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Within-Lab Precision of Accelerated-Cure Indirect Tensile Strength

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WITHIN-LAB PRECISION OF ACCELERATED-CURE INDIRECT TENSILE STRENGTH

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INTRODUCTION

Understanding the precision of a test method aids in evaluating the expected level of agreement of repeated test results for like materials. Every test is subject to some level of variation; these variations are due to both random errors and any systematic errors that result in imprecision.

Research Project 0-7027 developed an accelerated mix design procedure for cement-treated base materials, with attention to test turnaround time and inclusion of moisture conditioning. This project found that the indirect tensile (IDT) strength method with a 72-hour accelerated cure (where specimens are sealed at 104°F) followed by 24-hour moisture conditioning through water submersion (IDT_3) provided the most suitable basis for mix design of the accelerated-cure methods investigated. The recommended IDT_3 method used 4-inch-diameter, 2-inch-tall specimens, compacted in the Superpave gyrator compactor.

This product presents results quantifying the within-lab precision of the IDT_3 method. The results from this product can assist in evaluating the expected level of agreement between repeated tests of like materials when tested within a single laboratory.

METHODS

Researchers used existing triplicate measurements of IDT_3 for seven different materials, each treated with four levels of cement. Researchers used statistical tests to determine how to best pool variances across materials and/or across cement contents to determine the within-lab standard deviation. The within-lab standard deviation serves as the estimate of precision. Due to the relatively small sample size in the initial data analyzed (three replicates for each material-cement level combination), researchers performed additional experimentation fabricating and testing six replicates for IDT_3 with four different materials and three different cement contents. Researchers used these data with six replicates to revise the within-lab precision estimates.

RESULTS FROM INITIAL PRECISION ESTIMATE

Table 1 through Table 4 present the data for developing the initial precision estimates according to cement content. All materials used the same Type I/II cement source, except for the FM 205 New Base, which used Type I/II cement from the actual materials supplier to the construction project.

Table 1. Data with 2 Percent Cement.

Material	IDT_3 (psi) Replicate 1	IDT_3 (psi) Replicate 2	IDT_3 (psi) Replicate 3	Average IDT_3 (psi)	Variance
Crushed Concrete—FM 1155	79.8	55.9	43.1	59.6	346.0
FM 1746 Salvage Base	43.4	51.3	42.4	45.7	24.0
FM 1746 New Base	58.5	59.7	47.4	55.2	46.4
SH 18 Salvage Base	62.5	66.0	74.3	67.6	37.0
FM 205 New Base	44.7	29.1	40.4	38.0	65.1
FM 205 Salvage Base	49.9	46.5	48.0	48.1	2.8
FM 205 New Base—Project Cement	40.6	26.9	37.5	35.0	51.6

Table 2. Data with 3 Percent Cement.

Material	IDT_3 (psi) Replicate 1	IDT_3 (psi) Replicate 2	IDT_3 (psi) Replicate 3	Average IDT_3 (psi)	Variance
Crushed Concrete—FM 1155	54.3	61.8	65.3	60.5	31.3
FM 1746 Salvage Base	67.5	61.9	78.1	69.2	68.1
FM 1746 New Base	89.2	70.8	103.8	87.9	273.8
SH 18 Salvage Base	82.3	75.9	86.6	81.6	29.2
FM 205 New Base	67.8	48.1	64.2	60.0	110.4
FM 205 Salvage Base	47.7	58.8	63.7	56.8	67.4
FM 205 New Base—Project Cement	56.7	56.0	52.4	55.0	5.3

Table 3. Data with 4 Percent Cement.

Material	IDT_3 (psi) Replicate 1	IDT_3 (psi) Replicate 2	IDT_3 (psi) Replicate 3	Average IDT_3 (psi)	Variance
Crushed Concrete—FM 1155	82.9	83.0	86.6	84.2	4.5
FM 1746 Salvage Base	75.9	100.3	107.4	94.5	271.7
FM 1746 New Base	113.9	101.8	115.8	110.5	58.2
SH 18 Salvage Base	94.9	78.9	70.5	81.4	153.8
FM 205 New Base	83.5	89.0	72.5	81.6	70.6
FM 205 Salvage Base	66.7	63.9	74.3	68.3	28.8
FM 205 New Base—Project Cement	94.1	89.1	66.8	83.4	212.6

Table 4. Data with 6 Percent Cement.

