STATE OF FLORIDA

PRECISION STATEMENTS FOR THE IGNITION OVEN USING PLANT-PRODUCED MIX

Research Report
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ABSTRACT

The current precision values given in Florida Method FM 5-563 for the determination of asphalt binder content by use of the ignition oven are based on laboratory fabricated specimens with known binder contents and gradations *(1)*. This study was conducted to determine precision values for both asphalt binder content and gradation using plant produced mix. This approach encompasses the variability associated with: 1) differences in an asphalt mixture within the truck bed, 2) sampling the truck, 3) splitting the mix into sample size, 4) differences in ignition oven equipment, and 5) variability associated with the operator. The current precision values only include the variability associated with items four and five and the variability associated with batching and mixing laboratory prepared specimens. Twelve laboratories tested nine different mixtures containing a wide variety of gradations and aggregate types. The results of the study indicate that the allowable difference between two test results for asphalt binder content should be no greater than 0.32% within-lab and 0.44% between-labs. New graphs were developed for the within-lab and between-lab precision values for aggregate gradation. Separate graphs were developed for dense-graded Superpave mixtures and open-graded friction course mixtures since it was determined that allowable tolerances differ significantly for each type of mixture.

INTRODUCTION

The current precision values for the determination of asphalt binder content by use of the ignition oven were developed through a multi-laboratory study conducted in 1997 *(1)*. The study used laboratory-fabricated samples, which were batched and mixed at the Florida Department of Transportation (FDOT) State Materials Office (SMO). The gradation and asphalt binder content were known for all of the samples. Through this approach, both the precision and accuracy of the equipment/test method could be determined.

One potential drawback to using a precision statement based on laboratory fabricated samples is that during construction contractors and project personnel sample and test plant produced mix and the results are then compared to see if they meet established precision values. Plant produced mix has more potential sources of variability than laboratory fabricated samples. The potential sources of variability in plant produced mix include: 1) differences in an asphalt mixture within the truck bed, 2) sampling the truck, 3) splitting the mix into sample size, 4) differences in ignition oven equipment, and 5) variability associated with the operator. When testing laboratory fabricated samples the major sources of variability are the equipment and operator. There is a small variability associated with batching the samples. Therefore, it would be more appropriate in a production situation to have precision values for asphalt binder content and gradation based on plant-produced mix rather than on laboratory fabricated samples.

EXPERIMENTAL PLAN

The experimental plan was set up per the guidelines of ASTM E 691-92 *(2)* and ASTM C 802-94 *(3)*. These practices establish the minimum number of laboratories, materials, replicates, etc. and provide the framework for the statistical analysis necessary to determine the within and between-laboratory precision values.

Twelve laboratories participated in the round robin study; five FDOT District laboratories, the FDOT State Materials Office and six contractor laboratories. A survey was taken prior to the start of the study to determine exactly how many ovens of each brand were in use in the State of Florida for FDOT projects. Results of the survey indicated that almost all of the ovens were manufactured by either Thermolyne or Troxler. The ratio of Thermolyne ovens to Troxler ovens was approximately 5:1. There was also one oven in use manufactured by Hogentogler and one by Carbolite. Based on the quantities and brands of ovens in use, it was decided that of the twelve participating laboratories, ten would use Thermolyne ovens and two would use Troxler ovens.

In addition to the twelve laboratories participating in the round robin study, one additional laboratory of a local contractor was included in the testing for informational purposes only in order to evaluate a demonstration unit of the Troxler infrared New Technology Oven (NTO). The data from this oven was not included in the final precision values. The Troxler NTO was evaluated to see how it compared with the current ovens in use with respect to the average asphalt binder content determined and the within-laboratory precision obtained.

Nine different mixtures were sampled and tested: six Superpave mixtures and three open-graded friction courses (OGFC). All of the OGFC mixtures were of FDOT designation FC-5. **Table 1** lists the nine mixtures, the type of mixture, and the predominate aggregate types used in each mixture.

