Method of Test for

SURFACE RESISTIVITY INDICATION OF CONCRETE'S ABILITY TO RESIST CHLORIDE ION PENETRATION

DOTD Designation: TR 233

I. Scope

A. This test method covers the determination of the electrical resistivity of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. This test method is applicable for evaluating individual materials or their proportions for resistance to chloride ion penetration. This test method is applicable to type of concrete where established correlations between this test procedure and other permeability measurement procedures such as those described in ASTM C 1202.

Note 1: *This test method can produce misleading results when calcium nitrite has been admixed into a concrete. The results from this test on some such concretes indicate lower resistivity values, that is, lower resistance to chloride ion penetration, than from tests on identical concrete mixtures (controls) without calcium nitrite were at least as resistant to chloride ion penetration as control mixtures.*

Note 2: *Since the test results are a function of electrical resistance of the specimen, the presence of reinforcing steel or other embedded electrically conductive materials might have a significant effect. The test is not valid for specimens containing reinforcing.*

B. Reference Documents
   1. ASTM Standard C 1556 – Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion
   2. DOTD TR 225 – Obtaining and Testing Core Specimens from Hardened Concrete.
   3. DOTD TR 226 – Making, Field Curing, and Transporting Concrete Test Specimens.

II. Apparatus

A. Surface Resistivity Apparatus – Apparatus with Wenner array probe capable of adjustment of the probe tip spacing to 1.5-inches (Figure 1)
B. Specimen Holder – To prevent specimen rotation while under test (Figure 2).
C. Moist Room – To condition retain the sample prior to testing at specified age
D. Marking Device – Any device capable of producing an indelible mark on a wet concrete surface
E. Towel – To dry the excess moisture from the sample before marking and conducting the test
F. End Grinder – To remove surface treatments if necessary
G. Saw – To remove surface treatments if necessary
H. Thermometer – To measure air temperature at time of testing
I. DOTD Surface Resistivity Test Report**,** 22-2000-11 (Figure 6)
J. Shallow Pan – To hold a small amount of water to dip the tips into

Figure 1
Surface Resistivity Apparatus

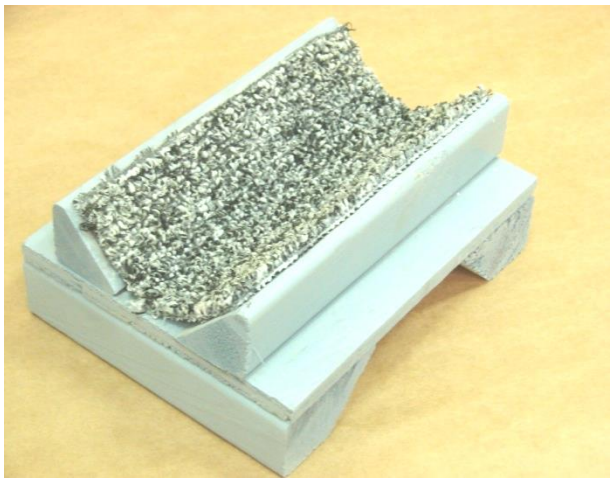


Figure 2
Specimen Holder

III. Samples, Test Specimens, Test Locations, etc.

A. A set is composed of a minimum of three (3) specimen samples. Sample preparation and selection depends on the purpose of the test.
B. Samples may be
   1. 4-inch cores from test slabs or from large diameter cylinders (6-inch diameter or greater)
   2. 4-inch diameter cast cylinders
   3. 6-inch diameter cast cylinders
C. For evaluation of structures, samples may be
   1. 4-inch diameter cylinders cast and cured at the field site
   2. 6-inch diameter cylinders cast and cured at the field site
D. Cylinders cast in the laboratory shall be prepared following procedures in DOTD TR 226. Unless specified otherwise, moist cure test specimens for 28 days prior to the start of specimen preparation.
E. When casting cylinders in the field to evaluate a structure, take care that the cylinders receive

the same treatment as the structure, for example, similar degree of consolidation, curing, and temperature history during curing.

