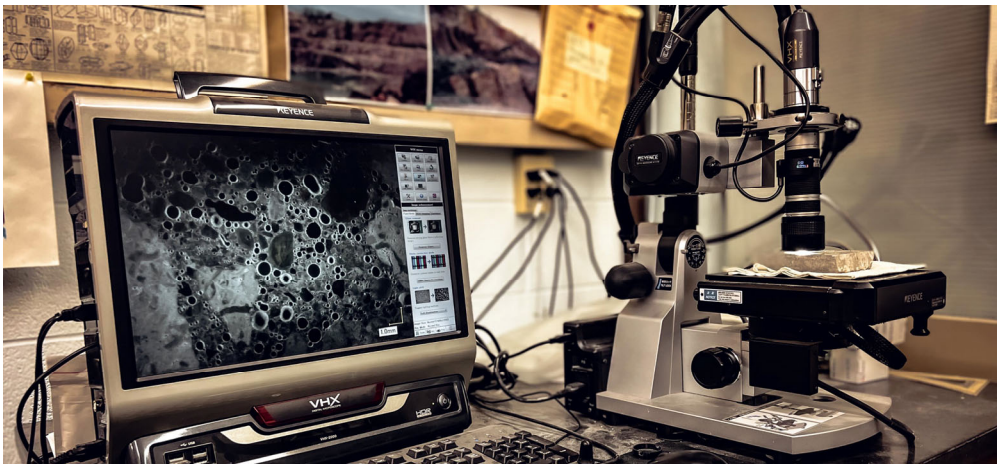
Chord Length Distribution - Table

Class No.	Chord size (1/100 inch)	Number of Chords in Class	Number of Chords in Percent	Air Content in Class	Cumulated Air Content	Chord length frequency	Air content, fraction
1	0.00-0.04	113	5.95	0.040	0.040	0.06	0.040
2	0.04-0.08	415	21.85	0.240	0.280	0.22	0.240
3	0.08-0.12	248	13.06	0.260	0.530	0.13	0.260
4	0.12-0.16	207	10.90	0.300	0.830	0.11	0.300
5	0.16-0.20	161	8.48	0.310	1.140	0.08	0.310
6	0.20-0.24	120	6.32	0.280	1.410	0.06	0.280
7	0.24-0.31	165	8.69	0.480	1.890	0.09	0.480
8	0.31-0.39	123	6.48	0.470	2.360	0.06	0.470
9	0.39-0.47	76	4.00	0.350	2.710	0.04	0.350
10	0.47-0.55	47	2.47	0.260	2.970	0.02	0.260
11	0.55-0.63	41	2.16	0.260	3.230	0.02	0.260
12	0.63-0.71	29	1.53	0.210	3.440	0.02	0.210
13	0.71-0.79	26	1.37	0.210	3.650	0.01	0.210
14	0.79-0.87	22	1.16	0.200	3.850	0.01	0.200
15	0.87-0.94	9	0.47	0.090	3.930	0.00	0.090
16	0.94-1.02	8	0.42	0.080	4.020	0.00	0.080
17	1.02-1.10	7	0.37	0.080	4.100	0.00	0.080
18	1.10-1.18	5	0.26	0.060	4.160	0.00	0.060
19	1.18-1.38	13	0.68	0.180	4.340	0.01	0.180
20	1.38-1.57	16	0.84	0.250	4.590	0.01	0.250
21	1.57-1.77	4	0.21	0.070	4.660	0.00	0.070
22	1.77-1.97	6	0.32	0.120	4.780	0.00	0.120
23	1.97-3.94	25	1.32	0.770	4.940	0.01	0.770
24	3.94-5.91	6	0.32	0.310	5.860	0.00	0.310
25	5.91-7.87	2	0.11	0.140	5.990	0.00	0.140
26	7.87-9.84	1	0.05	0.100	6.090	0.00	0.100
27	9.84-11.8	3	0.16	0.350	6.440	0.00	0.350
28	11.8-15.8	1	0.05	0.130	6.580	0.00	0.130
						1899	

Only chords from 30 to 4000 microns are included in results

Air Content (%):	6.04
Specific Surface (in^{-1}):	799.6
Spacing Factor (in):	0.0051
Void Frequency (in^{-1}):	12.08
Average Chord Length (in):	0.0050
Paste to Air Ratio:	4.04