Each individual mixture was sampled at the asphalt plant from the truck bed by the Quality Control Technician present at the time of sampling. This approach would allow for the variability associated with the person sampling the mixture. The mix was not sampled from either the beginning or end of production. The mix was sampled from three locations within the truck bed. Three shovelfulls of mix (one from each location) were used to fill a large silicone-lined box. Each box weighed approximately 30 to 40 lbs. when full. A maximum of only 18 lbs. from each box would be needed for testing. A total of 15 boxes were filled and numbered in the sequence they were filled. Thirteen of the boxes were then randomly distributed to the laboratories and two were kept as spares. Instructions and worksheets were given to all of the laboratories to detail the splitting and testing procedures and the format for reporting the data (see **Appendix**).

The individual laboratories were instructed to heat the mix for three hours in an oven at 300 °F and then roll and quarter the mix per FDOT method FM 1-T 168. For each mix, four replicate samples were split out to the appropriate weight as stated in FM 5-563 for the type of mix. The weight to be split out was written on the boxes. Participating laboratories were not given any information about the mix type, gradation, asphalt binder content, etc. The four samples were individually tested for asphalt binder content per FM 5-563 and gradation analysis on the post-ignition material per FM 1-T 030. The laboratories were instructed to have a single operator perform all testing for a particular mix using the same oven. However, it was encouraged to have different mixes tested by different operators using different ovens where available. This practice is encouraged in ASTM E 691-92 to better capture the true variability of the procedure. However, most of the laboratories used only one oven since that was all that was available.

The total number of samples tested was 468 (13 laboratories x 9 mixtures x 4 replicates). However, only 432 samples (12 laboratories x 9 mixtures x 4 replicates) were to be included in the precision value calculations because the thirteenth laboratory used the non-approved infrared oven. All the data was sent to the SMO for analysis. The actual number of samples used in the precision calculations was slightly less than 432 due to outliers, some missing data, etc. and will be discussed in subsequent sections.

It should be noted that laboratory #4 tested mixtures #8 and #9 but subsequently lost the data. Therefore, data analysis performed on mixtures #8 and #9 are based on four replicates each from 11 laboratories.

DATA ANALYSIS

ASTM E 691-92 thoroughly details the layout, analysis, and interpretation of the data in order to determine the within-lab and between-lab precision values. The procedure is the same whether examining % asphalt binder content, gradation, or any other test parameter. One important aspect of the procedure is the calculation of the consistency “k” and “h” statistics for the determination of data that may be deemed outliers.

The k statistic is a measure of one laboratory’s within-lab variability compared to all of the laboratories combined. k values are positive numbers with the value of “one” representing the average within-lab variability. A k value greater than "one" indicates higher within-lab variability compared to all of the laboratories combined whereas a k value less than "one" indicates less within-lab variability compared to all of the laboratories combined.

The h statistic is an indicator of how one laboratory's test average, for a given material, compares with the average of all the other laboratories. h values can be either positive or negative values with zero representing a laboratory average equal to the overall multi-laboratory average. A positive h value for a particular laboratory represents a higher average than the overall average and a negative value represents a lower average than the overall average. Critical values for both k and h statistics are given in ASTM E 691-92 at the 0.5% two-tailed significance level and are a function of the number of laboratories and number of replicates.

Asphalt Binder Content

General Information/Correction Factors

Each mix was analyzed separately and a tabular summary of the data is presented in **Tables 2-10.** The asphalt binder contents shown are those given from the printouts of the ignition ovens. No correction factor was applied to the binder content values. Correction factors have no influence on the within-lab variability. With respect to the calculation of the between-lab precision values, correction factors would have an affect on the results if each oven used had a different correction factor for each mix. However, for practical purposes, FDOT policy is to use only one correction factor for a particular mix, regardless of the oven used for testing. This correction factor is determined at the mix design stage by the contractor, verified by the FDOT, and is used for all subsequent testing provided there have been no changes to the mix design.

Given a constant correction factor for a particular mix, regardless of the oven used, the between-lab variability would be unaffected. Therefore, a correction factor was not applied to the binder content values for the data analysis.

