CONCRETE TESTS
5-694.500

5-694.501 SAMPLING OF CONCRETE

Taking concrete samples at the point-of-placement rather than the point-of-delivery is always preferable. Special situations may occur which create difficulties in sampling and transporting samples taken from the point-of-placement. When this occurs, sampling at the point-of-delivery is satisfactory but only after running correlation tests between the 2 sampling locations. **(Caution: The correction factors developed between the 2 sampling locations may vary due to changing conditions such as air and concrete temperature changes, pumping distances, etc. Perform correlation tests several times throughout the day.)**

If necessary, modify sampling procedures to fit a specific situation. If the slump test result is outside of the slump range, correct before placing the concrete in the work. Make corrections as follows:

<u>Slump too low</u>: Add water in measured amounts to bring the slump within the specified range. Record the added water on the Certificate of Compliance.

<u>Slump too high</u>: Add additional cement by full bag to bring the slump within the specified range. Provide cement from the same manufacturer as the original batch. Record the added bags of cement on the Certificate of Compliance.

After the addition of water, cement, or air-entraining admixture, remix the batch for 50 revolutions at mixing speed to insure adequate dispersion of the materials throughout the batch. Retest to verify compliance with the Specifications. If the concrete is placed in the work, report both tests on the *Weekly Concrete Report* (Form 2448) with a notation of the amount of water, cement or air-entraining admixture added. The number of revolutions at mixing speed shall not exceed 150 per Specification 2461.4C. Mix the concrete at agitating speed for all revolutions over 150.

Obtain samples for strength tests by the same procedure as for slump or air test, except obtain the sample from the middle half of the load whenever possible. If the sample is transported to a different location for specimen fabrication, remix the sample to ensure uniformity. The following sections provide procedures for sampling from various mixers.

Start slump, temperature, and air content tests within 5 minutes after obtaining the sample of fresh concrete. Start strength tests within 15 minutes of obtaining the sample.

5-694.503 SAMPLING FROM STATIONARY MIXERS

Sample the concrete by either passing a container through the discharge stream of the mixer or by diverting a portion, or the entire discharge stream into a sampling container. When a container is passed through the discharge stream, sample the entire stream to reduce segregation that may occur as the material leaves the mixer. When sampling by diverting the discharge, diversion of one-half the discharge is satisfactory provided it is full-depth.

5-694.504 SAMPLING FROM READY-MIX CONCRETE TRUCKS

Normally, take samples during the discharging operation. Obtain samples by collecting the full width of the discharge stream of the chute into a sampling container. Control the rate of discharge from the truck at a satisfactory rate for sampling. Do not reduce the rate of discharge by closing or reducing the size of the discharge opening of the truck. You may need to stop the discharge from the drum to collect the full width and depth of the discharge stream on the chute into the sampling container. Provide a sample of sufficient size to perform the tests without reusing the same concrete for subsequent tests.

Usually samples are not taken from the first one-quarter or last one-quarter of a cubic meter (cubic yard) of truck discharge. Should these or other portions of the discharge indicate improper mixing, reject the concrete. It is recommended that after sampling; stop further discharge from the mixer until the tests are completed. If the slump and air content meet requirements, complete the discharge. This delay in placing concrete is extremely important when the test is on the first load of concrete of the day.

5-694.505 CONCRETE AGE-STRENGTH RELATIONSHIP

Concrete strength varies with age. Under continuous favorable conditions, concrete continues to gain strength indefinitely. Samples of concrete taken from old pavements and tested in compression indicate higher strengths after 25 years than when the pavement was 1 to 3 years old. Tests for concrete strength are made shortly after it has been placed (7 to 90 days). It is always tested for acceptance at fairly early ages with respect to the concrete life and for this reason the strength obtained is less than the ultimate strength the concrete will attain.

Flexural strength and compressive strength develop at different rates within the concrete. Except for the first few days, the rate of strength gain is greater in compression than in tension (flexural).

5-694.510 COMPRESSIVE STRENGTH TESTS

Strength tests are required for one or both of the following purposes:

1. To check the potential strength of the concrete under controlled conditions against the desired strength; and
2. To establish a strength-age relationship for the concrete under job conditions as a control for construction operations or the opening of the work.

Tests made for the first purpose are referred to as standard tests and those for the second purpose are referred to as control tests.

For uniform and comparable results, follow a standard and consistent procedure in making all of the test specimens whether they are used either for standard or for control tests.

Twenty-four hours after casting, place the cylinders in water at a temperature of 15 to 25°C (60 to 80°F) for a period of 12 to 14 days. You do not need to remove plastic molds when curing cylinders in water however, remove the caps during the curing period. Transport the cylinder, in a capped plastic mold to prevent moisture loss, to the laboratory for further curing and testing. Adequately protect the specimens to avoid shipping damage. Completely fill out the *Concrete Cylinder ID card* (Form 2409) so that the cylinder is positively identified when it reaches the Mn/DOT Office of Materials Laboratory. Number cylinders made on each contract in consecutive order, beginning with number 1. Show the cylinder numbers on both the identification card and on the *Weekly Concrete Report* (Form 2448) for the concrete mix used.

Cylinders that have the suffix “C” after the numbers are considered control cylinders and are cured the same as the structure.

The standard cylinders are tested at 28 days, unless for special reasons, tests at different ages are desired. Control cylinders should indicate the desired test age. If the test age is not given, they will be tested at 28 days.

When sending samples, address shipping tags to:

> Office of Materials
> 1400 Gervais Avenue
> Maplewood, MN 55109

Some of the factors that can result in failures are listed below. Take precautions so none of these occur on the project. The first 3 factors do not affect the strength of the concrete in the structure, but cylinder test results do indicate lower strengths than the actual structure. The last 5 conditions affect the quality of the concrete in both the structure and in the specimens.

1. Improper molding of the specimens may result in honeycombed sections in specimens. Honeycombing indicates improper molding methods, segregation of the coarse aggregate or a batching error resulting in excessively high rock content of the mix.
2. Towards the end of each construction season, cylinders that broke below 80% of anticipated strength are checked to determine whether casting procedures were proper. In many cases the tops were poorly finished with open texture and projections. Identifications scribed in the tops are also observed as well as “nibs” on the bottom caused by striking the bottom of the mold with the rounded, semi-hemispherical rod. All cause reduced strength.
3. Inadequate curing of the cylinders may result in low strengths. Concrete subjected to poor curing conditions in the first 48 hours may never develop its potential strength. Cylinders that are exposed to frost, direct rays of the sun on warm days, and to adverse dry conditions during

early age are also affected. Low temperatures and lack of moisture retard strength gain, yielding 28-day strength values lower than expected; however, the concrete will eventually develop its full strength.

