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# Going Past TDOT Specifications to Lower Concrete Permeability

## Part 2: Already Gone

### SERIES OVERVIEW

This four-part series of papers is an investigation of going past current Tennessee Department of Transportation (TDOT) Class D concrete specifications (1) to increase surface resistivity (SR). The investigation explores both exceeding limitations on currently approved TDOT supplementary cementing materials (SCMs) and using SCMs not currently approved by TDOT. All concrete mixtures used in the investigation met TDOT's Class D concrete plastic and hardened property requirements. Further, all concrete mixtures used in the investigation were constrained to meet the following criteria:

- Water-cementing materials-ratio (w/cm) = 0.37
- Design air content of 7%
- Total cementing materials = 620-lbs/CY
- Same brand and type of Portland cement
- Same source and size of coarse aggregate
- Same source of fine aggregate
- Fine aggregate as a percentage of total aggregate by volume (FA/TA) of approximately 38%
- Same three TDOT-approved chemical admixtures

These additional constraints should facilitate easier comparison of the concrete mixtures used. It is important to note that w/cm = 0.37 and FA/TA ~ 38% are not considered optimal, but rather these values met TDOT Class D concrete specifications and have worked well for the authors. The authors hope that mixture designers and concrete professionals find the information useful.

In Part 2, the effect of increasing the Grade 120 slag replacement dosage on SR is examined. Subsequent articles in the series will examine:

3. Life in the Fast Lane – SCM Dosages for Rapidly Reaching the SR “Very Low” Category
4. New Kid in Town – Ground Pumice as an SCM

### INTRODUCTION

The Slag Cement Association recommends slag substitution levels of 25 to 65% to lower concrete permeability (2). Lowering SR by “going past” current TDOT specifications for slag substitution, was the purpose of this paper. Therefore, the research team decided to start with a 35% slag substitution since it is the highest substitution currently allowed by TDOT Class D concrete specifications (1).

### MATERIALS AND PROCEDURE

TDOT-approved materials used in the study are shown in Table 1, column 1. The proportions of the seven mixtures used in the study (see Table 1) were determined through trial batching. After trialing, all seven mixtures met TDOT Class D concrete plastic and hardened property requirements. Table 2 shows TDOT requirements for minimum cementing materials, w/cm ratio, fine aggregate percentage by total aggregate volume, and allowable SCM replacement percentages. The first mixture, 35% Slag, met all Table 2 criteria, whereas mixtures 40% through 65% (indicated in red) met all criteria except maximum SCM replacement percentage. Six batches of each mixture were made and tested as per Table 3 criteria.

Figure 1 below shows two cylinders tested in compression from this series. The cylinder on the right is a fly ash specimen from the aforementioned portion of this series “Take It to the Limit.” The cylinder on the left is from this portion of the series on slag substitutions. Notice the green/blue color of the paste in the slag cylinder shown on the left. This paste color change is caused by the slag’s oxidation state of the sulfide sulphur compounds during its hydration with Portland cement (2). This brief effect often disappears when the PCC is exposed to the air and environment and leaves the PCC often whiter than ordinary PCC (2). However, the authors do not recommend the PCC to be used for aesthetic applications where the slag PCC will continuously be exposed to moist conditions since the greening has been known to return even after the forms have been removed (2).



Figure 1: Compressive Specimens - Slag (left), Fly Ash (right)