Within-lab Statistical Analysis

The within-lab k statistical values organized by mixture number are presented in **Figures 1 and 2**. The critical k-value is 1.96 for mixtures 1-7 and 1.94 for mixtures 8 and 9 since only data from 11 laboratories were included for these two mixtures. These values are exceeded only once in mix #3, laboratory #5 (1.99 vs. 1.96). An alternative approach to examining high within-lab variances is presented in ASTM C802. The ratio of the largest within-lab variance for a particular mixture to the sum of the variances of all of the laboratories for that mixture is compared to a critical value. **Table 11** shows the ratios and critical values for mixtures 1-9. Examination of the data shows that the calculated ratio for mixture #3, laboratory #5 is 0.3296, which slightly exceeds the critical value of 0.3264. This agrees with the approach presented in ASTM E691. Though the critical values were exceeded, it was decided not to exclude mix #3, laboratory #5 data for two reasons: 1) the critical value was barely exceeded and 2) ASTM E 691-92 states that if no clerical, sampling, or procedural errors were uncovered, then the data should be retained. The within-lab k statistical values organized by laboratory number are presented in **Figures 3 - 5**. Examination of the data indicates that laboratories #3 and #5 tended to have above average within-lab variability compared to the other laboratories.

Between-lab Statistical Analysis

The between-lab h statistical values organized by mixture number are presented in **Figures 6 and 7**. The critical h-value is 2.38 for mixtures 1-7 and 2.34 for mixtures 8 and 9 since only data from 11 laboratories were included for these two mixtures. Examination of the data shows that the critical values were not exceeded in any case. The between-lab h statistical values organized by laboratory number are presented in **Figures 8 - 10**. **Figure 10** shows the average h statistic in terms of the absolute value of h (since h can be either positive or negative). A large absolute value of h would indicate that the mean values for binder content for a particular laboratory were further (either greater or less) from the overall means for all laboratories. It should be noted that laboratories #11 and #12 had the highest values for the absolute value of h. Both of these laboratories used Troxler ignition ovens. This would indicate that the correction factors would be slightly different for the Troxler ovens compared to the Thermolyne ovens. Whether the correction factors would be less or more is unknown since the exact binder contents of the mixtures is unknown.

Examination of Variances

Table 12 is a variance table showing mixture #, mixture type, within-lab variances, components of between-lab variances and the between-lab variances. Examination of the within-lab variance data shows relative consistency among the variance values despite the mixture type and % binder content. It should be noted that the two 9.5mm Superpave mixtures, the finest mixtures tested, have variance values slightly less than the other coarser mixtures tested. This should be expected because fine mixtures would tend to segregate less during sampling and splitting resulting in more consistent samples.

Examination of the between-lab variance data also shows relative consistency except for mixture #2, which has a relatively high variance value compared to the other eight mixtures. This is better observed graphically in **Figure 11**. Note that the component of between-lab variance and the between-lab variance for mixture #2 are much larger than the other values. Since the outlier evaluation procedures discussed previously did not identify any outliers for mixture #2, the data was examined in a different manner. ASTM C802 recommends plotting the % binder contents for each laboratory against the mixture # to determine if each laboratory is following the same trend for each mixture. Examination of **Figure 12** shows, that for mixture #2, laboratories #5 and #9 do not follow the same trend as the other 10 laboratories. The average binder contents for laboratories #5 and #9 are 4.70% and 4.76% respectively, which is over 0.5% less than the minimum average % binder content for the remaining 10 laboratories. This 0.5% difference is greater than the spread of the binder contents for all of the other ten laboratories, which range from 5.33% to 5.73%. It was decided to eliminate the data from laboratories #5 and #9 for mixture #2. Mixture #2 data was then reanalyzed and is shown in **Table 13**. The modified variance table is shown in **Table 14**. Also shown in **Table 14** are the standard deviations and coefficients of variation for each mixture. The elimination of laboratories #5 and #9 from mixture #2 resulted in a between-lab variance of 0.0270 for mixture #2, which is comparable to the other mixtures. It should be noted that both laboratories #5 and #9 did have relatively high h statistical values, though they did not exceed the critical h value. The two reasons those laboratories were not deemed outliers is because the significance level in ASTM E691 is set at a low value of 0.5% and for mixture #2, the standard deviation of the mean binder content values was the highest of all the mixtures (0.3097), see **Table 3**. Therefore, a large deviation from the mean binder content value, as occurred for laboratories #5 and #9, will not necessarily show up as statistically invalid. This is why the graphical presentation of the data, **Figure 12**, was necessary to determine the reason for the high variance. It should also be noted that in the random distribution of the boxes of mixture #2, laboratory #5 received box #10 and laboratory #9 received box #11. Perhaps these two boxes were sampled incorrectly or that area in the truck bed where the mix came from was not uniform.