4. Rough handling of cylinders, particularly during early ages, will cause fractures or planes of weakness in the cylinders. Disturbance of any nature during the setting period may reduce the concrete strength.
5. A decrease in the cement content of the mix by either withholding part of the cement per batch or by increasing the quantity of aggregates per batch reduces the concrete strength. During the proportioning operations, assure that the proper quantities are measured out. Where sacked cement is furnished, assure the full content of each sack is placed in the mixer.
6. The use of dirty or contaminated aggregates results in a lower bond strength between the cement paste and the aggregates, thus producing a poorer quality cement paste, thereby reducing concrete strength.
7. Increasing the water content of the mix for easier workability without increasing the cement content to compensate for the additional water results in a weakened cement paste. Use sufficient water to give the desired consistency; additional water will shorten the life of the concrete structure. Water above the amount in the batch design results in a weaker cement paste along with a decrease in strength.
8. Decreasing mix time, either intentional or otherwise, may leave portions of both sand and gravel that are uncoated with cement paste. Worn mixing blades can also result in reduced mixing action.

5-694.511 CASTING CYLINDERS

In making the test specimens, place molds on a level, firm foundation in a sheltered place where they can remain undisturbed and protected from direct sunlight and from temperatures below 15°C (60°F) for at least 24 hours. If metal molds are used, lightly oil the inside before placing concrete in them. If a suitable casting site is not available in the immediate proximity of the work, transport the concrete and cast specimens to a location where they are kept undisturbed for the initial 24-hour period. If sampling has caused segregation, re-mix by hand shoveling prior to casting the test cylinder.

Mn/DOT standard cylinder mold size is 100 x 200 mm (4 x 8 in.). If aggregate has a maximum size greater than 31.5 mm (1 1/4 in.), use 150 x 300 mm (6 x 12 in.) molds.

White is Mn/DOT's standard color for concrete cylinder molds. Mn/DOT also recommends using domed lids instead of flat lids. This is to discourage the practice of stacking cylinder molds containing plastic concrete on top of one another. This is to eliminate one possible cause for low cylinder strengths. White cylinder molds do not attract nearly as much heat from the sun as the black ones do. Standard cylinders must be kept in a protected area, out of the sun and protected from temperatures below 15°C (60°F), and undisturbed for the initial 24-hour period.

Cylinder Casting Procedure

1. Use steel, fiber, or plastic molds.
2. Cast on flat surface.
3. Start casting cylinder within 15 minutes of taking a representative sample of concrete.
4. Place the concrete in the mold and rod each layer 25 times per layer in 2 equal layers for 100 x 200 mm (4 x 8 in.) cylinders using a 9.5 mm (3/8 in.) diameter hemispheric-nosed steel rod. For 150 x 300 mm (6 x 12 in.) cylinders, rod concrete 25 times per layer in 3 equal layers with a 16 mm (5/8 in.) diameter, hemispheric-nosed steel rod. Uniformly distribute the rodding over the cylinder area and penetrate slightly into the previous layer when tamping the second and/or third layers.
5. Tap the sides of fiber and plastic molds after each layer lightly with the hand prior to the strike-off to remove entrapped air bubbles on the sides of the mold. When using steel molds, tap the mold lightly with the mallet.
6. After rodding the top layer, strike-off the surface evenly using a wood float or other suitable object. Do not use the cap as a finishing tool.
7. When casting cylinders in plastic molds, place the cylinder cap on the mold immediately after finishing the cylinder. Place adequate curing medium on other molds. Do not disturb for 24 hours.
8. Place SP and Field ID on cylinder mold, not on cylinder surface. Do not mark caps since they are reused. Do not etch identification into the surface of the cylinders. When using metal molds, transfer the ID to the top surface of cylinder and strip metal molds.
9. Place in curing tank. Cylinders in plastic molds may cure in water tank with caps off.
10. Fill out *Concrete Test Cylinder ID* card (Form 2409). See 5-694.754.
11. Protect cylinder from moisture loss and shipping damage. Ship sufficiently prior to testing date. Ship cylinders in plastic molds if the tops are sealed.

Protect the cylinder from moisture loss and extreme temperature change after casting. Control moisture loss by:

- Placing the specimen in an insulated box containing moisture
- Covering with polyethylene sheeting or bags
- Covering with a minimum of 4 thicknesses of wet burlap
- Covering with waterproof paper
- Placing caps on plastic cylinder molds

Protect specimens from the direct heat of the sun and from extreme changes in temperature. In cold weather, keep specimens in a heated enclosure and do not allow specimens to freeze.

Fill out the sample card completely, including the source of concrete when ready-mix concrete is used. See 5-694.754. Enter the full name of the concrete source each time a card is made out.

5-694.520 FLEXURAL STRENGTH TESTS

These routine tests are usually made only on paving jobs and are tested at the job site. Rehabilitation projects requiring early openings may also utilize flexural tests.

As with all testing practices, the value of the standard flexural test results depend entirely on uniform adherence to the standard procedure outlined below. Tests are normally made at the standard ages of 7 and 28 days. High early strength concrete may require additional beams to verify opening strengths.

Record the test data for all beams on *Concrete Test Beam Data* (Form 2162) and submit to the Mn/DOT Concrete Engineering Unit every week after the 28-day specimens are tested. Whenever there is a change in the mix or in the source of any of the materials, report this data so that only one set of conditions are on a sheet. A sample of Form 2162 is shown in Figure A 5-694.741.

5-694.521 CASTING BEAMS

Carefully make the beams of representative concrete as follows:

1. Obtain enough concrete to cast 7 and 28-day specimens. Casting should occur within 15 minutes of obtaining the representative concrete sample.
2. Clean and oil molds.
3. Cast on a flat surface.
4. Place concrete and rod 65 times per layer in 2 equal layers with a 16 mm (5/8 in.) rod. Spade along edges after each layer. Tap lightly along inside and outside edges after each layer.
5. Strike off surface with a straight edge and finish with a trowel or wood float.
6. Impress ID into the surface within 150 mm (6 in.) from outside edge. (If placed near the third point, the impressions of the numbers might adversely affect the test results.)
7. Adequately cure and do not disturb for 24 hours.
8. Place in curing tank.
9. Test beams according to the procedure described in 5-694.522.