Note 3: *This test method has been used with various test durations and curing regimens to meet agency guidelines or specifications. Exercise care when comparing results obtained from specimens subjected to differing conditions.*

Note 4: *There is no maximum allowable aggregate size established for this test. Users have indicated that the test repeatability is satisfactory on specimens from the same concrete batch for aggregates up to 1.5-inch nominal maximum size.*

F. Transport the cores of field-cured cylinders to the laboratory in moist condition in sealed (tied) plastic bags. If shipping specimens, properly package specimens to protect from freezing and damage in transit or storage. Use boxes to transport in accordance with TR 226.
G. Where the surface has been modified, special processing is necessary for core samples, for example, by texturing or by applying curing compounds, sealers, or other surface treatments where the intent of the test is not to include the effect of the modifications. In those cases, remove the modified portion of the core by means of end grinding or sawing.
H. Immediately after sample removal from the mold, make four indelible marks on top (finish face) circular face of the specimen marking the 0, 90, 180, 270 degree points of the circumference of the circle. Randomly assign one of the marks as 0°, then counter clockwise assign the next mark 90°, and so on. Extend the marks into the longitudinal sides of the specimens. On the longitudinal sides, mark the center of the longitudinal length of the specimen in order to use as a visual reference during testing. (Figure 3)
I. Conditioning
    1. In order to saturate, the concrete cylinder specimen must remain in a condition of 100% relative humidity for at least 7 days prior to testing.

Note 5: *The room should be a complete fog when entering.*

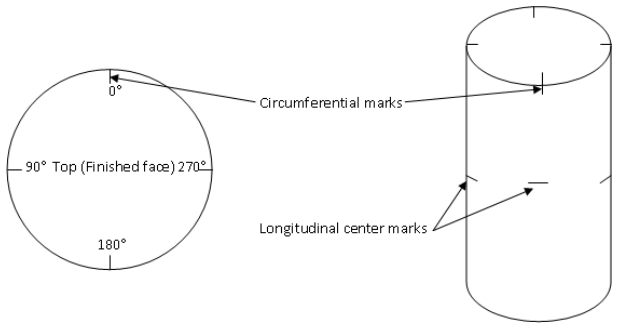


Figure 3
Specimen Marking

IV. Procedure

A. During the test, maintain the air temperature around the specimens in the range of 68 to 77°F.
B. Remove specimen from humidity room or water, blot off excess water, and transfer specimen to holder with the 0-degree mark on top.
C. Dip the Wenner array probe tips into the pan of water several times. Be sure to press against the bottom of the pan to fill the reservoirs.
D. Place Wenner array probe on longitudinal side on the specimen making sure longitudinal center mark is equidistance between the two inner probes (Figure 4).
E. Take reading to the nearest tenth on display unit when the number becomes stable and record it on the calculation report shown in Figure 5 or in the test results report shown in Figure 6.
F. Rotate specimen 0-degree to 90-degree mark, and repeat steps D and E.
G. Rotate specimen 90-degree to 180-degree mark, and repeat steps D and E.

Figure 4
Wenner Array Placement

H. Rotate specimen 180-degree to 270-degree mark, and repeat steps D and E.
I. Repeat last four readings at 0°, 90°, 180°, 270° marks.
J. Repeat steps A to I for other specimens in the set.