Precision Statement

From a practical point of view it is desirable not to have multiple precision statements dependent on factors such as aggregate size, aggregate type, and binder content. After eliminating the outlying data from laboratories #5 and #9 from mixture #2, the resulting within-lab and between-lab variances for all of the mixtures are similar, regardless of any of the factors just mentioned. This is desirable because there will only be one precision value for the maximum allowable difference between two test samples for the within-lab testing situation and one precision value for the between-lab testing situation.

Because the final number of laboratories used in the data analysis was not the same for each mixture tested, the within-lab and between-lab variances cannot be simply averaged in order to determine the standard deviations necessary to calculate the precision values. The variances have to be pooled: the within-lab variances pooled according to the number of samples tested for each mixture and the between-lab samples pooled according to the number of laboratories for each mixture. **Table 15** shows the final pooled variances and pooled standard deviations. The total number of samples used in the data analysis was 416 (6 mixtures x 12 laboratories x 4 samples + 1 mixture x 10 laboratories x 4 samples + 2 mixtures x 11 laboratories x 4 samples).

The precision values are calculated by multiplying the pooled within-lab and between-lab standard deviations by $2\sqrt{2}$ to determine the acceptable range between two test results. **Table 16** summarizes the standard deviations and acceptable precision values for asphalt content determination using the ignition oven and plant produced mix. The within-lab precision is 0.32% and the between-lab precision is 0.44%.

Aggregate Gradation

General Information

A gradation analysis was performed on all of the post-ignition oven samples per FDOT test method FM 1-T 030. This procedure requires washing and drying the sample prior to sieving. The standard Superpave sieves were used (19.0 mm, 12.5, 9.5, #4, 8, 16, 30, 50 100, and 200). The results of the statistical analysis are to be used to develop new within-lab and between-lab variability graphs to replace those in FM 1-T 030 which were developed in the 1980's and are based on a different method of extraction of the asphalt binder from the aggregate.

Statistical Analysis

For each sieve size per mixture, a table was set up similar to **Tables 2-10** that included the h & k statistical analysis for the determination of outliers. Since there are 10 sieve sizes and nine mixtures, this resulted in 90 tables that will not be included in this report for brevity. **Table 17** contains the gradation data for the #16 sieve of mixture #1 and is included in this report to serve as an example. Each table contains the gradation data, the h & k statistics, and the calculation of within-lab and between-lab standard deviations for that particular mixture and sieve size. There was some gradation data that was determined to be outliers per the h & k statistical analysis. The following data was removed from the analysis: laboratory #11 from mixture #2, laboratory #1 from mixture #5, and laboratory #3 from mixture #7. After removing the outlying data, the statistics were recalculated to determine the modified within-lab and between-lab standard deviations. The total number of samples used in the data analysis was 420 (6 mixtures x 12 laboratories x 4 samples + 3 mixtures x 11 laboratories x 4 samples). Each of the standard deviations was multiplied by $2\sqrt{2}$ to determine the acceptable range between two test results for each sieve size for each mixture. This resulted in 180 data points to be used to develop the new within-lab and between-lab variability graphs. The data is summarized in **Table 18**.

Variability Graphs

The precision data was then plotted and regression lines fitted to the data to develop the new variability graphs. The data was plotted in several formats: 1) Superpave and OGFC mixtures combined, 2) Superpave mixtures only, and 3) OGFC mixtures only. The current FM 1-T 030 data was also plotted on the same graph. **Figures 13 and 14** are the within-lab and between-lab variability graphs respectively, and show the individual data points, regression lines and R^2 values. Examination of **Figures 13 and 14** show that the precision has improved over the current FM 1-T 030 values when examining all of the data combined and the Superpave data alone. The OGFC mixtures had precision values much higher than the Superpave mixtures and current FM 1-T 030 values indicating a need to have two separate graphs; one for Superpave mixtures and one for OGFC mixtures. The R^2 values for all of the regression lines were reasonable considering the wide range of mixture types and aggregate types. It should be noted that the current FM 1-T 030 graphs were constructed in the same manner but were based on fine graded Marshall mixtures and did not contain data for OGFC mixtures, which were not in use at the time.