NOTE: Control beams are intended to verify opening strengths and therefore cure them in a similar manner as the pavement. In cases of late season paving, you may cure control beams in water tanks to avoid freezing and assume there is an equal trade off between the moist cure of the sample and the additional heat generated by the slab. In any case, ACI requires moist curing beams for at least 24 hours immediately before testing in water saturated with calcium hydroxide at 23 ± 2°C (73 ± 3°F).

Number the beams in consecutive order for each contract, beginning with number 1. Where more than one project is included in one contract, DO NOT use separate series of numbers. The numbers of the beams made each day and the station where they were cast are entered on the *Weekly Concrete Report* (Form 2448).

After casting, the specimens are left uncovered only until the identification numbers are inscribed and then covered with wet burlap, impermeable paper, or polyethylene plastic and left undisturbed for 24 hours. Protect these test specimens from direct sun and extreme temperatures.

When 24 hours old, carefully move the specimens in the molds to the testing locations. Exercise care in this operation to avoid damage to the beams. DO NOT throw or drop at any time. Upon arrival at the testing site, remove the beams from the molds and store the specimens in saturated limewater at 15 to 25EC (60 to 80EF) until the 7 or 28-day testing date has arrived. DO NOT subject the specimens to water temperatures lower than 15°C (60°F).

5-694.522 TESTING BEAMS FOR FLEXURAL STRENGTH

Nearly all State Departments of Transportation use third point beam breakers for flexural testing of concrete pavement. By using third point beam breakers, Mn/DOT can share its test results with other states and adapt the test results for use with AASHTO pavement design equations.

A. Before the First Use of the Beam Breaker After Transportation or Storage

1. Release all four case latches and lift the cover <u>straight</u> up.
2. Place the cover at the desired operating location and set the apparatus squarely on the top of the cover. See Figure A 5-694.522.
3. Remove any ties from the recorder or other components.

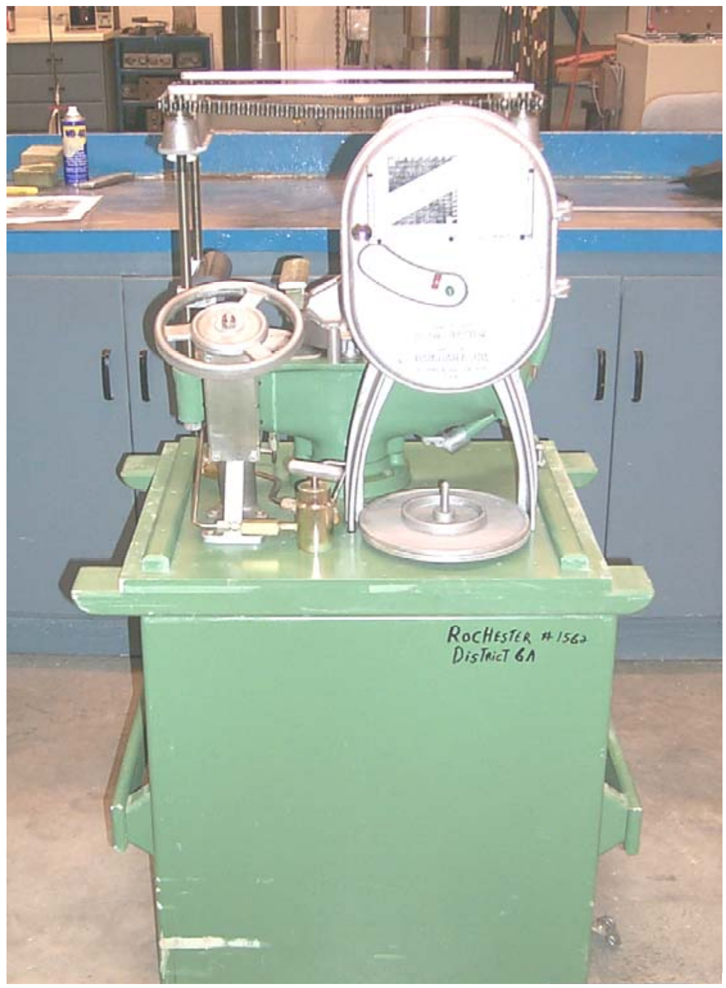

Figure A 5-694.522

B. Recording Charts

Third point loading recording charts are used to determine the Modulus of Rupture for each specimen. Proper use of the testing machine will apply a rate of loading between 861 and 1207 kPa (125 and 175 psi) per minute for any beam whose cross section dimensions are 150 x 150 mm (6 x 6 in.), ±8 mm (±5/16 in.). Four different spirals labeled A, B, C, and H are indicated on each recording chart. See Figure B 5-694.522. The chart in Figure E 5-694.522 is a guide to use in determining which spiral to use in testing each specimen. Note the exact dimensions of the specimen to determine which spiral to use. The chart is also used to correct the Modulus of Rupture values for specimens that do not have an exact 150 x 150 mm (6 x 6 in.) cross section. The spiral labeled H, is used for loading specimens at a rate of 861 kPa (125 psi) per minute, and is not used by Mn/DOT.

