5.9.71 AIR-VOID ANALYZER (Kansas Test Method KT-71)

1. SCOPE

This method of test covers the determination of characteristics of the air-void system of freshly mixed concrete using a sample of mortar. Spacing factor, specific surface and entrained air content are determined by capturing air bubbles released from a mortar sample.

The sample will only be representative of the depth of the concrete within approximately 2.5 in. (60 mm) below the level at which the sampling is begun. This method is applicable to fresh concrete with a minimum slump of 0.4 in. (10 mm) and air content between 3.5 and 10% by volume. Only air voids less than 0.1 in. (3 mm) in diameter are measured by this method. The test must be performed in sheltered, stable conditions.

2. REFERENCED DOCUMENTS

2.1. Part V**,** 5.9; Sampling and Test Methods Forward

2.2. KT-17; Sampling Freshly Mixed Concrete

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

2.4. KT-19; Air Content of Freshly Mixed Concrete by the Volumetric Method

2.5. KT-20; Mass per Cubic Meter (Foot), Yield Cement Factor and Air Content (Gravimetric) of Freshly Mixed Concrete

2.6. KT-21; Slump of Portland Cement Concrete

2.7 ASTM C 457; Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete

3. APPARATUS

3.1. The balance shall conform to the requirements of **Part V, Section 5.9; Sampling and Test Methods Forward** for the class of general purpose balance required for the principal sample mass of the sample being tested. The balance shall also have an integral arm from which the dish can be suspended.

3.2. Analysis and data collection apparatus assembly, the sampling equipment and materials is designed and built to function as an integrated system that is demonstrated by the manufacturer to accurately measure and calculate air-void distribution in fresh air-entrained concrete.

3.3. Riser cylinder made of clear plastic with a base and a collar approximately as shown in **Figure 1**. The base shall have an integral heating element capable of maintaining the analysis liquid at 73 ± 4° F (23 ± 2° C) and entry holes for the plastic rod and the sample syringe with gaskets to make a watertight seal.

3.4. Magnetic stirrer capable of maintaining 300 rpm during mixing.

3.5. A cabinet shall house the riser cylinder, magnetic stirrer and balance as shown in **Figure 2**.

3.6. A ferromagnetic steel rod approximately 0.2 in. (5mm) in diameter and 2.5 in. (62mm) in length.

3.7. A temperature sensor capable of detecting the temperature of the analysis liquid at the bottom of the cylinder. The temperature sensor should be capable of measuring yhr temperature to within 1.0° F (0.5° C) in the range of 59 to 86° F (15 to 30° C) and of transmitting such measurements to the computer through an appropriate interface.

3.8. 20 ml plastic syringes, with the tapered end removed, calibrated and marked for collecting the specified sample volume as shown in **Figure 3**.

3.9. Plastic rod at least 1.5 in. (35 mm) longer than the width of the base. The outside diameter of the body of the rod is the same as the syringes used in the test. A 0.04 in. (1 mm) length at the end of the rod shall have a reduced diameter that fits tightly within the inside diameter of the syringe as shown in **Figure 3**.

3.10. Clear, shallow dish that is large enough to cover the entire area of the cylinder, retain the rising bubbles and fit within the collar. The dish shall have an opening on the side to allow entrapped air to be removed.

NOTE: An inverted Petri dish with an appropriate slot, as shown in **Figure 3**, can fulfill these requirements.

3.11. A device to suspend the dish from a balance arm by a single wire as shown in **Figure 3**.

3.12. Control System. A computer, software and interface system capable of controlling the test, recording data, and displaying data at least once per minute during the test. It shall also calculate, display and record the air content(s), air-void spacing factor, and specific surface of the air-void system.

3.13. Sampling assembly to hold the syringe and a wire cage and vibrate at approximately 50 Hz with an amplitude that allows the mortar to flow into the wire cage.

NOTE: A drill operating at 3000 rpm with an eccentrically weighted, forked assembly as shown in **Figure 4** can fulfill these requirements. The hammering function of the drill can be used as needed in stiffer concrete mixes.

3.14. A wire cage that is of sufficient size to obtain a sample of fresh concrete mortar, similar to **Figure 4**. The cage wires shall have a clear spacing of 0.24 in. (6 mm).

3.15. Rigid, clear plastic plate approximately 10 x 10 x 1/8 in. (250 x 250 x 3 mm) with a center hole of a diameter approximately 1/8 in. (3 mm) greater than that of the wire cage.

3.16. A calibrated funnel marked for measuring a specified amount of analysis liquid similar to that shown in **Figure 4**. The funnel is capable of introducing the analysis liquid into the bottom of the water-filled riser cylinder with a minimum of mixing.

3.17. A spatula to trim the mortar sample flush with the end of the syringe.

3.18. A water container with a 2 gallon (4 liter) minimum capacity.

NOTE: A 5 gallon (19 liter) portable insulated drinking water cooler is useful for repeated testing.