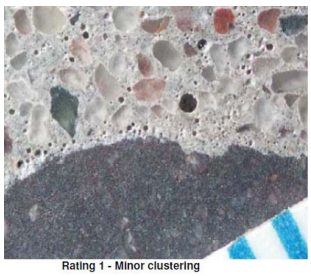
Microscopy/Petrographic/Forensic Analysis Using the Keyence Microscope

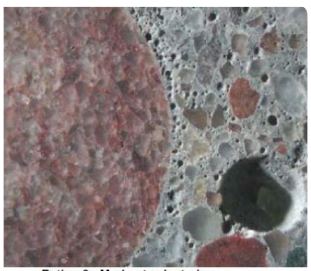


Air Void Clustering

- Clustering can be categorized as no clustering, minor, moderate or severe clustering


Rating 0 - No clustering present


Rating 1 - Minor clustering


Rating 2 - Moderate clustering


Rating 3 - Severe clustering

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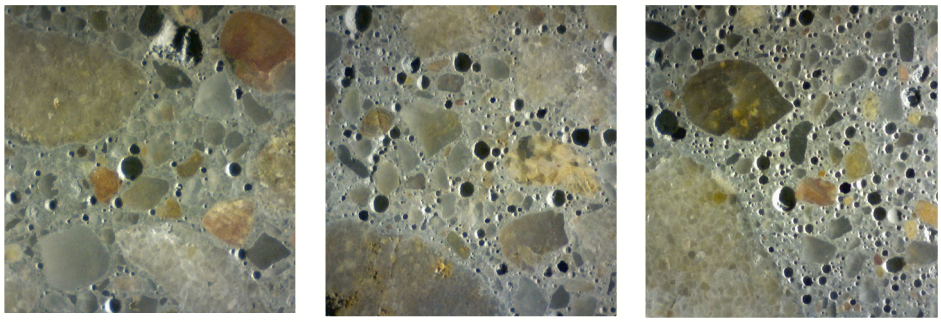
Percent Air Comparison

Low | Normal | High



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Microscopy/Petrographic/Forensic Analysis

- Air void system analysis—clustering, percent air
- Alkali-Aggregate Reactions (ASR & ACR)
- D-Cracking of limestone aggregates
- Frozen concrete
- Overwatered concrete
- Soil analysis—Gypsum in the soil
- Low break strength in concrete cylinders/cores
- Mineral identification
- Many other tasks……

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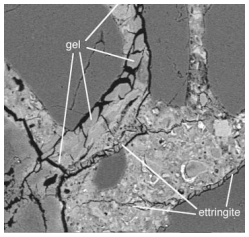
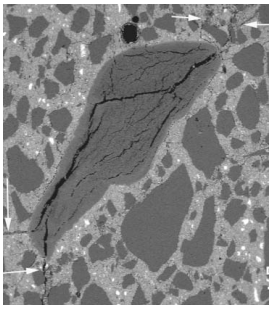
Alkali-Aggregate Reactivity

- **Alkali-Aggregate Reactivity (AAR)**
  - **Alkali-Silica Reaction (ASR)**
  - **Alkali-Carbonate Reaction (ACR)**





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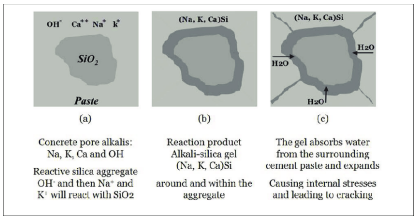
How Does ASR Occur?

- Reactive silica (from aggregates)
  - Chert, Quartz and other silica
- Alkalis' (mainly from Portland cement)
  - Sodium and Potassium
- Sufficient moisture



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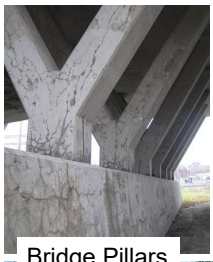
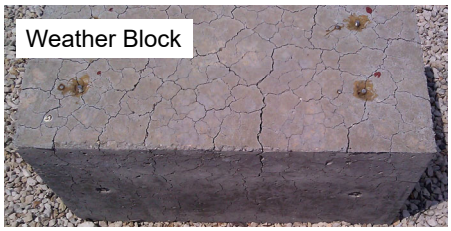
ASR in Concrete Structure