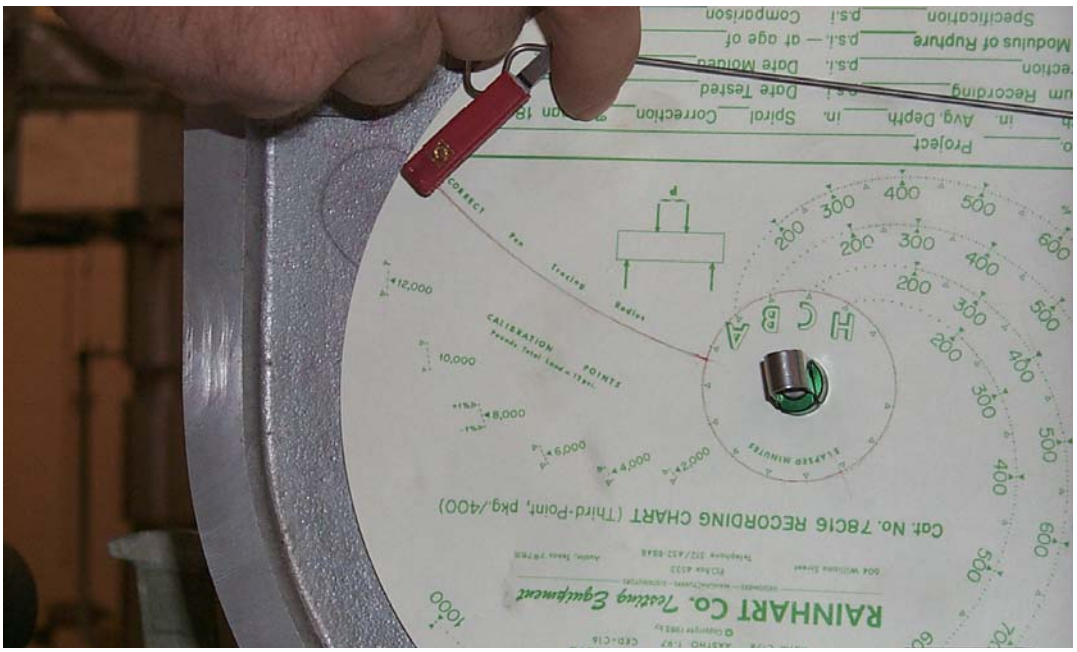

Figure B 5-694.522

C. Test Procedures

1. Remove the plastic dust cover.
2. Close the control valve and pump the loading head approximately 6 mm (1/4 in.) until the piston floats.
3. Open the recorder door and install a recording chart: slip the edge of the selected chart under the pen lifter and over the open chart hub. See Figure C 5-694.522. Do <u>not</u> clamp (in order to rotate the chart manually for checking).
   a. Adjust Zero - Adjust the cam as necessary until the pen traces the zero circle, turn the cam with your fingers: clockwise to raise the pen and vice versa. The piston must float under no load.
   b. Check the friction - Move the pen arm up the chart approximately 25 mm (1 in.) and release it. It must return to zero without help.
   c. Correct pen adjustment occurs when:
      - The pen arm assembly is fully inserted and clamped in the pen arm holder. Check that

the two pen arm fingers are under both rivets and clamped with the screw.

- The pen point trough is at approximately right angles to the chart both vertically and horizontally; flexing the pen arm and holding it close to the pen point adjust this.
- The pen point just makes contact with the chart. Too much pressure will cause skipping. Pressure is adjusted by flexing the pen arm.
- The length of the pen arm radius will trace a minute arc or a pen tracking arc on the chart. This length is important because an incorrect pen arm radius will generate an error directly proportional to the error in its length. To check this adjustment: swing the pen point to the maximum travel; rotate the chart and hand clamp it so that the pen point rests precisely on an arc at maximum reading; allow the pen to draw its own arc as it returns to the zero circle. Examine the coincidence of two arcs. If the two arcs vary more than 1 mm (1/32 in.) and are not corrected by adjustments as described in 1 and 2 above, the recorder needs calibration. You can also test the arc by tracing the radius shown in Figure B 5-694.522.

Figure C 5-694.522

4. With the beam on its side in relation to its position as molded, measure the width (b) and depth (d) at the center of the specimen. Take measurements to nearest 0.5 mm (0.02 in.). Use good outside calipers and a steel machinist's rule. See Figure D 5-694.522. Using these measurements turn to Figure E 5-694.522 to determine which spiral you should trace.

Figure D 5-694.522

Example:

If the depth (d) is 149.0 mm (5.87 in.) and the width (b) is 147.5 mm (5.80 in.), the convergence of these points in Figure E 5-694.522 is in the shaded area labeled C. Therefore you should trace spiral "C" during the testing.

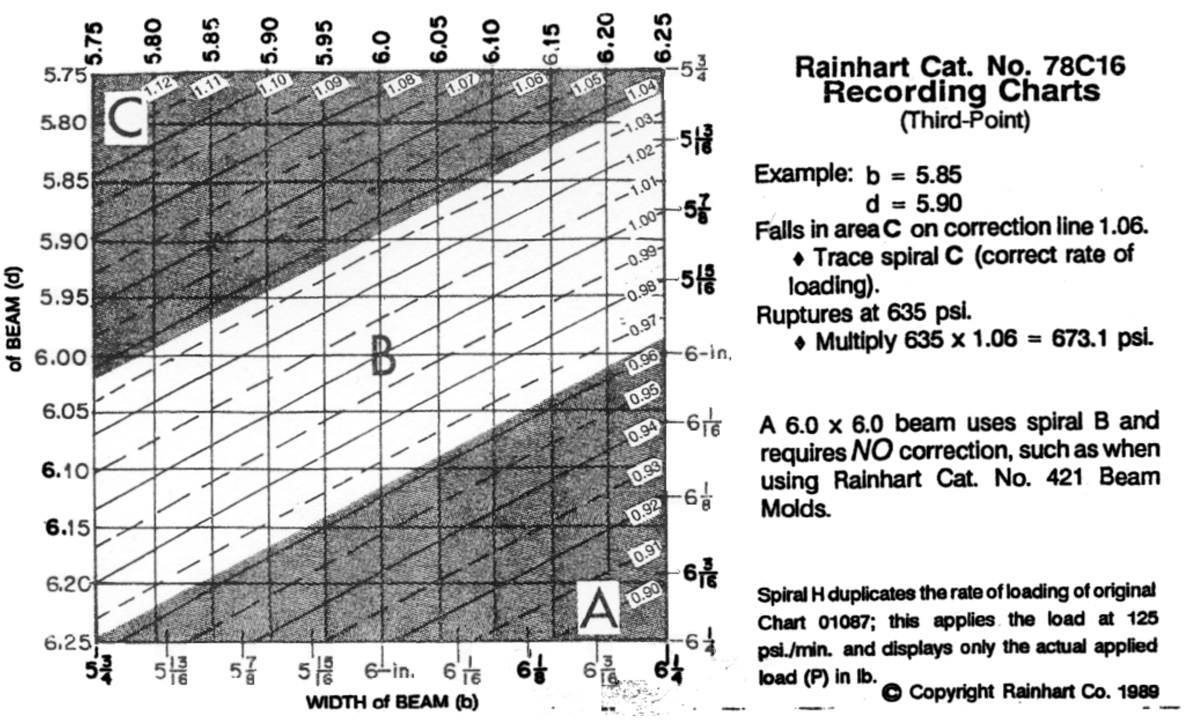

Figure E 5-694.522

5. Use the key and wind the chart drive clockwise approximately one full turn. See Figure F 5-694.522. Rotate the chart to its starting position, and then clamp the recording chart.