Troxler Infrared New Technology Oven (NTO)

General

As mentioned in the **Experimental Plan**, one contractor had a Troxler NTO and agreed to test each mixture so that the data could be compared to the conventional ignition ovens. At the time this study was conducted, this was the only known NTO in Florida. Some of the potential advantages of an infrared oven versus a conventional oven are: 1) less aggregate degradation, 2) less emissions produced, and 3) quicker initial heat-up time. It is acknowledged that firm conclusions cannot be drawn about the NTO from the following analysis simply due to the fact that only one NTO was used in the comparison against twelve conventional ignition ovens.

Asphalt Binder Content

The asphalt binder content was analyzed with respect to mean value and within-lab standard deviation. Because only one NTO was utilized, no analysis of between-lab variability could be conducted. For each mixture, the average binder content of the four NTO test samples was determined and compared to the overall average of the twelve laboratories using the conventional ignition oven. This data is presented in **Figure 15**. **Table 19** is a summary for all of the laboratories, including the NTO. **Table 19** shows the differences between a particular laboratory's mean binder content for a particular mixture and the overall mean for all of the laboratories combined for that same mixture. The average difference and the standard deviation of the differences were then calculated from the data. From **Figure 15** and **Table 19**, it is apparent that the NTO was reading on the same mean level as the conventional ovens (0.00% average difference) and the standard deviation of differences, 0.13%, was only slightly higher than the average standard deviation of differences for the conventional ignition ovens, 0.11%.

With respect to within-lab variability, the variance of the NTO was compared to the pooled variance of the conventional ovens for each mixture. This data is shown in **Table 20** and **Figure 16**. In eight of the nine mixtures, the variance was higher for the infrared oven compared to the conventional ovens. The F-statistic was calculated for each mixture to determine which of the NTO variances were statistically greater than the conventional oven variances. The null hypothesis is $s^2_{conventional} = s^2_{NTO}$ and the alternative hypothesis is $s^2_{NTO} > s^2_{convnetional}$. The alpha level is 0.05. **Table 21** shows the results of the statistical analysis. The F-statistic for mixtures two and seven exceeded the critical F-statistic, indicating that the NTO variance for those two mixtures was statistically higher than the variance for the conventional ovens.

<u>Aggregate Gradation</u>

For each mixture and each sieve size, the gradations for the conventional ovens and NTO were compared. **Table 22** shows the gradations for each mixture and each sieve for both oven types and the difference between the two gradations (conventional – NTO). A positive difference indicates the conventional oven gradation was finer and a negative difference indicates the NTO gradation was finer. The average difference for each sieve is shown at the bottom of **Table 22**. Examination of the data shows that, in general, the NTO gradation was slightly finer. The biggest average difference was –0.4% for the #4 sieve. The #100 and #200 sieves had average differences of zero.

CONCLUSIONS / RECOMMENDATIONS

1. Current precision values contained in Florida test method FM 5-563 for asphalt binder content using the ignition oven were based on laboratory fabricated samples. These values do not include the variability associated with sampling and testing plant-produced asphalt mixtures. New precision values were developed in this study that include the sources of variability associated with sampling and testing plant-produced mixtures. The new precision values for the maximum difference between two test results for asphalt binder content should be 0.32% and 0.44% for within-lab and between-lab tests, respectively. These new values should be added to FM 5-563 with the stipulation that they should be used for plant-produced mixture only. The current values of 0.13% and 0.21% should remain in FM 5-563 with the stipulation that they should be used for laboratory fabricated samples, such as occurs during mix design and research.

2. New aggregate gradation precision graphs were developed for within-lab and between-lab tests and the results indicate that the precision has improved slightly compared to the existing graphs contained in Florida test method FM 1-T 030. Furthermore, there is a significant difference in the precision of dense-graded Superpave mixtures compared to open-graded friction course mixtures (FC-5). The Superpave mixtures have much smaller precision values than the open-graded friction course mixtures. It is recommended that the existing graphs in FM 1-T 030 be replaced with separate graphs for Superpave and open-graded friction course mixtures.