Bridge Pillars

Weather Block



Sidewalk

Cores

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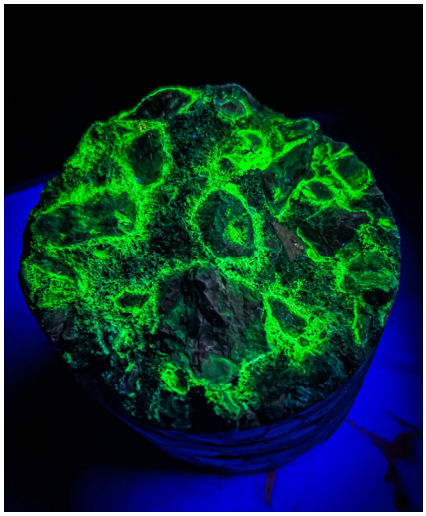
ASR Uranyl Acetate Treatment

- **Treated with uranyl acetate solution and viewed under UV light**



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Alkali-Carbonate Reactivity (ACR)

- Alkali in the cement reacts with dolomite crystals present in limestone aggregate
- Forms reaction rings within the limestone aggregate
- Makes the aggregate more porous allowing more water absorption

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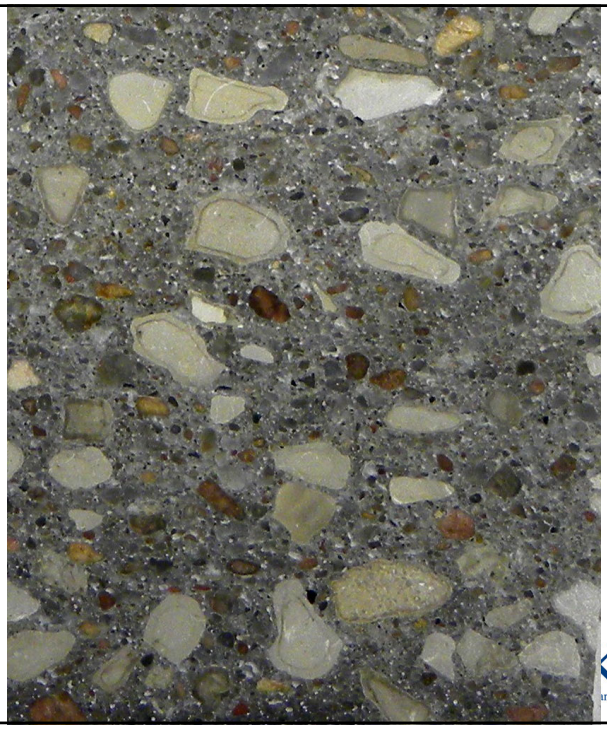
Alkali-Carbonate Reactivity (ACR)

Damage pattern in concrete very similar to ASR



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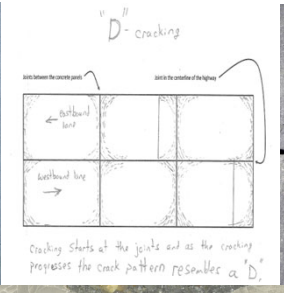
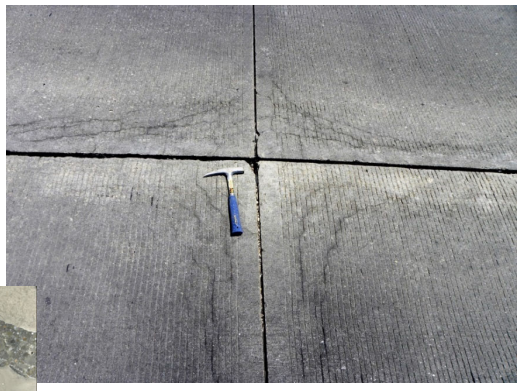
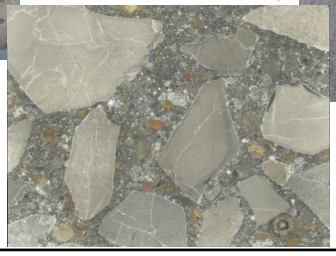
D-cracking Evaluations

- D-Cracking is an aggregate issue
- Aggregates absorb water and cracks form during freeze thaw cycles
- D-Cracking patterns differ from those that form from ASR and ACR
- Cracking begins at the joints in a pavement and progress outward

D-Cracking Examples







Cylinder/Core Low Break Strengths Causes

- Air issues
  - For every 1% increase in air there is a 5% decrease in strength
- Paste issues
  - Un-hydrated paste
- Poor Paste-Aggregate Bond
- Handling/Making of cylinders
- Concrete placement issues—cores

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Questions?