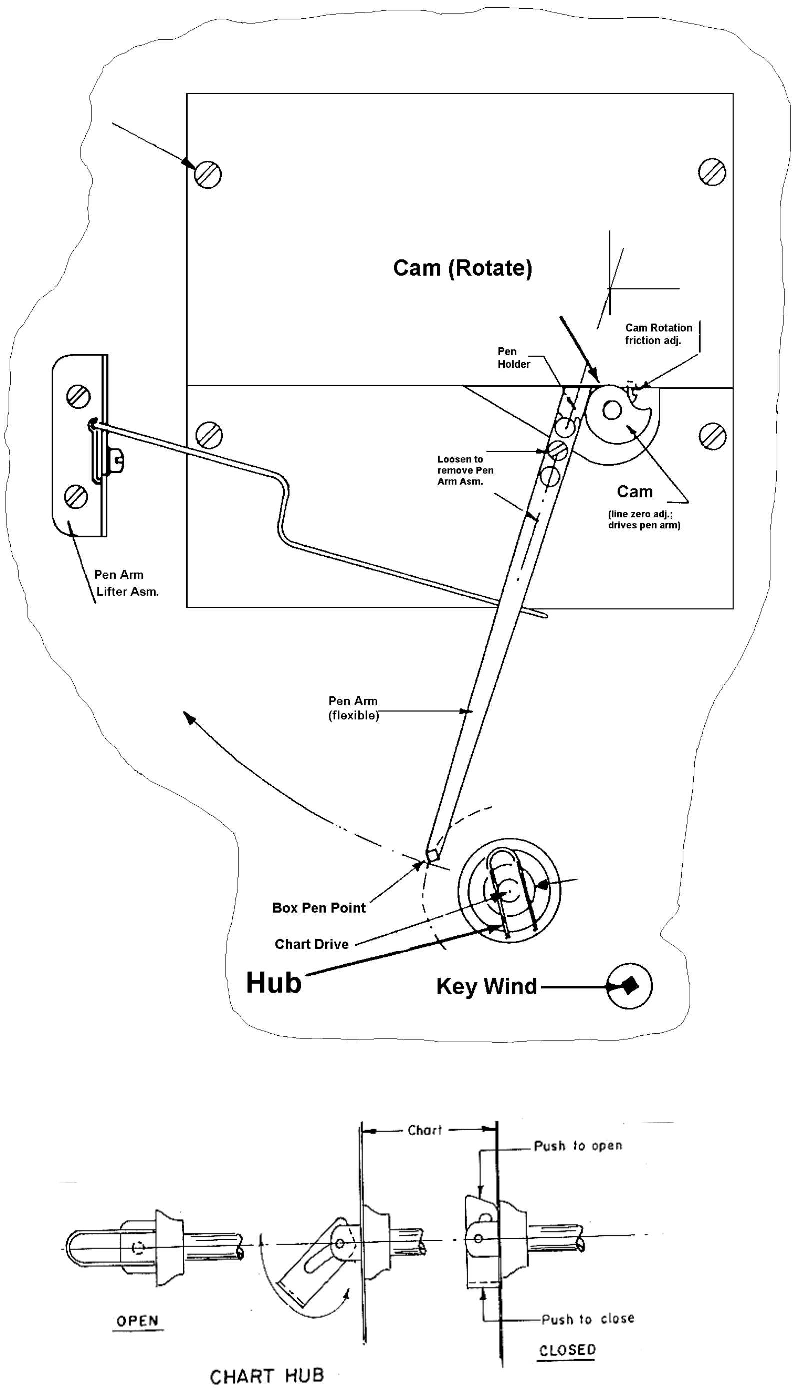

Figure F 5-694.522

6. With the beam **on its side** in relation to its position as molded (same position as used for taking the previous measurements), insert the beam from either end of the apparatus between the tie rods. Center the beam in relation to the four tie rods and have at least 25 mm (1 in.) of concrete protrude outside of each of the two cross-head bearing blocks. See Figures G and H 5-694.522.