3. A preliminary evaluation was conducted of Troxler's new NTO ignition oven. With respect to mean binder content and aggregate gradation, the NTO compared very well to the

conventional ignition ovens. One potential concern is with respect to within-lab variability. In eight of the nine mixtures, the within-lab variance of the NTO was higher than the conventional ovens. However, the variances of only two of those eight mixtures were deemed to be statistically different. The concern with high variability is that mean values are not typically used during production testing. When only one test result from one oven is compared to one test result from a different oven, differences could be large due to the high variability of one or both of the ovens. If other NTO ignition ovens exhibit the same characteristics of the NTO that was tested in this study, then there will be a greater chance that test results using an NTO may not meet the new precision values for asphalt binder content.

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Table 1 – Mixture Information

Mix ID	Mix Type	Major Aggregate Type(s)
1	SP 12.5 Fine	West Central FL Limestone, RAP
2	OGFC, FC-5	Georgia Granite
3	SP 12.5 Coarse	AL Limestone, GA Granite, N FL Limestone
4	OGFC, FC-5	South FL Limestone
5	SP 9.5 Coarse	South FL Limestone, RAP
6	SP 19.0 Fine	Georgia Granite, N FL Limestone, RAP
7	SP 19.0 Coarse	Georgia Granite, RAP
8	OGFC, FC-5	Georgia Granite
9	SP 9.5 Coarse	South FL Limestone, GA Granite, RAP

Table 2 – Asphalt Binder Content Data for Mixture #1

Laboratory	Test Results, x									
Number	1	2	3	4	Average	s	d	s^2	h	k
1	6.62	6.63	6.59	6.38	6.56	0.1179	0.14	0.013900	1.1083	1.0348
2	6.46	6.42	6.39	6.25	6.38	0.0913	-0.04	0.008333	-0.3174	0.8012
3	6.06	6.21	6.37	6.44	6.27	0.1699	-0.15	0.028867	-1.2136	1.4912
4	6.33	6.53	6.43	6.61	6.48	0.1215	0.06	0.014767	0.4566	1.0666
5	6.16	6.11	6.47	6.28	6.26	0.1601	-0.16	0.025633	-1.3358	1.4052
6	6.62	6.62	6.42	6.66	6.58	0.1083	0.16	0.011733	1.3120	0.9507
7	6.50	6.43	6.56	6.43	6.48	0.0627	0.06	0.003933	0.4973	0.5505
8	6.42	6.49	6.39	6.29	6.40	0.0830	-0.02	0.006892	-0.1748	0.7286
9	6.14	6.27	6.31	6.32	6.26	0.0829	-0.16	0.006867	-1.2950	0.7273
10	6.36	6.46	6.54	6.53	6.47	0.0830	0.05	0.006892	0.4362	0.7286
11	6.46	6.32	6.15	6.36	6.32	0.1292	-0.10	0.016692	-0.7858	1.1339
12	6.61	6.43	6.60	6.68	6.58	0.1061	0.16	0.011267	1.3120	0.9316
				Average	6.42			0.155775		
				$s_{x\ bar}$	0.122745					
								Critical h value =	2.38	
				s_r =	0.113935			Critical k value=	1.96	
				$(s_R)^*$ =	0.157488					
				s_R =	0.157488					

Table 3 - Asphalt Binder Content Data for Mixture #2

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	5.47	5.28	5.60	5.41	5.44	0.1329	0.10	0.017667	0.3215	1.1236
2	5.51	5.09	5.26	5.44	5.33	0.1888	-0.02	0.035633	-0.0498	1.5958
3	5.80	5.61	5.78	5.72	5.73	0.0854	0.39	0.007292	1.2497	0.7219
4	5.61	5.55	5.52	5.44	5.53	0.0707	0.19	0.005000	0.6120	0.5978
5	4.78	4.74	4.74	4.53	4.70	0.1132	-0.64	0.012825	-2.0756	0.9574
6	5.44	5.60	5.73	5.57	5.59	0.1190	0.24	0.014167	0.7896	1.0062
7	5.31	5.31	5.45	5.36	5.36	0.0660	0.02	0.004358	0.0552	0.5581
8	5.35	5.21	5.25	5.51	5.33	0.1337	-0.01	0.017867	-0.0336	1.1300
9	4.84	4.91	4.51	4.79	4.76	0.1754	-0.58	0.030758	-1.8657	1.4826
10	5.36	5.47	5.37	5.49	5.42	0.0670	0.08	0.004492	0.2650	0.5666
11	5.35	5.29	5.33	5.45	5.36	0.0681	0.01	0.004633	0.0471	0.5754
12	5.59	5.51	5.42	5.69	5.55	0.1150	0.21	0.013225	0.6847	0.9722
				Average	5.34			0.167917		
				sx bar	0.309752					
								Critical h value =	2.38	
				s_r =	0.118292			Critical k value=	1.96	
				$(s_R)^*$ =	0.326253					
				s_R =	0.326253					