V. Calculation and Interpretation of Results

A. Calculate the average resistivity for each specimen in the set.

$$Avg.S_{Avg.A} = \frac{S_{0.1} + S_{90.1} + S_{180.1} + S_{270.1} + S_{0.2} + S_{90.2} + S_{180.2} + S_{270.2}}{8}$$

$$Avg.S_{Avg.A} = \frac{177 + 195 + 168 + 184 + 178 + 193 + 171 + 183}{8}$$

$$Avg.S_{Avg.A} = \text{ 181.1 KOhm-cm}$$

B. Calculate Average Resistivity for Set

$$Avg.SR = C \times \frac{S_{Avg.A} + S_{Avg.B} + S_{Avg.C}}{3}$$

$$Avg.SR = 1 \times \frac{181.1 + 154.6 + 195.8}{3}$$

$$Avg.SR = \text{ 177.2 KOhm-cm}$$

Where:

S = Individual Surface Resistivity Measurement (KOhm-cm)

S_{Avg} = Average Surface Resistivity for Specimen (KOhm-cm)

C = Curing Condition Correction Factor

C. If cured specimens are in limewater, multiply set average by 1.1 to account for reduction caused by limewater curing. If cured specimens were in moist room, multiply set average by 1.0.

Note 6: *Specimen curing condition affects the resistivity of the solution in the pore structure. Limewater curing on average reduces resistivity by 10%.*

D. Use Table 1 and the size of specimens to evaluate the test results based on the resistivity. These developed values resulted from data on various types of concrete.

Note 7: *Factors that are known to affect chloride ion penetration include: water-cement ratio, pozzolans, the presence of polymeric admixtures, sample age, air-void systems, aggregate type, degree of consolidation, and type of curing.*

VI. Report

A. Source of core or cylinder, in terms of particular location the core or cylinder represents.
B. Identification number of core or cylinder and specimen.
C. Location of specimen within core or cylinder.
D. Type of concrete, including type and quantity of cementitious materials, water-cement ratio, and other relevant information supplied with samples.
E. Description of specimen, including presence and location of reinforcing steel, presence and thickness of overlay, and presence and thickness of surface treatment.
F. Curing history of specimen.
G. Unusual specimen preparation, for example, removal of surface treatment.
H. Test results, reported as the surface resistivity measured
I. The qualitative chloride- ion penetrability equivalent to the surface resistivity measured from Table 1.

VII. Normal Test Reporting Time

The normal test reporting time is 4 hours from the time of test.