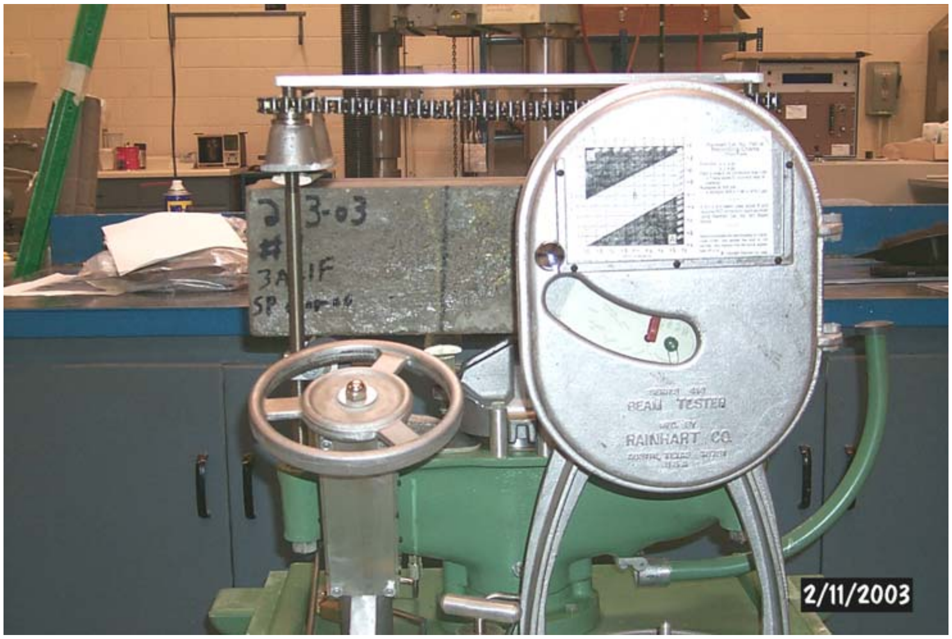

Figure G 5-694.522

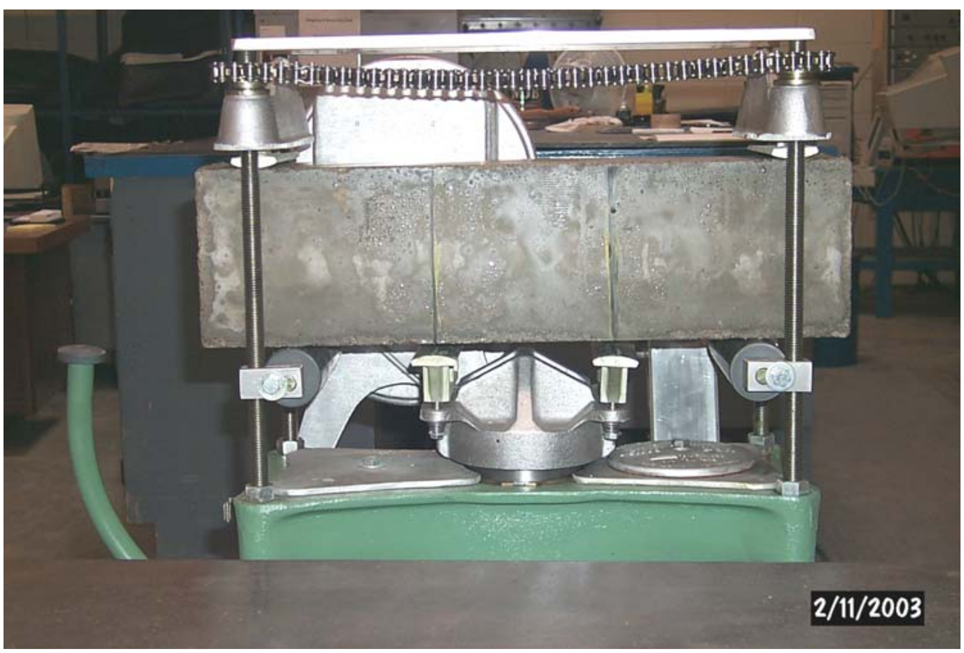

Figure H 5-694.522

7. The chain drive provides a quick method of adjusting the crossheads synchronized in height so that the load is applied normal to the beam. To operate, grasp opposite sides and move simultaneously clockwise to bring them down into contact with the beam, and counterclockwise to raise them. Stop as soon as they touch the beam; further loading is hydraulic.
8. Close the Control Valve clockwise. Counterclockwise rotation of the pump handwheel will fill the pump with oil and clockwise rotation will introduce it into the main hydraulic system to apply load. The centerhead is quickly raised to establish initial contact with the beam by rapidly spinning the hand wheel clockwise. As soon as contact is established and the loading block(s) seated (the recorder pen will show a small load), refill the pump.
9. Carefully trace the spiral of the rotating chart and load the beam until failure.
10. Open the control valve (counterclockwise two turns only), to allow the piston to retract by gravity, raise the crossheads and remove the beam sections.
11. Unclamp and remove the chart. After the end of the test, the chart drive will tick away until run down (clamp loop inverted). **NOTE**: You can rewind the chart drive at any time.
12. Fill in all pertinent test result data. Measure the average width and average depth of the specimen at the section of failure, and record. If the beam does not measure exactly 152.5 x 152.5 mm (6 x 6 in.), refer to the chart in Figure E 5-694.522. This chart is stored in the plastic holder on the front of the recorder door. Specimens must break in the middle one-third or 228.5 mm (9 in.) of the beam or they are not acceptable.

Example:

Beam Dimensions:
151.0 mm (5.95 in.) depth = d
152.0 mm (5.98 in.) width = b

From Figure E 5-694.522, use spiral B. If beam breaks at 3585 kPa (520 psi), check dimensions, follow line to upper right of chart, chart indicates that 1.02 (+2%) should be subtracted.

Final Strength

$$(1.02 \times 3585\, kPa) = 3657 \text{ kPa} = 3.66 \text{ MPa} \quad \underline{\text{or}}$$
$$(1.02 \times 520\ psi) = 530\ psi$$

D. After Each Day's Operation

1. Close the recorder door.
2. Open the control valve until the head bottoms and close the control valve.
3. Using a damp rag or brush, clean the top of the loading head and the base casting being careful to move all particles away from the hydraulic cylinder. DO NOT clean by flushing with water because some might find its way into the hydraulic system and cause disastrous rusting.
4. Position the dust cover over the machine.

E. Hydraulic Fluid

The most important item of maintenance on the Beam Tester is controlling the quality and quantity of the hydraulic fluid. Check this yearly during calibration, or whenever leakage is found, and after periods of extended storage.

Below are guidelines for checking the hydraulic fluid in the Beam Tester:

- **Fluid Specification** - All Rainhart Beam testers are furnished with factory installed Automatic Transmission Fluid with Dexron (GM type); an extra quart can is tied inside the case cover. This fluid is readily available from any quality petroleum products distributor.
- **Quantity** - With the piston fully retracted, remove the left hand cover of the base casting. Add if the fluid is more than 40 mm (1 1/2 in.) from the top undersurface of the base casting. Full is 12 mm (1/2 in.) from the top undersurface. A can is packed in the cover of every Beam Tester when shipped from the factory.
  - The capacity of the entire system is 1.6 L (1 1/2 qt.).
  - The right hand cavity of the Beam Tester base casting is dry and has no hydraulic function.
- **Quality** - With the piston fully retracted, remove the left hand cover of the base casting and check the condition of the oil in the reservoir at its deepest point next to the main cylinder.
  - Inspect for sludge, color, smell and water. **Do not use** automobile brake fluid. If the oil is extremely dark or has heavy viscosity, replace it. Since the hydraulic oil circulates in one direction only, all grit or impurities are transported to the reservoir where they can settle harmlessly to the bottom. The filter prevents foreign matter from entering through the pump.

5-694.530 CONSISTENCY (SLUMP) TESTS

Check and control the consistency of the concrete during each pour. According to Specification 2461.4A4a, the slump test is a measure of the consistency of the concrete. The consistency therefore is a measure of the water content of the concrete. The water content controls and affects the cement content of the concrete. Since the slump test is important, do not substitute a guess for an actual test.