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Concrete Testing & Sampling

KDOT Concrete Research

Basic Laboratory Course
May 2023

Jennifer Distlehorst
Research Staff Engineer

Kansas Department of Transportation

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Outline

- What KDOT Concrete Research does
- Permeability testing and requirements
- Air system testing and requirements

2

What does Concrete Research do?

Improve durability of Kansas concrete pavements by

- Evaluating new tests, materials, and construction methods
- Answering questions about concrete and testing
- Surveying pavement condition in test sections and for specific reasons, like D-Cracking
- Developing new test methods and specifications
  - Air void testing 2004
  - Permeability 2008
- Performs permeability testing for verification

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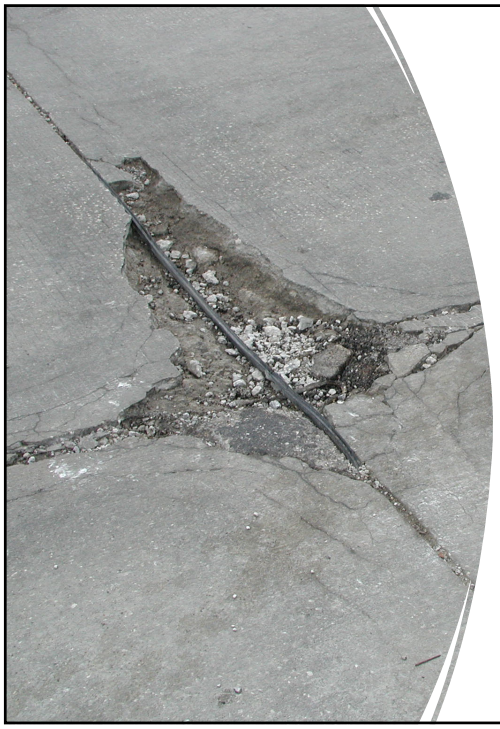

Our goal: durable concrete

- Concrete must be strong AND durable
- Freezing water destroys pavements
- Salt rusts reinforcing steel destroying bridge decks
- Concrete Research develops and implements tests and requirements to protect concrete
- *Photo: freeze-thaw joint damage on K-68 in Franklin County*

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Why prequalify mix designs?

- Durability must be part of the mix from the beginning
- Air voids protect pavement from freeze/thaw damage
- Lowering permeability protects structures from salt that rusts steel
- Aggregate gradation, additives and cements all affect air quality and permeability
- Reactive aggregates are kept out
- Once concrete is placed none of this can be changed or fixed

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Keeping the water out

- PERMEABILITY is the ability of water and salt to travel through concrete
- Low permeability concrete keeps water and salt out.
- Water and salt travel through the concrete paste.
- Paste is everything except the aggregates: cement, water and air voids.
- *Photo: polished slab of concrete with dark aggregates and light paste.*

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Permeability for Mix Design Approval

Permeability test results are required for mix design approval for

- All projects with over 250 cubic yards of concrete TOTAL, including structures and pavements AND
- All bridge deck overlay concrete
- All moderate permeability structural concrete
- *Specifications Section 401.3, General Concrete Mix Design*

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Permeability Testing Requirements

- Test for mix design approval at the **highest water to cementitous materials ratio** that meets the permeability requirements
- Choice of three tests
  - KT-73 (Volume of Permeable Voids) at **28** days
  - KT-79 (Surface Resistivity) at **28** days
  - AASHTO T-277 (Rapid Chloride Permeability) at **56** days
- Test **three cylinders** for each mix
- Verify project concrete permeability **with same test** used for approval for each mix design

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Permeability for Structural Concrete