Table 4 - Asphalt Binder Content Data for Mixture #3

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	6.47	6.62	6.25	6.56	6.48	0.1622	0.01	0.026300	0.1203	1.2567
2	6.47	6.38	6.36	6.28	6.37	0.0780	-0.09	0.006092	-0.7253	0.6048
3	6.41	6.37	6.47	6.54	6.45	0.0741	-0.01	0.005492	-0.1066	0.5743
4	6.42	6.33	6.48	6.26	6.37	0.0971	-0.09	0.009425	-0.7253	0.7523
5	6.16	6.12	6.54	6.62	6.36	0.2566	-0.10	0.065867	-0.8284	1.9888
6	6.40	6.45	6.62	6.46	6.48	0.0954	0.02	0.009092	0.1822	0.7389
7	6.40	6.33	6.35	6.60	6.42	0.1236	-0.04	0.015267	-0.3334	0.9575
8	6.35	6.16	6.40	6.41	6.33	0.1163	-0.13	0.013533	-1.0759	0.9015
9	6.37	6.35	6.38	6.41	6.38	0.0250	-0.08	0.000625	-0.6840	0.1937
10	6.67	6.56	6.46	6.32	6.50	0.1489	0.04	0.022158	0.3472	1.1535
11	6.69	6.50	6.79	6.75	6.68	0.1284	0.22	0.016492	1.8321	0.9952
12	6.65	6.82	6.60	6.74	6.70	0.0974	0.24	0.009492	1.9971	0.7550
				Average	6.46			0.199833		
				$s_{x\ bar}$	0.121215					
								Critical h value =	2.38	
				s_r =	0.129046			Critical k value=	1.96	
				$(s_R)^*$ =	0.164871					
				s_R =	0.164871					

Table 5 - Asphalt Binder Content Data for Mixture #4

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	7.13	7.04	6.86	7.10	7.03	0.1209	-0.08	0.014625	-0.5714	0.8755
2	6.99	7.12	7.29	7.10	7.13	0.1240	0.01	0.015367	0.0998	0.8974
3	7.31	7.41	7.43	7.36	7.38	0.0538	0.27	0.002892	1.9317	0.3893
4	7.23	7.61	7.21	7.30	7.34	0.1857	0.23	0.034492	1.6415	1.3446
5	7.17	7.22	7.01	6.68	7.02	0.2437	-0.09	0.059400	-0.6620	1.7645
6	7.30	6.94	6.90	6.92	7.02	0.1907	-0.10	0.036367	-0.6983	1.3806
7	7.01	7.24	7.18	7.24	7.17	0.1087	0.06	0.011825	0.4081	0.7873
8	7.09	6.79	6.87	6.82	6.89	0.1357	-0.22	0.018425	-1.5871	0.9827
9	7.06	7.02	7.17	7.09	7.09	0.0635	-0.03	0.004033	-0.1905	0.4598
10	6.89	6.96	7.17	7.13	7.04	0.1340	-0.07	0.017958	-0.5351	0.9702
11	7.25	7.16	7.04	7.25	7.18	0.0995	0.06	0.009900	0.4625	0.7203
12	7.11	6.98	7.09	7.10	7.07	0.0606	-0.04	0.003667	-0.2993	0.4384
				Average	7.11			0.228950		
				$s_{x\ bar}$	0.13783					