**TABLE 1. MIXTURES USED TO EVALUATE SLAG REPLACEMENT PERCENTAGE EFFECT**

|                                    | 35% SLAG | 40% SLAG | 45% SLAG | 50% SLAG | 55% SLAG | 60% SLAG | 65% SLAG |
|------------------------------------|----------|----------|----------|----------|----------|----------|----------|
| Type I PC, (lbs/CY)                | 403      | 372      | 341      | 310      | 279      | 248      | 217      |
| Grade 120 Slag, (lbs/CY)           | 217      | 248      | 279      | 310      | 341      | 372      | 403      |
| No. 57 Stone, (SSD lbs/CY)         | 1867     | 1870     | 1867     | 1865     | 1865     | 1866     | 1865     |
| River Sand, (SSD lbs/CY)           | 1128     | 1127     | 1126     | 1125     | 1124     | 1125     | 1125     |
| Water, (lbs/CY)                    | 229.5    | 229.5    | 229.5    | 229.5    | 229.5    | 229.5    | 229.5    |
| Design Percent Air                 | 7        | 7        | 7        | 7        | 7        | 7        | 7        |
| Air Entrainer, (oz/cwt)            | 0.35     | 0.60     | 0.60     | 0.60     | 0.60     | 0.60     | 0.75     |
| Mid-Range Water Reducer, (oz/cwt)  | 3.00     | 4.00     | 3.70     | 4.00     | 4.00     | 4.00     | 4.00     |
| High-Range Water Reducer, (oz/cwt) | 4.00     | 3.85     | 3.10     | 3.40     | 3.70     | 3.85     | 4.00     |

**TABLE 2: SLAG REPLACEMENT EFFECT WITH TDOT CLASS D PCC REQUIREMENTS**

| MIXTURE ID                                 | CEMENTING MATERIALS CONTENT, (LBS/CY) | W/CM RATIO   | PERCENT FINE AGGREGATE BY TOTAL AGGREGATE VOLUME | PERCENT GRADE 120 SLAG SUBSTITUTION (BY WEIGHT) FOR PC |
|--|---------------------------------------|--------------|--|--|
| 35   | 620                                   | 0.37         | 38   | 35   |
| 40   | 620                                   | 0.37         | 38   | 40   |
| 45   | 620                                   | 0.37         | 38   | 45   |
| 50   | 620                                   | 0.37         | 38   | 50   |
| 55   | 620                                   | 0.37         | 38   | 55   |
| 60   | 620                                   | 0.37         | 38   | 60   |
| 65   | 620                                   | 0.37         | 38   | 65   |
| TDOT 604.03<br>Class D PCC<br>Requirements | 620 minimum                           | 0.40 maximum | 44 maximum                                       | 35 maximum for Grade 100 or Grade 120 Slag             |

**TABLE 3. COMPARISON OF AASHTO ALLOWABLE COEFFICIENTS OF VARIATION**

| TEST METHOD                                 | FREQUENCY                         | SPECIMENS                                      |
|---|-----------------------------------|--|
| Compressive Strength, AASHTO T22 (3)        | 3 @ 28 and 56 days                | 4 x 8 cylinders                                |
| Surface Resistivity, AASHTO T 95-11 (4)     | 3 @ 7, 14, 21, 28, 42 and 56 days | 56-day compressive strength<br>4 x 8 cylinders |
| Hardened Concrete Absorption, ASTM C642 (5) | 3 @ 56 days                       | 3 x 6 cylinders                                |

**TABLE 4. 28-DAY COMPRESSIVE STRENGTH RESULTS AND DATA QUALITY (PSI)**

| % SLAG | BATCH 1 | BATCH 2 | BATCH 3 | BATCH 4 | BATCH 5 | BATCH 6 | MEAN | RANGE | ALLOWABLE RANGE |
|--------|---------|---------|---------|---------|---------|---------|------|-------|-----------------|
| 35     | 8150    | 8020    | 7730    | 8130    | 7860    | 7680    | 7928 | 470   | 1015            |
| 40     | 7010    | 7600    | 7190    | 7370    | 6950    | 7480    | 7267 | 650   | 930             |
| 45     | 7690    | 7730    | 7540    | 7710    | 7420    | 8000    | 7682 | 580   | 983             |
| 50     | 8940    | 8890    | 8040    | 8850    | 7370    | 7920    | 8335 | 1570  | 1067            |
| 55     | 7820    | 7690    | 7680    | 7590    | 7480    | 7900    | 7693 | 420   | 985             |
| 60     | 7270    | 7970    | 8100    | 7720    | 8150    | 8340    | 7925 | 1070  | 1014            |
| 65     | 7690    | 8250    | 8650    | 8540    | 8140    | 8060    | 8222 | 960   | 1052            |