Three permeability classes for structural concrete

- Low Permeability Concrete (LPC) for bridge overlays
- Moderate Permeability Concrete (MPC) for full-depth bridge decks
- Standard Permeability Concrete (SPC) for all other structural concrete not specified as LPC or MPC

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Permeability for On-grade Concrete

- Same permeability requirements for pavement and shoulders
- Same as Standard Permeability Concrete for structures
- Not required for patching materials on pavements over ten years old

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Three Permeability Test Methods

- **KT-73** Volume of Permeable Voids (Boil Test)
  - Standard Test Method For Density, Absorption, And Voids In Hardened Concrete
- **KT-79** Surface Resistivity Test (SRM)
  - Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration
- **AASHTO T 277** Rapid Chloride Permeability Test (RCP)
  - Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

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Permeability Requirements

	KT-73 Volume of Permeable Voids	KT-79 Surface Resistivity Measurement	AASHTO T-277 Rapid Chloride Permeability
Age at testing	28 days	28 days	56 days
Limit	Maximum	Minimum	Maximum
LPC	9.5%	27.0 kΩ-cm	1000 Coulombs
MPC	11.0%	13.0 kΩ-cm	2000 Coulombs
SPC and On-grade	12.5%	9.0 kΩ-cm	3000 Coulombs

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KT-73 Boil Test Introduction

- The Boil Test measures the volume of permeable voids in concrete.
- Not all voids in concrete are permeable so they don't dry out completely and don't fill completely during boiling.
- Boiling forces air out of permeable voids and water in.
- Permeability is easily water travels through the concrete
- Low percent permeable voids = Low permeability
- Can be used accurately on cores

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KT-73 Boil Test Timeline

- Day 0: Cast cylinders
- Day 1: Demold and standard cure
- Day 26: Cut specimens and dry in oven
- Day 28: Weigh dry then boil for five hours
- Day 29: Weigh in water and at SSD

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What is Percent Permeable Voids?

How much of the volume of the concrete is permeable voids?

- Compare amount of water forced into voids by boiling to amount of total water displaced
- SSD weight – dry weight = water in permeable voids
- SSD weight - weight in water = water displaced by whole specimen
- $\frac{Water\ in\ permeable\ voids}{Total\ water\ displaced}$ x 100 = Percent Permeable Voids
- Record result to nearest 0.01%

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Percent Permeable Void Requirements

Age at testing	28 days
Limit	Maximum
Low Permeability Concrete (LPC)	9.5%
Moderate Permeability Concrete (MPC)	11.0%
Standard Permeability Concrete (SPC) and On-grade	12.5%

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KT-79 Surface Resistivity Introduction

- Electrical current is carried through concrete by water
- **Resistance** to current is measured by Surface Resistivity in kΩ-cm
- High resistance means LOW permeability
- A **minimum** resistivity is required
- SRM must be performed on 4”x 8” standard cylinders

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KT-79 Surface Resistivity Timeline

- Day 0: Cast three cylinders
- Day 1: Demold and standard cure
- If transporting cylinders to testing lab
  - Wrap in wet towels, then place in plastic bag and seal
  - Deliver cylinders within 48 hours of casting
  - Remove cylinders from bags within 30 minutes of arrival and cure
  - DO NOT ALLOW SAMPLES TO DRY OUT AT ANY TIME
- Day 28: Measure surface resistivity in kΩ-cm, taking four measurements on each cylinder

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Calculating Surface Resistivity

- Average four resistivity measurements for each specimen
- Average three specimens for sample
- Adjust sample results for curing condition
  - If lime-cured, multiply sample average by 1.1
- Record result to nearest 0.1 kΩ-cm

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Surface Resistivity Requirements

Age at testing	28 days
Limit	Minimum
Low Permeability Concrete (LPC)	27.0 kΩ-cm
Moderate Permeability Concrete (MPC)	13.0 kΩ-cm
Standard Permeability Concrete (SPC) and On-grade	9.0 kΩ-cm