Chloride Ion Penetrability Based

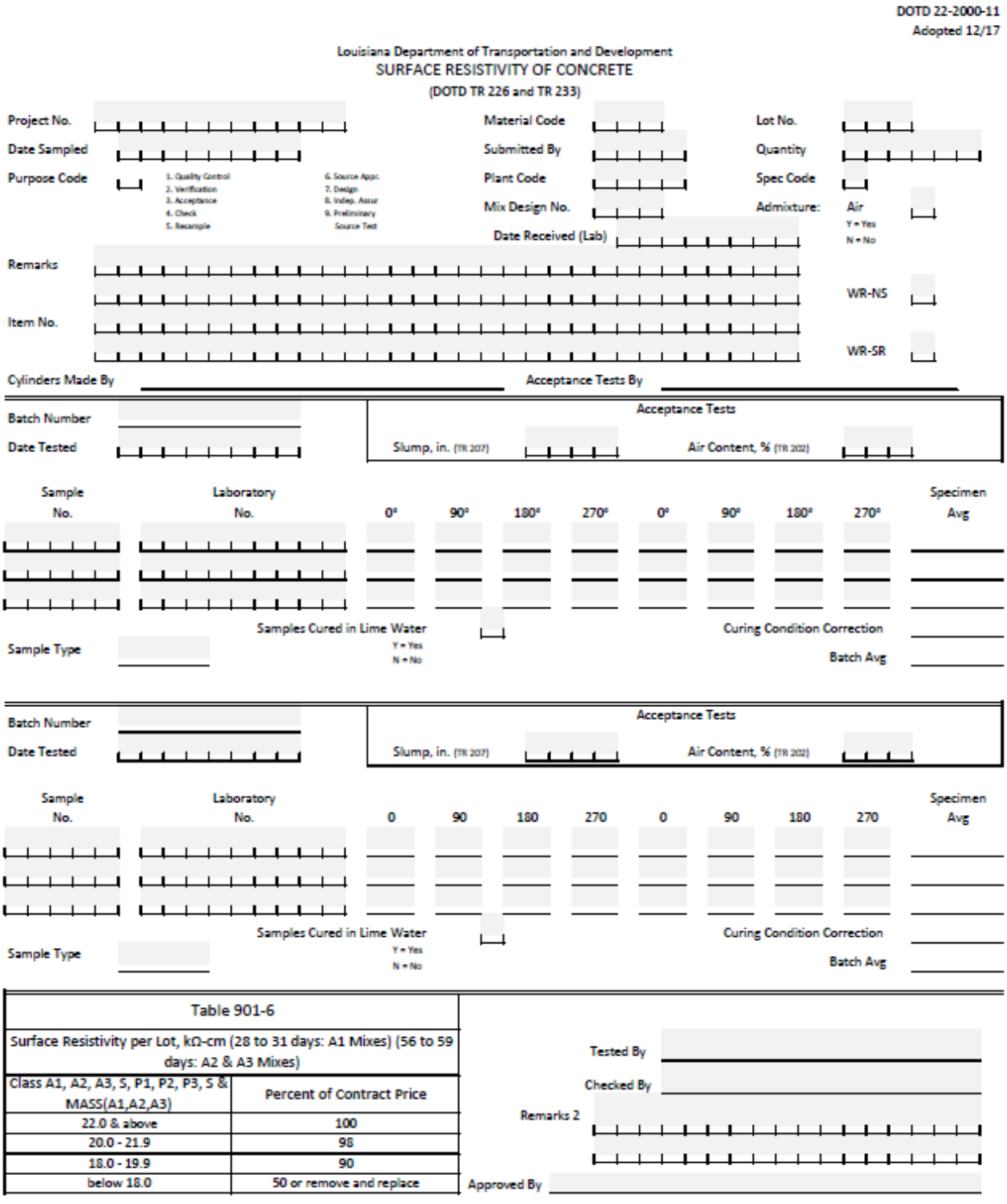
Chloride Ion Penetrability	Surface Resistivity Test	
	4 inch X 8 inch Cylinder (KOhm-cm) a=1.5	6 inch X 12 inch Cylinder (KOhm-cm) a=1.5
High	< 12.0	< 9.5
Moderate	12.0 – 21.0	9.5 - 16.5
Low	21.0 – 37.0	16.5 – 29.0
Very Low	37.0 – 254.0	29.0 – 199.0
Negligible	> 254.0	> 199.0

a = Wenner probe tip spacing

Table 1

Surface Resistivity (SR) Readings (KOhm-cm)									
Sample	**0°**	**90°**	**180°**	**270°**	**0°**	**90°**	**180°**	**270°**	**Average**
A	77.2	95.2	68.6	84.5	78.9	93.1	71.5	83.3	81.5
B	61.3	70.6	75.8	70.3	61.9	85.2	84.2	69.9	72.4
C	81.0	90.5	79.3	95.0	79.8	68.9	76.4	94.5	83.2
Set Average (KOhm-cm)									79.0
Curing Condition Correction (Multiply by x 1.1 lime tank or 1.0 for moist room)									79.0
Penetrability Based on Test									Very Low

Figure 5
Calculation Report



DOTD 22-2000-11
Adopted 12/17

Louisiana Department of Transportation and Development
SURFACE RESISTIVITY OF CONCRETE
(DOTD TR 226 and TR 233)

Project No.
Date Sampled
Purpose Code
1. Quality Control 2. Verification 3. Acceptance 4. Check 5. Resample 6. Source Appr. 7. Design 8. Indep. Assur 9. Preliminary Source Test
Material Code
Submitted By
Plant Code
Mix Design No.
Date Received (Lab)
Lot No.
Quantity
Spec Code
Admixture:
Air Y = Yes N = No
Remarks
WR-NS
Item No.
WR-SR
Cylinders Made By
Acceptance Tests By