# Going Past TDOT Specification to Lower Concrete Permeability

## Part 2: Already Gone

### RESULTS AND DATA QUALITY

Tables 4 and 5 show 28-day compressive strength and 56-day absorption results, respectively. The SR results are shown in Table 6 for 7, 14, 21, 28, 42 and 56 days. The acceptable range of the hardened properties results was determined by obtaining the standard deviation or coefficient of variation from the appropriate test method and multiplying by an ASTM C 670 factor for the number of test results (6). The multi-laboratory precision was used for the 4x8-inch cylinder results, since AASHTO T 22 states that the preparation of cylinders by different operators would probably increase the variation above multi-laboratory precision criteria (3). All hardened property test results met the acceptable precision criteria except the 50 and 60 percent slag compressive strengths (indicated in red in Table 4). Unfortunately, no precision criteria are available for hardened concrete absorptions after boiling.

### ANALYSIS OF RESULTS

#### Statistical Comparison of SR Results

The hypothesis test results of SR equality are represented in Tables 7 and 8 for the various mixtures at a given curing time and for the same mixture over various curing times, respectively. A statistical t-test with the assumption of unequal variances was performed. The estimated t-value was observed to be less than the critical t-value at the corresponding degree of freedom with a 5 percent significance level. The compared mixes that were deemed to have statistically equal SR values were denoted as NSD in Tables 7 and 8. When the estimated t-value exceeded the critical t-value at the corresponding degree of freedom with 5 percent significance level, the compared mixes were deemed to have significantly different SR values. Significantly different SR values were denoted as SD in Tables 7 and 8. The green shaded cells in Tables 7 and 8 indicate a statistically significant difference between SR values. Red shaded cells indicate there was not a statistically significant difference between compared SR values.

#### Graphical Comparison of SR Results

A graphical comparison of SR results for all slag percentages and curing times are shown in Figure 1, with the exception of those

for 21 and 42 days. The 21 and 42-day results were not included in the plot in an attempt to reduce congestion. Further, there were not significant differences between the 42-day SR results and the 56-day SR results in four out of the seven cases in Table 8. Figure 2 appears to show an increase in SR for all substitution percentages for every curing time increment increase. The coded results of the statistical analysis shown in Table 8 supports this observation in the vast majority of cases (99 of 105 comparisons) with only six exceptions. All six cases in which the difference between compared SR values were not statistically significant involved comparisons with the 21 or 42-day time increments.

Figure 2 appears to show an increase in SR for most of the substitution percentages for increases in percent slag replacement. The coded results of the statistical analysis shown in Table 7 supports this observation in the vast majority of cases (121 of 126 comparisons) with only five exceptions. All five exceptions involved either 40 or 45% slag substitutions. Further, three of the five exceptions involved comparisons between the 40 and 45% slag substitutions alone.

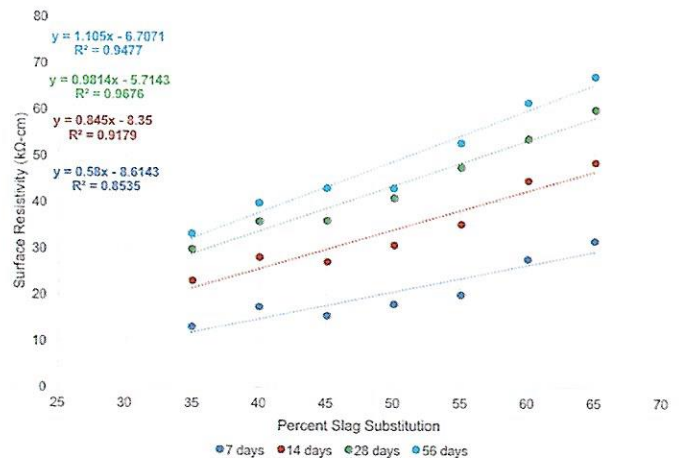


Figure 2: Effect of Slag Substitution on Surface Resistivity

TABLE 5. 56-DAY ABSORPTION AFTER BOILING RESULTS AND RANGES (%)