Material	IDT_3 (psi) Replicate 1	IDT_3 (psi) Replicate 2	IDT_3 (psi) Replicate 3	Average IDT_3 (psi)	Variance
Crushed Concrete—FM 1155	105.1	107.9	99.3	104.1	19.1
FM 1746 Salvage Base	114.1	121.4	100.1	111.8	116.7
FM 1746 New Base	144.6	170.9	180.0	165.2	338.1
SH 18 Salvage Base	123.6	127.8	86.1	112.5	527.4
FM 205 New Base	152.7	136.7	121.7	137.0	240.4
FM 205 Salvage Base	99.6	88.3	103.3	97.1	60.9
FM 205 New Base—Project Cement	97.5	119.7	135.6	117.6	366.7

Four different statistical tests were conducted to evaluate the equality of variance across the 28 different material-cement combinations. Three of these tests resulted in insufficient evidence to conclude the variances were unequal, while one test indicated the variances might be unequal. However, the statistical tests assume a minimum of five replicates, while the underlying data only contained three replicates.

Four different statistical tests were also conducted to evaluate the equality of variance across the seven different materials at each cement content. The results from these tests showed the data did not have sufficient evidence to conclude unequal variances across the different materials for a given cement content.

Only equal variances should be pooled, so based on the results from the statistical tests, researchers developed initial within-lab precision estimates using the within-lab standard

deviation by cement level. Table 5 presents this result and shows, as expected, generally increasing average IDT_3 and increasing variability with increasing cement content.

Table 5. Initial Within-Lab Precision Estimate.

Cement Content (Percent)	Average IDT_3 (psi)	Pooled Within-Lab Standard Deviation (psi)
2	49.9	9.0
3	67.3	9.1
4	86.3	10.7
6	120.8	15.4

REVISED PRECISION ESTIMATE

Based on the relatively small number of replicates (three) in the underlying data from which researchers developed Table 5, they conducted additional testing, performing six replicates for IDT_3. This additional testing used four different materials and three different cement contents. Researchers used cement contents of 2, 4, and 6 percent to capture the expected range of potential cement contents in practice. Due to availability, researchers used a single source of Type IL cement. Table 6 through Table 8 present the IDT_3 results by cement content.

Table 6. Replicate Results from 2 Percent Cement.

Material	IDT_3 (psi) Result 1	IDT_3 (psi) Result 2	IDT_3 (psi) Result 3	IDT_3 (psi) Result 4	IDT_3 (psi) Result 5	IDT_3 (psi) Result 6
FM 205 New Base	29.4	28.5	28.2	24.2	23.8	29.7
FM 2097	62.4	70.9	64.0	64.4	69.3	62.1
SH 18	58.8	65.6	68.3	69.1	55.2	59.0
FM 1746 New Base	31.6	30.9	27.6	28.4	24.2	33.4

Table 7. Replicate Results from 4 Percent Cement.

Material	IDT_3 (psi) Result 1	IDT_3 (psi) Result 2	IDT_3 (psi) Result 3	IDT_3 (psi) Result 4	IDT_3 (psi) Result 5	IDT_3 (psi) Result 6
FM 205 New Base	59.3	65.6	74.1	54.5	70.2	65.4
FM 2097	92.9	108.9	99.8	93.4	94.8	87.2
SH 18	89.2	94.0	91.2	78.3	74.3	81.5
FM 1746 New Base	76.7	83.3	82.2	82.4	66.1	82.5

Table 8. Replicate Results from 6 Percent Cement.