The minimum tests required according to the Schedule of Materials Control may not provide a sufficient number of tests to assure quality. An individual slump test may not indicate the true consistency of the concrete because of unavoidable variations in the composition of the concrete and because of variations in the manipulation of the concrete. For this reason, take several tests to obtain a true average value. On small pours, one test may not provide sufficient information to assure quality.

Enter the results of slump tests on the *Weekly Concrete Report* (Form 2448). See Figure B 5-694.727.

The consistency of concrete mixes, in terms of millimeters (inches) of slump, is determined by their relative water contents. Thus, a given change in the water content of a mix will result in a corresponding change in slump. The percentage change in water content per millimeters (inches) of slump change is not constant over the whole range of consistency. It is greater at the dry end of the range and less at the wet end. Only use this procedure when the plant has held back water from the design mix and the slump is less than required by the mix design. The added water to increase the slump cannot exceed the design water by more than 4% per Specification 2461.3J(2).

Guidelines for the approximate changes in water content, in percent, for various changes in slump are shown in Table A 5-694.530.

To illustrate the use of the table, assume the water for a given mix will produce a 50 mm (2 in.) slump. If a 100 mm (4 in.) slump is desired with this mix, increase the water content 7.9%. In another illustration, the water content is decreased 10.3% to reduce the slump from 125 to 50 mm (5 to 2 in.).

Guidelines for Slump Adjustment

From a slump of:	To a slump of:					
	25 mm (1 in.)	50 mm (2 in.)	75 mm (3 in.)	100 mm (4 in.)	125 mm (5 in.)	150 mm (6 in.)
25 mm (1 in.)		+6.5%	+11.3%	+14.9%	+17.5%	+19.9%
50 mm (2 in.)			+4.5%	+7.9%	+10.3%	+12.6%
75 mm (3 in.)				+3.2%	+5.6%	+7.7%
100 mm (4 in.)					+2.3%	+4.4%
125 mm (5 in.)						+2.0%

Table A 5-694.530

5-694.531 CONSISTENCY (SLUMP) TEST PROCEDURE

Equipment needed:
- Slump cone in clean and good condition
- Smooth, rounded 16.0 mm (5/8 in.) diameter steel rod with a rounded tip

Consistency (Slump) Test Procedure:
1. Obtain a representative concrete sample. Start test within 5 minutes of when sample was taken.
2. Dampen the slump cone and place on a flat, moist, non-absorbent and rigid surface; hold the cone firmly in place by standing on the foot pieces.
3. Immediately fill the cone in 3 layers, each layer approximately one-third the volume of the mold or about 67 mm (2 5/8 in.) for the first layer and 155 mm (6 1/8 in.) for the middle layer.
4. Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross-sections of each layer making approximately half of the strokes near the perimeter, then progress with vertical strokes spirally toward the center, slightly penetrating into the underlying layer. In rodding the top layer, an excess of concrete is maintained above the top of the cone. After the top layer is rodded, the surface of the concrete is struck off even with the top of the cone.

5. Remove any excess spillage of concrete from around the base of the cone and lift the cone clear of the concrete allowing the concrete to settle or slump under its own weight. Slowly lift the cone vertically and carefully to secure a proper result, with the lifting operation taking approximately 3 to 7 seconds.
6. The amount of slump is measured immediately after the mold is lifted by placing the rodding bar across the inverted mold and measuring from the top of the mold to the displaced original center of the top of the concrete. Record the slump as measured to the nearest 5 mm (1/4 in.).
7. If the slump test shows results higher than the maximum of the 25 mm (1 in.) slump range specified in 2461.3B3, notify the Contractor of the results and test the next load. When testing the next load, do not allow the placing of any concrete until the test shows acceptable slump.

Notes:

- Specification 2461.4A4a allows an additional 25% above or 50% below the upper end of the specified range on an occasional basis. This does not change the slump range. This is intended to give the Contractor some time to correct any problems they may have and get the slump back within the range as soon as possible. If any load's Certificate of Compliance shows the water used (including any added on site) is greater than mix design water subject to 2461.3J(2), reject the load and do not place into the work.
- Water reducers are currently more frequently used. According to Mn/DOT Specifications, water reducers must have the Engineer's approval for use. If approval is granted, investigate any slump failures to verify if the high slump is due to the water or admixture. The price reductions listed in the Schedule of Price Reductions for high slumps, especially bridge deck concrete, were originally based on high slumps due to high water. High slumps caused by admixture may not warrant the price reduction imposed similar to that caused by water. In any case, the slump of the concrete should remain constant.

Figures A and B 5-694.531 illustrate the slump test for consistency. Figure A shows a low slump and Figure B a high slump.

Figure A 5-694.531[1]

Figure B 5-694.531[2]

5-694.532 VERIFICATION OF WATER IN FRESH CONCRETE BY USE OF A MICROWAVE OVEN

Mn/DOT has incorporated the use of AASHTO TP23-93 to verify the Contractor's water in concrete pavements. This test uses a microwave oven to drive the water out of fresh concrete. Mn/DOT has an incentive/disincentive program for the water-cementitious (w/c) ratio. This incentive is based on the Contractor's actual batch weights and is verified using the microwave.

Knowing the weight of the fresh concrete and the weight of the dried concrete, the total water content can be calculated. This total water content is not the same as the total batch water content because the total water content includes all absorbed moisture in the aggregates. The water content used to determine the w/c ratio is the batch water added by the Contractor plus any free moisture; this does not include the absorbed moisture.

There are many variables in this procedure. The most significant are the absorption and moisture of the aggregates. For this reason, Mn/DOT will run new absorption tests on all aggregate sources before paving begins. The Paving Contractor will also need this information since they will be designing their own mixes. Together with the Agency, the Contractor will have to submit samples to the Mn/DOT Office of Materials when they decide which aggregates they are going to use.

Moisture tests and microwave oven testing are performed by the Agency. Testing rates are found in the special provisions.

A. Verification of Water in Fresh Concrete Test Procedure

See 5-694.734 for instructions and the worksheet for performing the microwave oven test procedure.

Figure A 5-694.532 shows an example of a dried microwave oven sample.