| % SLAG | BATCH 1       | BATCH 2 | BATCH 3 | BATCH 4 | BATCH 5 | BATCH 6 | MEAN | RANGE |
|--------|---------------|---------|---------|---------|---------|---------|------|-------|
| 35     | Not Available |         |         |         |         |         |      |       |
| 40     | 5.46          | 5.43    | 5.45    | 5.21    | 5.30    | 5.13    | 5.33 | 0.33  |
| 45     | 5.01          | 5.03    | 5.11    | 5.02    | 5.08    | 4.95    | 5.03 | 0.16  |
| 50     | 4.87          | 4.89    | 5.13    | 5.06    | 5.10    | 5.15    | 5.03 | 0.28  |
| 55     | 4.64          | 4.58    | 4.54    | 4.54    | 4.46    | 4.61    | 4.56 | 0.18  |
| 60     | 5.56          | 5.30    | 5.24    | 5.58    | 5.08    | 5.15    | 5.32 | 0.50  |
| 65     | 5.84          | 5.63    | 5.47    | 5.52    | 5.63    | 5.59    | 5.61 | 0.37  |

**TABLE 6. SURFACE RESISTIVITY RESULTS AND DATA QUALITY**

| SLAG SUBSTITUTION (%) | TEST AGE (DAYS) | MEAN RESULT (K $\Omega$ -CM) | RANGE OF RESULTS (K $\Omega$ -CM) | ALLOWABLE RANGE OF RESULTS (K $\Omega$ -CM) |
|-----------------------|-----------------|------------------------------|-----------------------------------|---|
| 35                    | 7               | 13.0                         | 1.5                               | 6.5   |
| 35                    | 14              | 23.0                         | 1.4                               | 11.5  |
| 35                    | 21              | 24.8                         | 3.7                               | 12.4  |
| 35                    | 28              | 29.8                         | 1.4                               | 14.9  |
| 35                    | 42              | 32.9                         | 4.2                               | 46.4  |
| 35                    | 56              | 33.1                         | 1.9                               | 16.5  |
| 40                    | 7               | 17.3                         | 0.8                               | 8.6   |
| 40                    | 14              | 28.0                         | 2.7                               | 14.0  |
| 40                    | 21              | 32.4                         | 4.9                               | 16.2  |
| 40                    | 28              | 35.8                         | 3.0                               | 17.9  |
| 40                    | 42              | 36.6                         | 2.7                               | 18.3  |
| 40                    | 56              | 39.8                         | 2.8                               | 19.9  |
| 45                    | 7               | 15.4                         | 1.1                               | 7.7   |
| 45                    | 14              | 27.1                         | 1.5                               | 13.6  |
| 45                    | 21              | 32.6                         | 2.5                               | 16.3  |
| 45                    | 28              | 36.0                         | 2.0                               | 18.0  |
| 45                    | 42              | 40.1                         | 2.8                               | 20.0  |
| 45                    | 56              | 42.9                         | 2.2                               | 21.5  |
| 50                    | 7               | 17.8                         | 1.7                               | 8.9   |
| 50                    | 14              | 30.7                         | 2.0                               | 15.4  |
| 50                    | 21              | 36.6                         | 4.4                               | 18.3  |
| 50                    | 28              | 40.9                         | 3.3                               | 20.58                                       |
| 50                    | 42              | 42.9                         | 1.6                               | 21.5  |
| 50                    | 56              | 42.9                         | 1.8                               | 21.4  |
| 55                    | 7               | 19.9                         | 2.3                               | 10.0  |
| 55                    | 14              | 35.2                         | 3.2                               | 17.6  |
| 55                    | 21              | 44.1                         | 2.1                               | 22.1  |
| 55                    | 28              | 47.5                         | 2.8                               | 23.7  |
| 55                    | 42              | 51.2                         | 1.8                               | 25.6  |
| 55                    | 56              | 52.7                         | 6.8                               | 26.4  |
| 60                    | 7               | 27.6                         | 3.1                               | 13.8  |
| 60                    | 14              | 44.7                         | 3.9                               | 22.3  |
| 60                    | 21              | 50.6                         | 3.8                               | 25.3  |
| 60                    | 28              | 53.6                         | 5.5                               | 26.8  |
| 60                    | 42              | 59.3                         | 5.1                               | 29.7  |
| 60                    | 56              | 61.4                         | 4.8                               | 30.7  |
| 65                    | 7               | 31.7                         | 1.7                               | 15.8  |
| 65                    | 14              | 48.6                         | 2.7                               | 24.3  |
| 65                    | 21              | 58.4                         | 4.3                               | 29.2  |
| 65                    | 28              | 59.9                         | 4.4                               | 30.0  |
| 65                    | 42              | 64.0                         | 2.9                               | 32.0  |
| 65                    | 56              | 67.0                         | 2.6                               | 33.5  |