Batch Number
Date Tested
Acceptance Tests
Slump, in. (TR 207)
Air Content, % (TR 202)

Sample No.	Laboratory No.	0°	90°	180°	270°	0°	90°	180°	270°	Specimen Avg

Samples Cured in Lime Water Y = Yes N = No
Curing Condition Correction
Sample Type
Batch Avg

Batch Number
Date Tested
Acceptance Tests
Slump, in. (TR 207)
Air Content, % (TR 202)

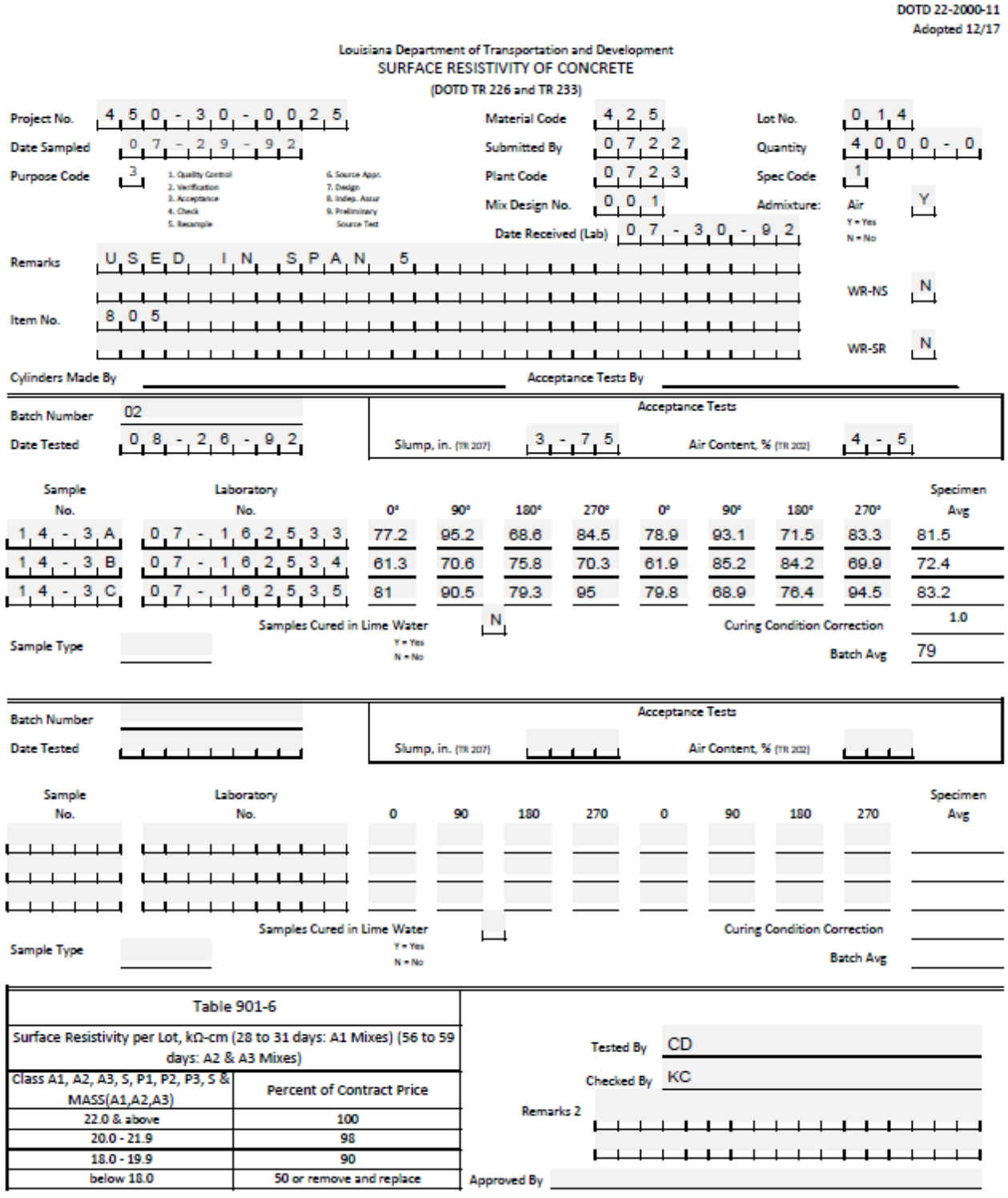
Sample No.	Laboratory No.	0	90	180	270	0	90	180	270	Specimen Avg