3.19. An immersible heating element capable of maintaining the water in the container at approximately 73 ± 4° F (23 ± 2° C).

3.20. Thermometer accurate to ± 1.0° F (± 0.5° C) over the range of 50 to 86° F (10 to 30° C).

3.21. Brush with a handle longer than the riser cylinder is tall and an angled head.

3.22. An insulated "cooler-type" lunchbox is useful.

3.23. Sealable plastic bags, commercially available in pint and quart sizes.

4. MATERIALS

4.1. Analysis Liquid. The analysis liquid shall have physical and chemical properties such that the air-void bubbles remain discrete. The viscosity of the analysis liquid must remain constant over the range of temperatures found in the test and be compatible with the apparatus and the control system. The viscosity of the analysis liquid used shall provide a measurable separation in time between the arrivals of bubbles of different sizes at the top of the water column. The analysis liquid and its viscosity shall be specified by the equipment manufacturer.

NOTE: A commercially-available solution of glycerol in water can fulfill these requirements. A mixture of 4 parts glycerol to 1 part distilled water has been known to work well.

4.2. De-Ionized water from the Materials and Research Chemistry Lab. The water shall be de-aerated and maintained at atmospheric pressure and approximately 73 ± 4° F (23 ± 2° C) for a minimum of 12 hours before use.

NOTE: Properly de-aerated water is crucial to this test. The solubility of air in water increases as pressure increases and temperature decreases. The change in dissolved air content due to temperature occurs slowly; thus, the water must be maintained at constant temperature for a minimum of 12 hours before use. De-aerated water also reabsorbs air when cooled. If the water is not de-aerated correctly or if it is used shortly after reheating, air may be liberated in the riser cylinder. Air bubbles may form in the riser cylinder and on the dish, and may have a considerable effect on the specific surface and spacing factor results.

4.3. Ice as needed in cubes or chips or frozen, re-freezable ice packs or cubes.

5. SAMPLING

5.1. Take samples as soon as possible after the concrete is in the desired state. The sampling location depends on the purpose of the test. Samples can be extracted from concrete in place (pavements, structural members, decks, etc.), from concrete sampling containers such as unit weight buckets, beam molds, or cylinder molds, or from other locations.

5.2. Insert a syringe into the sampling assembly and mount the wire cage onto the sampling assembly. Fully collapse the syringe.

5.3. Place the plastic plate in good contact with the surface of the concrete to be sampled. Begin the vibration of the sampling assembly. Lower the wire cage through the hole in the plastic plate into the concrete. The vibration will cause the mortar fraction of the concrete to flow into the wire cage. Advance the wire cage into the concrete at a rate such that the concrete surface under the plate and the surface of the mortar within the cage remain at approximately the same level at all times. Avoid filling the cage with surface mortar by pressing the plastic plate against the fresh concrete. The pressure is adequate when the air bubbles under the plastic plate do not move towards the hole while sampling.

5.4. Advance the wire cage into the concrete until the end of the syringe plunger is in full contact with the surface of the mortar. While maintaining the vibration, push the syringe cylinder smoothly into the mortar at such a rate that the wire cage remains full of mortar until the syringe is fully extended. Stop the vibration and withdraw the wire cage and syringe from the concrete.

5.5. Remove the wire cage and the syringe from the sampling assembly saving the excess mortar from the wire cage. Pack this excess mortar around the end of the syringe to be used to displace any large air bubbles from the syringe.

5.6. Immediately place the sample in a plastic bag on ice or freezer packs in the insulated box to retard the onset of initial set. Testing must begin before the initial set of the concrete.

5.7. If large air bubbles are present at the base of the syringe, remove the plunger and pack enough excess mortar through the opposite end of the syringe to remove the air bubble. Replace the plunger to contact the mortar. Remove the excess mortar from the outside of the syringe and clean the outside of the syringe with a damp cloth. Advance the plunger to the mark corresponding to the specified sample volume and trim the mortar flush with the end of the syringe cylinder using the spatula. Retract the plunger approximately 0.04 in. (1 mm) to allow room for the recessed end of the plastic rod. This step may be performed at any time before **Section 7.9** of this test method, seating the syringe on the plastic rod.

6. PREPARATION OF APPARATUS

6.1. Bring the analysis liquid and at least 0.5 gallon (2 liters) of de-aerated water to a temperature of 73 ± 4° F (23 ± 2° C) without altering other characteristics of the liquids.

NOTE: Using ice in sealed plastic bags, or freezer packs to cool the liquids is acceptable.

6.2. Select a test location protected from any wind, vibration or movement that may affect the balance readings. Place the cabinet on a stable and level surface. Allow the balance to stabilize so that it does not drift more than 0.01 g in four minutes. If the balance has auto-zeroing capability, place a small load on the balance to obtain a non-zero reading in order to observe the variation of the reading.