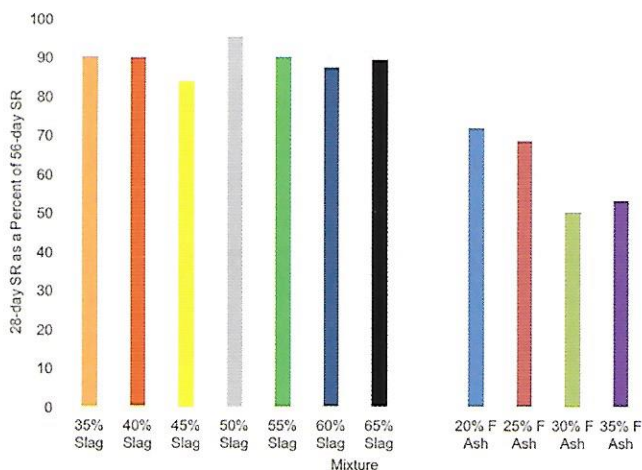
# Going Past TDOT Specification to Lower Concrete Permeability

## Part 2: Already Gone

### Rate of Increase of SR Results

The curing time required to reach various SR chloride permeability categories for all seven slag mixtures in the study are shown in Table 9. Class F fly ash mixtures from Part 1 of the study are shown as a comparison. By 56 days, all slag mixtures, except 35%, achieved the “Very Low” SR chloride permeability category. Meanwhile, no Class F fly ash mixture reached the “Very Low” SR category within the allotted time (56 days). Further, the slag mixtures reached the “Moderate” and “Low” SR chloride permeability categories sooner than the Class F fly ash mixtures.

Figure 3 shows 28-day mean SR results expressed as a percentage of 56-day mean SR results. The slag mixtures achieved a very high percentage (83-96%) of their 56-day SR by 28 days. However, Class F fly ash substitution mixtures achieved a much lower percentage (50-72%) of their 56-day SR by 28 days. It appears that in the short term (0-56 days) in which most state DOTs are interested in, slag mixtures are superior to Class F fly ash mixtures in SR for the given parameters. Slag mixtures achieve much lower chloride permeability levels (higher SR results) overall and much sooner when compared to Class F fly ash mixtures.