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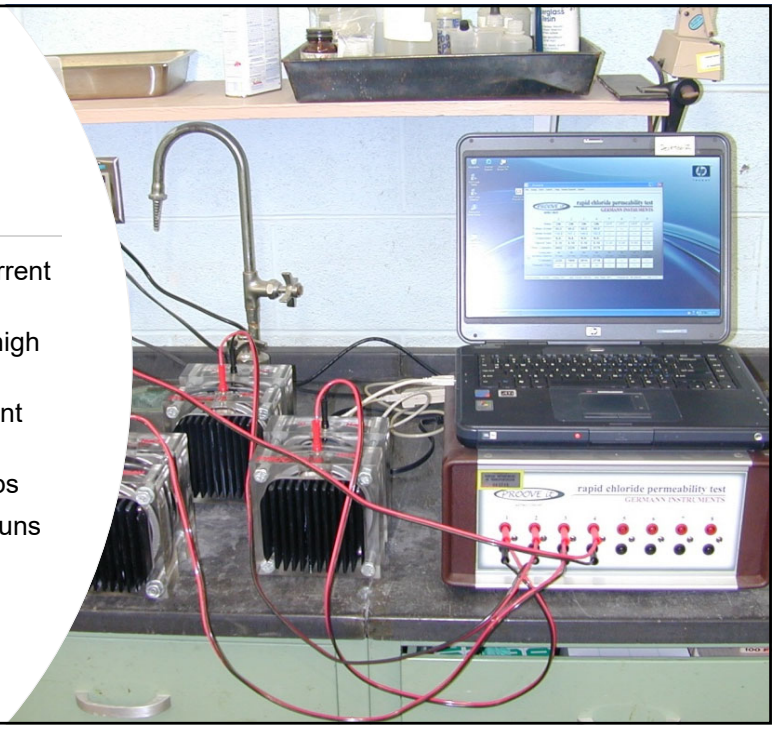
AASHTO T 277 Rapid Chloride Permeability

- Measures transmission of electric current through concrete
- HIGH RCP means high current and high permeability
- RCP is specified by MAXIMUM current passed
- RCP current is measured in Coulombs
- Research is the only KDOT lab that runs RCP



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Rapid Chloride Permeability Timeline

- Day 0: Cast three cylinders
- Day 1: Demold and standard cure
- Day 54: Cut specimens to 2”, weigh in water and SSD
- Day 55: Vacuum saturate specimens and keep in water until testing
- Day 56: Run RCP Test

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Day 55 Vacuum Saturation

- Place specimens in vacuum chamber
- Apply vacuum for three hours
- Add water to chamber without opening
- Apply vacuum for another hour

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Day 56 Running the RCP Test

- Specimens are placed in RCP cells
- NaCl solution (salt water) is added to one cell and NaOH (sodium hydroxide) solution is added to the other
- Electrical leads connect each side of the cell to the voltage applicator
- Current must pass through the concrete to complete the circuit

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Rapid Chloride Test Results

- Results are measured in Coulombs of current passed through the concrete
- Adjust results for size of sample with equation

$$Q_s = Q_x * \left(\frac{3.75}{x} \right)^2$$

  - X = diameter of specimen in inches
  - Q_X = Coulombs measured in test
  - Q_S = Coulombs reported, adjusted for a 3.75 in. specimen diameter
- Record result to nearest 10 Coulombs

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Rapid Chloride Permeability Requirements

Age at testing	56 days
Limit	Maximum
Low Permeability Concrete (LPC)	1000 Coulombs
Moderate Permeability Concrete (MPC)	2000 Coulombs
Standard Permeability Concrete (SPC) and On-grade	3000 Coulombs

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Air in Concrete

- Air voids give freezing water space to expand without cracking the concrete
- Freezing water can only travel 0.01 inches before cracking starts
- Need air voids within 0.01 inches or less for protection
- **Spacing Factor** is the average distance to an air void from any point in the concrete

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Air everywhere without too much total air?

- Distribute the air in lots of smaller air voids
- Think lots of chocolate chips in ice cream vs one big chunk: *same amount of chocolate but more bites with chocolate!*

Small spacing factor

Ice cream with chips all the way through!