6.3. Connect the control system.

NOTE: Place the control system so that if the plastic rod is accidentally removed from the base of the riser cylinder the contents of the riser cylinder will not spill onto the control system.

6.4. See **section 11** of this test method for additional hints on preparation of apparatus.

7. PROCEDURE

7.1. Enter all required data into the control system.

7.2. Place the stirrer rod flat on the bottom of the riser cylinder. Insert the plastic rod through the hole on the wider side of the base of the riser cylinder so that the full diameter of the plastic rod protrudes though the hole on the opposite (narrower) side of the base.

NOTE: Using a light coat of waterproof grease on the rubber o-rings will improve the seal between the plastic rod and the base of the riser cylinder.

NOTE: When testing low-viscosity materials such as self-consolidating concrete, it is permissible to tilt the riser column to seat the syringe on the plastic rod before the liquids are added to the riser column.

7.3. Fill the riser cylinder with de-aerated water to about 0.5 in. (15 mm) above the bottom of the top collar. Use the brush to remove all bubbles from the stirrer rod, the plastic rod and the riser cylinder.

NOTE: Rotating the plastic rod can be helpful in assuring that all bubbles are removed.

7.4. Mount the riser cylinder in position on the cabinet. It is permissible to fill the riser cylinder with the water after positioning the riser cylinder on the cabinet.

7.5. Fill the funnel with the manufacture's specified amount of the analysis liquid.

7.6. Insert the analysis liquid into the bottom of the riser cylinder using the funnel to minimize the mixing of the analysis liquid with the de-aerated water. Replace the stopper once the specified amount of analysis liquid has been discharged. Remove the funnel from the riser cylinder and discard any remaining liquid in the funnel.

7.7. Connect the integral heating element of the riser cylinder and the temperature sensor to the control system.

7.8. Insert the dish into the riser cylinder collar. Submerge the dish in the de-aerated water and tilt to allow all entrapped air to escape through the opening. Suspend the dish from the balance arm in such a way that it is approximately centered and does not touch the walls of the riser cylinder collar. Only a single wire of the suspension device may break the surface of the water. Add more de-aerated water if necessary.

7.9. Seat the syringe containing the sample on the reduced end of the plastic rod. Move the syringe and plastic rod together through the riser cylinder base until the junction of the syringe and plastic rod is at the nearest inside edge of the riser cylinder. Leaving the syringe in position, continue withdrawing the plastic rod until the reduced end is flush with the opposite inside edge of the riser cylinder.

NOTE: To make positioning the plastic rod and syringe with respect to the riser cylinder easier, mark the correct position on the plastic rod and note the position of the syringe before starting the test. If moving the plastic rod and syringe is difficult, use a small amount of waterproof grease or analysis fluid on the gaskets and use a twisting motion.

7.10. Remove enough of the air that may have risen during the separation of the syringe and the plastic rod from under the dish so that the dish is neither touching nor close to the wall of the riser cylinder collar.

7.11. When the temperature of the analysis liquid as measured by the temperature sensor is 73 ± 4° F (23 ± 2° C), inject the mortar from the syringe into the riser cylinder. Immediately start the mixing and data collection.

7.12. If any of the recorded temperature readings are outside the range of 73 ± 4° F (23 ± 2° C), discard the test.

7.13. If unusual variations that may be due to vibration or disturbance are noted in the data, discard the test.

7.14. Analyze samples as soon as possible. However, samples may be used whenever they can be completely dispersed in the analysis liquid by the stirring action.