**Figure 3: 28-day Surface Resistivity as a Percentage of 56-day Surface Resistivity**

### Compressive Strength Analysis

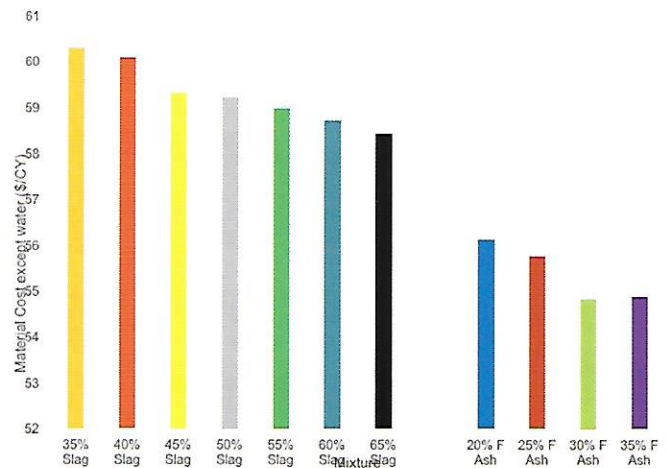
The 28-day compressive strength results that are shown in Table 4 all exceed the TDOT Class D concrete specification requirement by at least 3200-psi. The results for the seven mixtures in the study appear to have no discernable trend as percent slag substitution increases.

### Absorption Analysis

The hardened concrete absorption after boiling results shown in Table 5 are adequate but not excellent. The mean absorption after boiling result for the 55% slag mixture meets high performance concrete criteria. High performance concrete has absorption after boiling requirements of less than 5.0% (7). The results for the other five mixtures range from 5.03 to 5.61% and appear to have no discernable trend as percent slag substitution increases.

### Material Cost Analysis

Table 10 shows material cost assumptions for concrete materials except water. Calculations using Table 1 mixture proportions and Table 10 cost assumptions were used to generate Figure 4. Class F fly ash mixtures costs from Part 1 of the study are shown for comparison. The slag mixtures all have a higher cost than the Class F fly ash mixtures. However, using the TDOT-approved 25% Class F fly ash mixture as a reference, slag mixtures ranged from 3.3 to 8.1% higher in cost. Therefore, material cost would not be a major factor in mixture choice.



**Figure 4: Material Cost Comparisons**

### Cautionary Statement

Some of the mixtures are close to current TDOT mixtures. However, some of the mixtures with very high slag substitution are considerably diverse when compared to current TDOT Class D mixtures. Caution should be taken with these higher substitution mixtures by thorough verification in the laboratory prior to use. If the laboratory investigations are deemed acceptable, an experimental field placement should be placed and monitored for further verification.

**TABLE 7: STATISTICAL ANALYSIS COMPARING DIFFERENT MIXTURES AT A GIVEN CURING TIME**

|           | 7 DAYS | 14 DAYS | 21 DAYS | 28 DAYS | 42 DAYS | 56 DAYS |
|-----------|--------|---------|---------|---------|---------|---------|
| 35 vs. 40 | SD     | SD      | SD      | SD      | SD      | SD      |
| 35 vs. 45 | SD     | SD      | SD      | SD      | SD      | SD      |
| 35 vs. 50 | SD     | SD      | SD      | SD      | SD      | SD      |
| 35 vs. 55 | SD     | SD      | SD      | SD      | SD      | SD      |
| 35 vs. 60 | SD     | SD      | SD      | SD      | SD      | SD      |
| 35 vs. 65 | SD     | SD      | SD      | SD      | SD      | SD      |
| 40 vs. 45 | SD     | NSD     | NSD     | NSD     | SD      | SD      |
| 40 vs. 50 | NSD    | SD      | SD      | SD      | SD      | SD      |
| 40 vs. 55 | SD     | SD      | SD      | SD      | SD      | SD      |
| 40 vs. 60 | SD     | SD      | SD      | SD      | SD      | SD      |
| 40 vs. 65 | SD     | SD      | SD      | SD      | SD      | SD      |
| 45 vs. 50 | SD     | SD      | SD      | SD      | SD      | NSD     |
| 45 vs. 55 | SD     | SD      | SD      | SD      | SD      | SD      |
| 45 vs. 60 | SD     | SD      | SD      | SD      | SD      | SD      |
| 45 vs. 65 | SD     | SD      | SD      | SD      | SD      | SD      |
| 50 vs. 55 | SD     | SD      | SD      | SD      | SD      | SD      |
| 50 vs. 60 | SD     | SD      | SD      | SD      | SD      | SD      |
| 50 vs. 65 | SD     | SD      | SD      | SD      | SD      | SD      |
| 55 vs. 60 | SD     | SD      | SD      | SD      | SD      | SD      |
| 55 vs. 65 | SD     | SD      | SD      | SD      | SD      | SD      |
| 60 vs. 65 | SD     | SD      | SD      | SD      | SD      | SD      |

