Addendum: Optimal Curing/Conditioning for Resistivity Specimens

There were several curing/conditioning methods used in this research program. Of these, the following are more commonly under consideration:

- Immersion in simulated pore solution
- Immersion in saturated lime water.
- Sealed curing or Sealed Cured followed by immersion in simulated pore solution

Conditioning specimens in simulated pore solution is the preferred option in AASHTO T 359, TP 119, and ASTM C1876. The intent is to reduce leaching of alkalis and progress towards attaining a steady-state between the simulated pore solution and the internal pore solution within the concrete specimen. ASTM C1876 requires that measurements should be recorded after allowing the readings to stabilize for 2 to 5 s. It is not possible to adhere to this requirement since the bulk resistivity measurements for specimens conditioned in pore solution do not stabilize and continue to increase with time. Recent work (Table A1) verified that bulk resistivity of three different mixtures (three specimens/mixture) increased between 8% and 20% (average 14%) when measured at 2 min. when compared to the measurement at 5 s. The specimens had been blotted off after removing from the pore solution as required in ASTM C1876 and were maintained between the plates over the 2-min duration.

As part of the evaluation, specimens conditioned in pore solution were washed under tap water for 45 s before the measurement. After this treatment, the bulk resistivity measurements were stable and did not show the drifting trend over a 2-min. duration. Testing variation based on the range of three specimens reduced from 13% before washing to 4% after washing. This additional evaluation suggests that washing the specimens conditioned in pore solution under tap water for 45 s will stabilize the measurements without causing an increasing drift with time and results in a lower testing variation. After washing, the bulk resistivity of specimens conditioned in pore solution increased between 20% and 44% (average 28%) for the three mixtures. However, the measured resistivity was still lower than the measured bulk resistivity of specimens conditioned in lime water. After washing, the measured surface resistivity of specimens conditioned in pore solution increased between 4% and 14% (average 9%) for the three mixtures, a much lower increase than the measured bulk resistivity. It is postulated the presence of the pore solution on the surface impacted the bulk resistivity measurements considerably. This is an artifact of the test method and not the concrete mixture and is therefore of concern. Further, in pore solution conditioning there is a potential for error in preparing the pore solution and its unknown impact on the resistivity results.

Specimens conditioned in lime water provided reliable measurements that did not drift with time and had a low level of testing variation. Mixtures were predictably classified for transport properties and consistent with classification with ASTM C1202 (RCPT). Based on all the curing conditions evaluated in this research project it is recommended that test specimens be immersed in lime water for 56 days after casting. If test results are desired at an earlier age the specimens can be subjected to accelerated curing - immersion in saturated lime water at 73°F for seven days followed by 21 days at 100°F in accordance with the accelerated curing methods of ASTM C1202, Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration (RCPT). This would be important for mixtures containing slower reacting pozzolans like fly ash.

There are several problems associated with subjecting specimens to sealed curing (Condition SC and SCB) and therefore they are not recommended for conditioning specimens for resistivity testing. If the specimens are sealed very well, it is surmised that consumption of water from the hydration reaction causes self-desiccation, which prevents an effective degree of hydration/degree of reaction of supplementary cementitious materials, especially with fly ash, and can inaccurately classify mixtures for lower chloride penetrability. Specimens subjected to condition SC and SCB were at a lower degree of saturation compared to specimens subjected to other conditions and this can result in higher measured resistivity. It is also suggested that because of the potential curtailment of reactivity of SCMs, the comparability of mixtures for transport properties will be uncertain. The specimen sealing process is likely to be inconsistent and is also a source of testing error.

There does not appear to be any advantage in measuring bulk resistivity on 2 in. disk specimens. If disk specimens are prepared for the RCPT or if disks are obtained as cores, bulk resistivity may be measured on these specimens. If comparisons need to be made to results from whole cylinders, based on a limited evaluation, it is recommended that the disk specimens be immersed in lime water and not in simulated pore solution.

Based on these findings, it is recommended that ASTM C1876 be modified to:

1. Incorporate lime water conditioning as an option

2. For the pore solution conditioning option, require that specimens be washed for 45 s in tap wash before the measurements