Material	IDT_3 (psi) Result 1	IDT_3 (psi) Result 2	IDT_3 (psi) Result 3	IDT_3 (psi) Result 4	IDT_3 (psi) Result 5	IDT_3 (psi) Result 6
FM 205 New Base	126.3	124.8	98.9	108.9	102.2	93.9
FM 2097	116.0	125.5	90.9	93.2	97.3	99.89
SH 18	97.9	100.9	85.8	88.1	100.7	98.1
FM 1746 New Base	139.3	95.2	110.4	111.7	151.9	153.3

Figure 1 illustrates the pooled standard deviation with average IDT_3 and with cement content. Figure 1 illustrates generally increasing standard deviation with increasing strength and with increasing cement content.

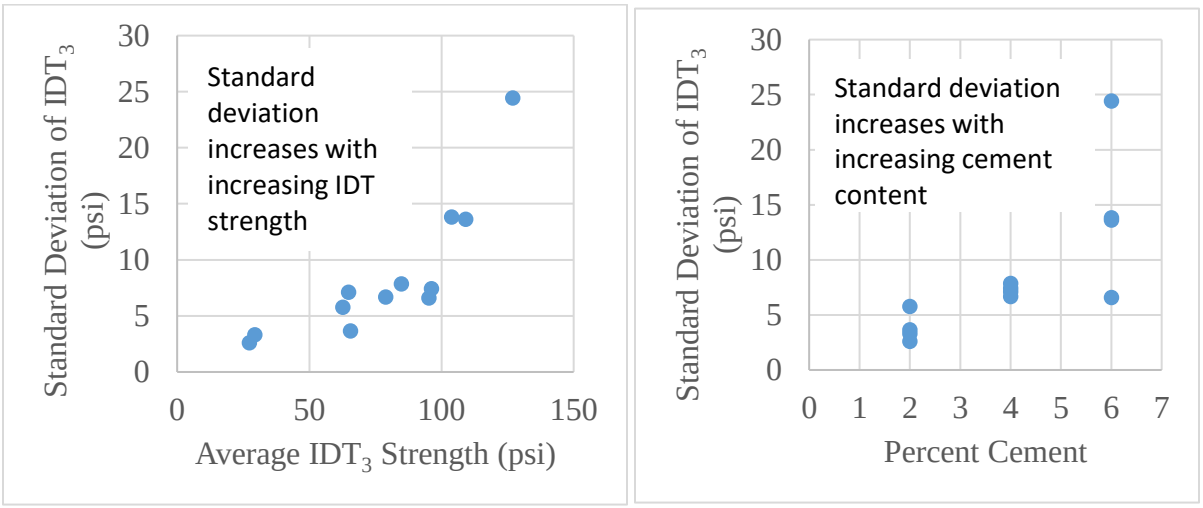

Figure 1. Pooled Standard Deviation with Average IDT_3 (Left) and Cement Content (Right).

Table 9 presents the revised precision estimates. The results in Table 9 should be more accurate estimates of actual precision than those in Table 2 because of the additional number of replicates included in the underlying data used to develop Table 9.

Table 9. Revised Within-Lab Precision Estimate.

Cement Content (Percent)	Average IDT_3 (psi)	Pooled Within-Lab Standard Deviation (psi)
2	46.2	4.0
4	81.2	7.3
6	108.8	15.9

CONCLUSIONS AND RECOMMENDATIONS

Understanding the precision of a test method helps identify when data from any replicate test specimen may be suspect. This document described developing a preliminary estimate of the precision of the accelerated-cure IDT strength of cement-treated bases. The within-lab standard deviation quantifies the precision and generally increased with strength and increasing cement content. Data showed the within-lab standard deviation ranged from 4 to about 16 psi, with the lowest standard deviation at 2 percent cement, and the highest standard deviation at 6 percent cement. While this result should be considered preliminary since multiple labs did not perform testing for development of this precision estimate, these values should prove useful to evaluate the reasonableness of test data. The difference between any two replicates within a single lab when tested for IDT_3 should generally not exceed 2.8 times the standard deviation. While this work did not include multiple labs, and thus could not estimate between-lab precision, the expected precision between labs will not be better than the within-lab precision.

Future work should be considered to perform a full interlaboratory study of the accelerated-cure mix design method for cement-treated bases developed in this research project. Such an effort, while significant, provides a more extensive set of underlying data and, through its inclusion of multiple laboratories, also results in an estimate of between-lab precision.