8. REPORT

8.1. The report shall include the following information:

8.2. Project identification

8.3. Test identification number

8.4. Date of test

8.5. Sampling location

8.6. Slump by **KT-21** (if known)

8.7. Air content by **KT-18** or **KT-19** (if known)

8.8. Unit weight by **KT-20** (if known)

8.9. Mortar (material less than 6 mm) volume, percent, as calculated from the mix design

8.10. Paste volume, percent, as calculated from the mix design

8.11. Sample volume, ml

8.12. Test temperature range, °F (°C)

8.13. Air content(s), percent

8.14. Spacing factor, in. (mm)

8.15. Specific Surface, $in.^2/in.^3$ (mm^2/mm^3)

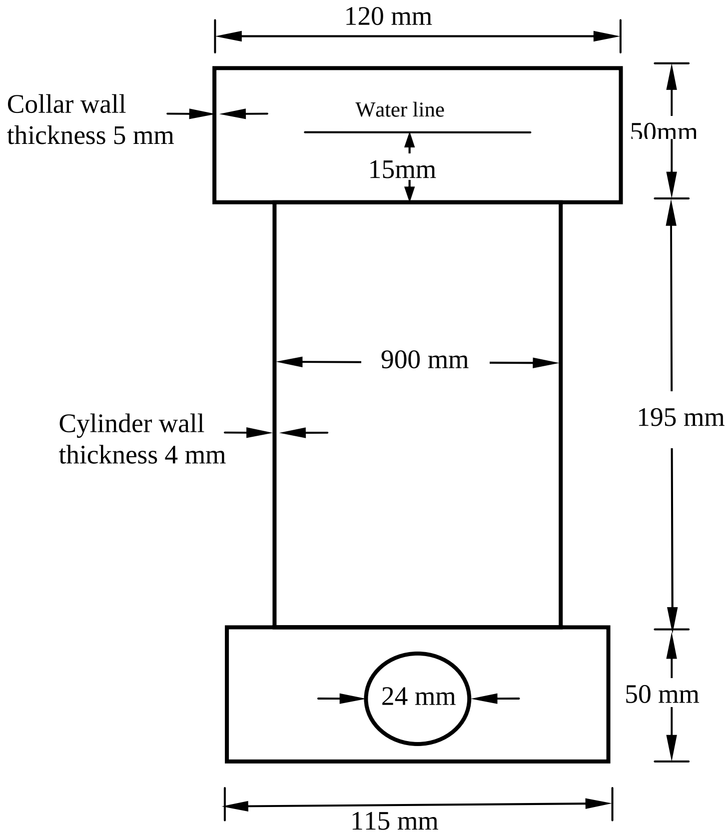

Figure 1
Riser Cylinder

Figure 2
Typical Apparatus with Riser Cylinder, Cabinet, and Computer

Figure 3
Petri dish, 20 ml syringe, and temperature sensor

Figure 4
Wire cage and funnel

9. VERIFICATION

9.1 To correlate the air-void characteristics (spacing factor, entrained air content or specific surface) as determined by the buoyancy-change method from fresh concrete with those obtained by **ASTM C 457** from hardened concrete, compare a minimum of five pairs of samples. Each pair of samples of the fresh and hardened concrete should be from the same batch of concrete, placed and consolidated uniformly, of comparable depth and located as close together as possible without including any of the area disturbed during sampling the fresh concrete in the hardened sample. Calculate the percent difference of the buoyancy test results from the **ASTM C 457** results for each pair, and then average these percent differences. The average of the percent differences of the five pairs of should be 20% or less for the results to be considered equivalent. Average percent differences greater than 20% may arise from **ASTM C 457** testing errors such as mistaking fly ash spheres or voids left by sand grains plucked from the polished surface of the specimen during sample preparation for air voids in the concrete paste. Sampling errors, testing errors in the buoyancy change method, admixtures that affect the viscosity or the miscibility of fresh concrete, or other factors may also cause some variation. The buoyancy change method is less likely than **ASTM C 457** to overestimate the quantity and quality of the air voids in any given concrete. In the buoyancy change method, bubbles may coalesce after release into the fluid, and the portion of entrained air associated with the coarse aggregate is excluded from the sample. Thus the buoyancy change method will tend to give a lower specific surface and higher spacing factor than **ASTM C 457**.

10. REPEATABILITY

10.1 Although each buoyancy test requires a unique sample and therefore cannot be duplicated exactly, researchers at the Kansas Department of Transportation have found that pairs of samples obtained within 1.5 feet of each other in the field vary 10% from each other on average.

11. SET UP HINTS

11.1 Several steps can be taken to reduce the amount of time necessary to set up the buoyancy testing equipment Preparing the de-aerated water and the bottle of analysis liquid in an insulated water container at least one day before testing occurs will save time. If the water container will be stored in an area that is cooler than the specified temperature, set the immersible heater to the correct temperature and put it into the covered water container. If the room temperature is slightly higher than the specified temperature, uncovering the container will allow the water to cool approximately 5°F (3°C). If the room temperature is much higher than the specified temperature, a sealed bag of ice or freezer packs placed in the covered water container the night before testing will generally result in the correct water and analysis fluid temperature.

11.2 After the water has been brought to the proper temperature, care should be taken to keep the temperature as constant as possible. Protect the water container from temperature extremes, such as may be encountered in an enclosed vehicle.

11.3 Obtaining a constant balance reading at the beginning of the test may also take a significant amount of time if the equipment is set up in an unstable location. Mobile work trailers that are resting on their tires are generally not stable enough. Any movement by people in the trailer can move the trailer enough to disturb the apparatus and render the test unusable. Generally, only trailers that have been put up on blocks so they are not sitting on their tires are at all acceptable, and only as a last alternative.

11.4 Isolating the test equipment from vibration will reduce the time necessary to obtain a constant balance reading at the beginning of the test. One or two anti-vibration pads may be used under each corner of the cabinet to attenuate shock and vibration.