Table A1. Stability of Measured Resistivities

Spec ID[1]	**BR LW**		**BR PS**		**BR LW (AW)**		**BR PS (AW)**		**SR LW**	**SR PS**	**SR LW (AW)**	**SR PS (AW)**
	5 sec.	**2 min.**	**5 sec.**	**2 min.**	**5 sec.**	**2 min.**	**5 sec.**	**2 min.**	**5 sec.**	**5 sec.**	**5 sec.**	**5 sec.**
M1-1	139.5	140.2	100.4	111.5	137.2	137.2	114.3	114.0	106.5	103.0	100.8	103.1
M1-2	140.0	141.0	91.1	106.3	137.9	137.9	112.1	112.0	114.1	91.5	105.1	98.1
M1-3	146.9	148.1	91.1	105.6	144.6	144.6	115.3	115.3	115.3	90.1	111.1	95.6
M1-Avg.	142.2	143.1	94.2	107.8	139.9	139.9	113.9	113.7	111.9	94.9	105.7	98.9
M2-1	391.0	399.4	188.8	233.1	382.7	384.4	259.7	257.0	305.6	211.5	291.2	229.0
M2-2	347.6	355.9	160.6	194.0	344.2	344.2	242.8	238.8	285.5	188.8	268.6	216.1
M2-3	381.0	389.4	170.3	198.0	371.0	369.3	245.7	236.8	286.3	180.4		217.9
M2-Avg	373.2	381.6	173.2	208.4	366.0	366.0	249.4	244.2	292.5	193.6	279.9	221.0
M3-1	94.6	95.1	69.0	73.4	92.2	92.4	77.2	76.2	79.3	62.1	75.5	67.1
M3-2	101.6	102.3	60.0	66.2	99.8	100.1	75.9	75.2	79.9	59.9	74.2	64.0
M3-3	110.3	111.1	61.7	65.5	110.5	109.8	74.9	74.9	80.0	57.9		62.8
M3-Avg	102.2	102.8	63.6	68.3	100.8	100.8	76.0	75.4	79.7	60.0	74.9	64.6

[1]Specimen ID = M1, M2, M3 are 3 different mixtures. Specimens 1, 2, 3 correspond to 3 different specimens each conditioned either in lime water or pore solution.

BR=bulk resistivity; SR=Surface resistivity; PS=pore solution, LW=lime water; AW=After washing under tap water for 45 s. SR PS (AW) = Surface resistivity of specimen conditioned in pore solution measured after washing under tap water for 45 s.

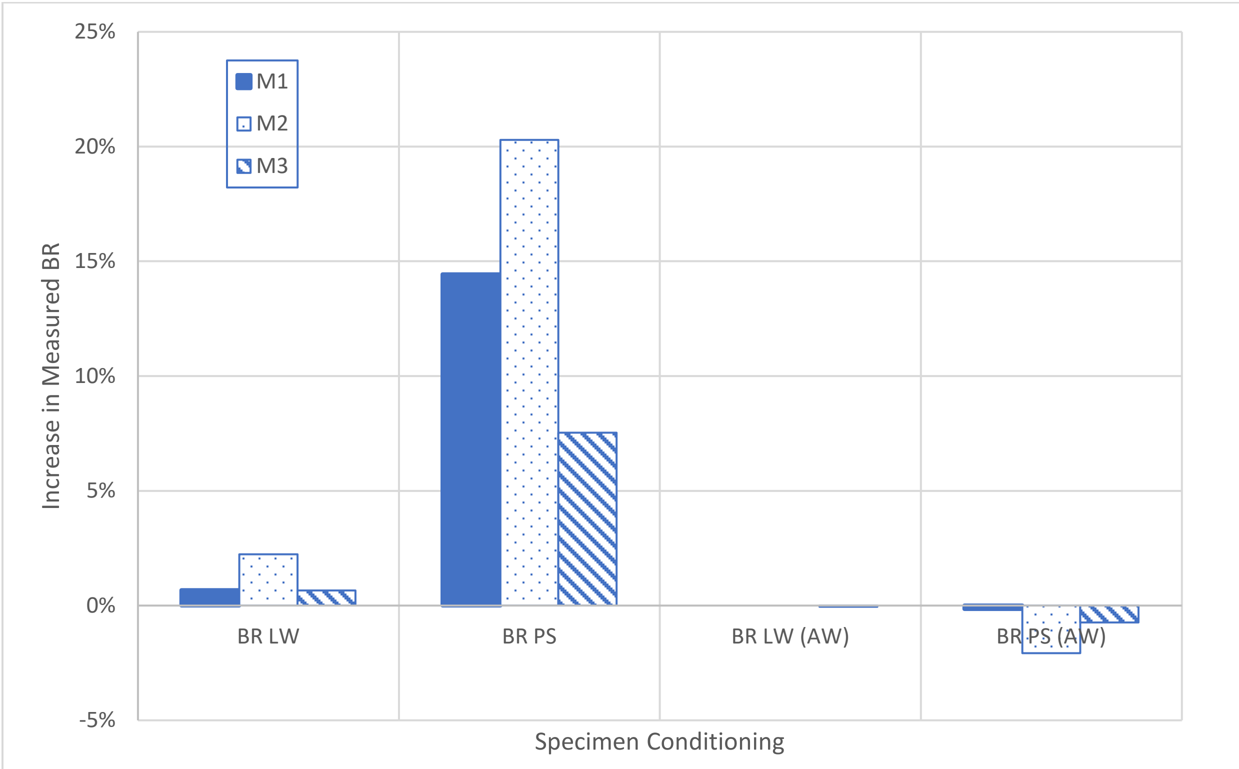

Fig. A1. Increase in Bulk Resistivity Measured at 2 min. when Compared to the Measurement at 5 s for the three Different Mixtures.