**TABLE 8: STATISTICAL ANALYSIS COMPARING SR RESULTS OF THE SAME MIXTURE OVER VARIOUS CURING TIMES**

|                | 35% | 40% | 45% | 50% | 55% | 60% | 65% |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| 7 vs. 14 days  | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 7 vs. 21 days  | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 7 vs. 28 days  | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 7 vs. 42 days  | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 7 vs. 56 days  | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 14 vs. 21 days | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 14 vs. 28 days | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 14 vs. 42 days | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 14 vs. 56 days | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 21 vs. 28 days | SD  | SD  | SD  | SD  | SD  | SD  | NSD |
| 21 vs. 42 days | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 21 vs. 56 days | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 28 vs. 42 days | SD  | NSD | SD  | SD  | SD  | SD  | SD  |
| 28 vs. 56 days | SD  | SD  | SD  | SD  | SD  | SD  | SD  |
| 42 vs. 56 days | NSD | SD  | SD  | NSD | NSD | NSD | SD  |

## Going Past TDOT Specification to Lower Concrete Permeability

### Part 2: Already Gone

#### CONCLUSIONS

Compared to Class F fly ash mixtures, slag mixtures achieve much lower chloride permeability levels (higher SR) and achieve them much sooner. If this were a race, the slag mixtures are already gone.

#### DISCLAIMER

The opinions expressed herein are those of the authors and not necessarily the opinions of the Tennessee Department of Transportation or the Tennessee Concrete Association (TCA).

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**TABLE 9: CURING TIMES REQUIRED TO REACH SURFACE RESISTIVITY CHLORIDE PERMEABILITY CATEGORIES**

| MIXTURE             | MODERATE (SR≥12)<br>(2000≤RCP≤4000) | LOW (SR≥21)<br>(1000≤RCP≤2000) | VERY LOW (SR≥37)<br>(100≤RCP≤1000) |
|---------------------|-------------------------------------|--------------------------------|------------------------------------|
| 35% Grade 120 Slag  | 7 days                              | 14 days                        | Did not reach                      |
| 40% Grade 120 Slag  | 7 days                              | 14 days                        | 56 days                            |
| 45% Grade 120 Slag  | 7 days                              | 14 days                        | 42 days                            |
| 50% Grade 120 Slag  | 7 days                              | 14 days                        | 28 days                            |
| 55% Grade 120 Slag  | 7 days                              | 14 days                        | 21 days                            |
| 60% Grade 120 Slag  | < 7 days                            | 7 days                         | 14 days                            |
| 65% Grade 120 Slag  | < 7 days                            | 7 days                         | 14 days                            |
| 20% Class F Fly Ash | 28 days                             | Did not reach                  | Did not reach                      |
| 25% Class F Fly Ash | 28 days                             | Did not reach                  | Did not reach                      |
| 30% Class F Fly Ash | 28 days                             | 42 days                        | Did not reach                      |
| 35% Class F Fly Ash | 28 days                             | 42 days                        | Did not reach                      |

**TABLE 10: COST ASSUMPTIONS**

| COMPONENT                             | ASSUMED COST DELIVERED TO READY MIX PRODUCER |
|---------------------------------------|--|
| Type I PC, (\$/ton)                   | 110.00                                       |
| Class F Fly Ash, (\$/ton)             | 30.00  |
| Grade 120 Slag, (\$/ton)              | 85.00*                                       |
| No. 57 Limestone, (\$/ton)            | 18.00  |
| River Sand, (\$/ton)                  | 15.00  |
| Air Entrainer, (\$/gallon)            | 4.50   |
| Mid-Range Water Reducer, (\$/gallon)  | 8.50   |
| High-Range Water Reducer, (\$/gallon) | 12.00  |

\*plus freight