Figure A 5-694.532

B. Definition of Lots and Sublots Involving Water/Cementitious Ratios

For determination of water/cementitious ratio incentive/disincentive, a lot represents one day of paving. Paving includes integrant curb and gutter and curb and gutter placed with the same mixture as paving. A change in mix design requires beginning a new lot. Changes in mix design for small quantities such as hand work and high early mixes greater than 356 kg/m^3 (600 lbs/yd^3) cementitious are not included as part of a lot or sublot for incentive/disincentive determinations.

All samples for testing are taken in a random manner according to the prescribed sampling rate. A minimum of 2 tests and a maximum of 4 tests are required per day. The minimum sublot size is 250 cubic meters (cubic yards). Gradation testing is not required when production is less than 250 cubic meters (cubic yards) per day.

If less than 3 sublots are produced in a day before the new mix design is initiated, the sublots shall be averaged with the previous lot and included as part of that lot. On the first day of production or whenever the mix design is changed prior to the production of 3 sublots, this production is hereby defined as a lot. If production is less than 3 sublots, the sublots are included in the next day's production. On the last day of paving or on the last day of using a specific mix design, the concrete involved shall constitute a separate lot/sublot unless the above applies regarding less than 3 sublots.

5-694.540 AIR CONTENT TESTS

The general statements made in an earlier section with reference to consistency apply as well to testing of the air content of the concrete.

Accurate determination of the air content is essential in computations of cement content and yields, as well as a check for compliance with Specification 2461.4A4b limitations on the air content itself.

For all air-entrained concrete the Specification limits for air content is in the range of 5 to 8%. The target air content for all concrete is 6.5%.

Perform enough tests during the pour to accurately determine the average air content of the concrete.

The air test is subject to the variations and limitations of each batch; therefore, spread the tests out over the entire period of the placement operation. When the tests are taken at proper intervals, a relatively accurate average value for air content is obtained. On large pours, many tests are required. On small pours a minimum of two tests is desirable. Check a current Schedule of Materials Control for minimum testing rates. Send a sample of each lot of air-entraining admixture to the Laboratory for infrared scan and percent of solids tests.

It is the duty of the Inspector to inform the Contractor of the air content test results. It is then the responsibility of the Contractor to determine and adjust the air-entraining agent dosage rate to maintain the air content within the specified range. Concrete which is placed in the work before air test results are known is subject to reduced payment if the air content is outside of the Specifications.

In making the test, it is very important to use concrete of representative composition in filling the testing apparatus container. This is necessary since the air contained in the concrete is all in the mortar portion of the concrete. If the sample used in the test contains either too much or too little mortar with respect to the amount of coarse aggregate, the test will indicate an incorrect air content. Another factor that may contribute to erroneous test results is the use of water in the test that contains a considerable amount of small air bubbles. Water that is freshly drawn from a pressurized line or a valve on the mixer possibly may contain some entrained air. When water is taken from such sources, allow it to stand for 10 to 15 minutes before using it in the test. This will permit the air contained in the water to escape.

It is important to complete the test without interruption and as quickly as possible once it is started. Make the test on freshly mixed concrete, since there is a loss of workability if the sample is allowed to stand for some time after mixing.

5-694.541 AIR CONTENT TEST PROCEDURE

A. Operation of the Pressure Meter (Type B Meter)

Figure A 5-694.541

1. Obtain a representative sample. Begin air content testing within 5 minutes of obtaining the representative sample.
2. Dampen bowl. On a level surface, fill container in 3 equal layers, slightly overfilling the last layer.
3. Rod each layer 25 times with a 16 mm (5/8 in.) rounded tip rod, uniformly distributing strokes.
4. Rod bottom layer throughout its depth without forcibly striking bottom of container.
5. Rod the middle and top layer throughout their depths and penetrating 25 mm (1 in.) into the underlying layer.
6. Tap the sides of the container smartly 10 to 15 times with the mallet after rodding each layer.
7. Strike off concrete level with top of container using the bar and clean off rim.
8. Clean and moisten inside of cover before clamping to base.
9. Open both petcocks.
10. Close air valve between air chamber and the bowl.
11. Inject water through petcock until it flows out the other petcock.
12. Continue injecting water into the petcock while jarring and tapping the meter to insure all air is expelled.
13. Close air bleeder valve and pump air up to initial pressure line.
14. Allow a few seconds for the compressed air to stabilize.
15. Adjust the gage to the initial pressure.
16. Close both petcocks. **DO NOT TILT THE METER AT ANY TIME**.
17. Open air valve between chamber and bowl.
18. Read the air percentage after lightly tapping the gage to stabilize the dial.
19. Close the air valve and then open petcocks to release pressure before removing the cover.
20. Calculate air content:

$$Air\ Content = \left(meter\ reading - aggregate\ correction\ \ factor\ if\ \ requred\right)$$

21. Properly report (record) the results.
22. Clean up the base, cover, and petcock openings.

When the test indicates an air content outside the limits specified in Specification 2461.4A4b, run recheck test immediately. Record the results of the air tests on the *Weekly Concrete Report* (Form 2448). See 5-694.727.

5-694.542 UNIT WEIGHT (DENSITY) TEST

The unit weight (density) test is a measure of the weight per cubic meter (cubic foot) of freshly mixed concrete. By knowing the unit weight of the concrete, other information can be determined such as the concrete yield and water content for microwave oven testing. See 5-694.734 for the unit weight test procedure.

5-694.550 TEMPERATURE TEST

The Inspector should determine and record the concrete temperature at time of placement. Unless the Special Provisions for the Contract provide otherwise, the concrete temperature requirement is in the range of 10 to 30°C (50 to 90°F) per Mn/DOT Specification 2461.4A3. The Certificate of Compliance provides a space for the concrete temperature and air temperature.

On most work, take the temperature with issued thermometers that have been checked for accuracy. On massive pours in large bridge piers or abutments, special installations of electrical thermocouples are sometimes needed to secure data on the rate of temperature change as produced by the heat of hydration of the cement. Such data is very important in determining how long protective coverings, forms, etc. shall remain in place before exposing the concrete to atmospheric conditions.

REFERENCES

1. Figure A 5-694.531, Design and Control of Concrete Mixtures, 14th Edition, Portland Cement Association, 2002.
2. Figure B 5-694.531, Design and Control of Concrete Mixtures, 14th Edition, Portland Cement Association, 2002.