=

Large spacing factor

+

Lots of ice cream with no chocolate in it

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KT-71 Air-Void Analyzer (AVA) Measures Spacing Factor

- Older spacing factor methods required hardened concrete
- Air Void Analyzer: a faster test of fresh concrete
- Sample from pavement behind the paver
- Vibrating drill with cage fills syringe with mortar
- Three samples at one location

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Where to run an AVA test

- Field samples, lab testing
- The AVA is a sensitive instrument and needs a stable location away from wind and vibration
- District labs, area offices and sub-area shops are used
- The AVA is set up before testing begins

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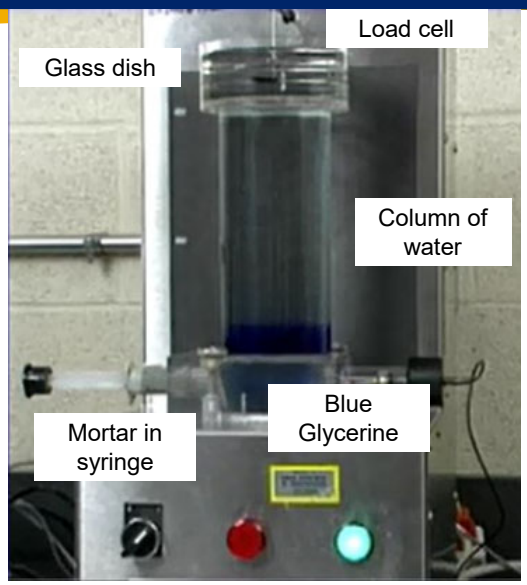
How the AVA test works

AVA measures bubbles released from fresh mortar

- Mortar is mixed with glycerine at the bottom of a column of water
- Bubbles rise to a glass dish at the top
- Big bubbles go faster and are first at the dish
- Speed of bubbles is known so all bubbles arriving at the same time are the same size
- The load cell measures buoyancy of the dish
- Computer calculates bubble distribution from change in weight of dish with time



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AVA Results and Requirements

- Test two samples and compare spacing factor results
  - Valid results agree within 0.0025 inch
  - If first two tests don't agree, run third test
- Average all results that agree within 0.0025 in
- Report spacing factor to nearest 0.0001 in
- Minimum spacing factor is 0.0100 in
- Required for **pavement** mix design prequalification and field verification

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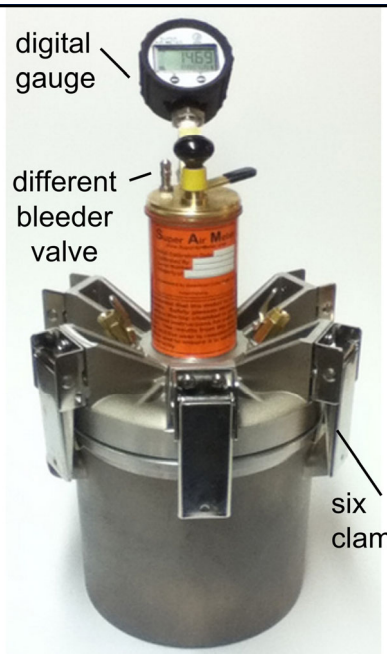

In Development: Super Air Meter

- KT-86 Characterization of the Air-void System Of Freshly Mixed Concrete by the Sequential Pressure Method
- Evolved from pressure meter, with
  - Digital pressure gauge
  - Different bleeder valve
  - Six clamps
- Gives total percent air and SAM number

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Running the SAM test

- Use KT-18 procedures to fill the measurement bowl
- Secure the lid
- Add water through the petcocks
- Pump the pressure up to 14.5 psi, then 30, then 45
- Let pressure off, pump up three steps again
- The SAM records the equilibrium pressure at each step

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SAM test results

- Different sizes of air voids respond to pressures differently
- SAM number is the difference in equilibrium pressures after the first and second 45 psi pressure steps
- Valid SAM tests give SAM numbers between 0.03 and 0.70 psi
- Larger air voids compress more, giving a higher SAM number
- Higher SAM number indicates higher spacing factor
- Report SAM number to nearest 0.01 psi

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Summary

- Concrete Research works to improve concrete durability
- Three different tests measure permeability
  - KT-73 Volume of Permeable Voids (Boil Test)
  - KT-79 Surface Resistivity
  - AASHTO T 277 Rapid Chloride Permeability
- KT-71 Air Void Analyzer measures spacing factor of air voids in concrete
- Super Air Meter test in development also measures air system quality
- Permeability and AVA test results are required for mix design prequalification

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