Samples Cured in Lime Water Y = Yes N = No
Curing Condition Correction
Sample Type
Batch Avg

Table 901-6	
Surface Resistivity per Lot, kΩ-cm (28 to 31 days: A1 Mixes) (56 to 59 days: A2 & A3 Mixes)	
Class A1, A2, A3, S, P1, P2, P3, S & MASS(A1,A2,A3)	Percent of Contract Price
22.0 & above	100
20.0 - 21.9	98
18.0 - 19.9	90
below 18.0	50 or remove and replace

Tested By
Checked By
Remarks 2
Approved By

Figure 6
Surface Resistivity of Concrete
Test Report



DOTD 22-2000-11
Adopted 12/17

Louisiana Department of Transportation and Development
SURFACE RESISTIVITY OF CONCRETE
(DOTD TR 226 and TR 233)

Project No. 450-30-0025
Date Sampled 07-29-92
Purpose Code 3 (1. Quality Control, 2. Verification, 3. Acceptance, 4. Check, 5. Resample, 6. Source Appr., 7. Design, 8. Indep. Assur, 9. Preliminary Source Test)
Material Code 425
Submitted By 0722
Plant Code 0723
Mix Design No. 001
Date Received (Lab) 07-30-92
Lot No. 014
Quantity 4000-0
Spec Code 1
Admixture: Air Y (Y = Yes, N = No)
Remarks USED IN SPAN 5
WR-NS N
Item No. 805
WR-SR N
Cylinders Made By
Acceptance Tests By

Batch Number 02
Date Tested 08-26-92
Acceptance Tests
Slump, in. (TR 207) 3-75
Air Content, % (TR 202) 4-5

Sample No.	Laboratory No.	0°	90°	180°	270°	0°	90°	180°	270°	Specimen Avg
14-3A	07-162533	77.2	95.2	68.6	84.5	78.9	93.1	71.5	83.3	81.5
14-3B	07-162534	61.3	70.6	75.8	70.3	61.9	85.2	84.2	69.9	72.4
14-3C	07-162535	81	90.5	79.3	95	79.8	68.9	76.4	94.5	83.2

Samples Cured in Lime Water N (Y = Yes, N = No)
Curing Condition Correction 1.0
Sample Type
Batch Avg 79

Batch Number
Date Tested
Acceptance Tests
Slump, in. (TR 207)
Air Content, % (TR 202)

Sample No.	Laboratory No.	0	90	180	270	0	90	180	270	Specimen Avg

Samples Cured in Lime Water (Y = Yes, N = No)
Curing Condition Correction
Sample Type
Batch Avg

Table 901-6	
Surface Resistivity per Lot, kΩ-cm (28 to 31 days: A1 Mixes) (56 to 59 days: A2 & A3 Mixes)	
Class A1, A2, A3, S, P1, P2, P3, S & MASS(A1,A2,A3)	Percent of Contract Price
22.0 & above	100
20.0 - 21.9	98
18.0 - 19.9	90
below 18.0	50 or remove and replace

Tested By CD
Checked By KC
Remarks 2
Approved By

Figure 7
Example of Filled
Surface Resistivity of Concrete Test Report