Critical h value = 2.38

Critical k value= 1.96

s_r = 0.138127

$(s_R)^*$ = 0.182501

s_R = 0.182501

Table 6 - Asphalt Binder Content Data for Mixture #5

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	6.95	6.86	6.90	6.90	6.90	0.0369	0.02	0.001358	0.4635	0.5319
2	6.83	7.03	6.90	6.91	6.92	0.0830	0.04	0.006892	0.7487	1.1981
3	6.80	7.06	6.95	6.88	6.92	0.1103	0.04	0.012158	0.8437	1.5914
4	6.92	6.90	6.83	6.94	6.90	0.0479	0.02	0.002292	0.3684	0.6909
5	7.02	6.79	6.80	6.89	6.88	0.1066	0.00	0.011367	-0.0594	1.5387
6	6.91	6.89	6.87	6.72	6.85	0.0866	-0.03	0.007492	-0.5823	1.2492
7	6.81	6.84	6.80	6.80	6.81	0.0189	-0.07	0.000358	-1.2478	0.2732
8	6.96	7.04	6.90	7.08	7.00	0.0806	0.12	0.006500	2.2222	1.1636
9	6.87	6.83	6.86	6.84	6.85	0.0183	-0.03	0.000333	-0.5348	0.2635
10	6.76	6.80	6.81	6.88	6.81	0.0499	-0.07	0.002492	-1.2478	0.7204
11	6.84	6.92	6.79	6.79	6.84	0.0614	-0.04	0.003767	-0.8200	0.8858
12	6.87	6.89	6.92	6.80	6.87	0.0510	-0.01	0.002600	-0.1545	0.7359
				Average	6.88			0.057608		
				$s_{x\ bar}$	0.052593					

Critical h value = 2.38

Critical k value= 1.96

s_r = 0.069287

$(s_R)^*$ = 0.079791

s_R = 0.079791

Table 7 - Asphalt Binder Content Data for Mixture #6

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	6.17	6.21	6.19	6.18	6.19	0.0171	-0.01	0.000292	-0.1298	0.1300
2	6.28	6.28	6.35	6.44	6.34	0.0759	0.14	0.005758	1.3781	0.5777
3	6.21	5.93	6.40	6.19	6.18	0.1931	-0.02	0.037292	-0.1801	1.4701
4	6.28	6.09	6.20	6.03	6.15	0.1117	-0.05	0.012467	-0.5068	0.8500
5	6.41	6.25	6.19	6.01	6.22	0.1652	0.01	0.027300	0.1466	1.2578
6	6.07	5.84	6.00	6.14	6.01	0.1284	-0.19	0.016492	-1.8891	0.9776
7	6.12	6.14	6.40	6.31	6.24	0.1352	0.04	0.018292	0.4231	1.0296
8	6.12	6.24	6.14	6.03	6.13	0.0862	-0.07	0.007425	-0.6828	0.6560
9	6.13	6.17	6.01	6.06	6.09	0.0714	-0.11	0.005092	-1.0849	0.5432
10	6.21	6.19	6.29	6.14	6.21	0.0624	0.01	0.003892	0.0712	0.4749
11	6.47	6.41	6.23	6.01	6.28	0.2069	0.08	0.042800	0.8000	1.5749
12	6.46	6.24	6.20	6.56	6.37	0.1731	0.16	0.029967	1.6545	1.3178
				Average	6.20			0.207067		
				$s_{x\ bar}$	0.099475					

		Critical h value =	2.38
s_r =	0.13136	Critical k value=	1.96
$(s_R)^*$ =	0.15112		
s_R =	0.15112		

Table 8 - Asphalt Binder Content Data for Mixture #7

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	4.98	4.76	4.97	4.96	4.92	0.1053	0.17	0.011092	1.2296	1.0151
2	4.63	4.46	4.54	4.48	4.53	0.0763	-0.22	0.005825	-1.5470	0.7356
3	4.74	4.42	4.64	4.47	4.57	0.1486	-0.18	0.022092	-1.2622	1.4326
4	4.74	4.84	4.84	4.83	4.81	0.0486	0.07	0.002358	0.4820	0.4681
5	4.80	4.72	4.86	4.90	4.82	0.0783	0.08	0.006133	0.5354	0.7548
6	4.72	4.67	4.76	4.88	4.76	0.0896	0.01	0.008025	0.0905	0.8634
7	4.76	4.62	4.90	4.73	4.75	0.1153	0.01	0.013292	0.0549	1.1112
8	4.62	4.71	4.59	4.68	4.65	0.0548	-0.09	0.003000	-0.6749	0.5279
9	4.65	4.59	4.50	4.74	4.62	0.1010	-0.12	0.010200	-0.8885	0.9734
10	4.82	4.74	4.65	4.56	4.69	0.1124	-0.05	0.012625	-0.3723	1.0830
11	5.14	5.06	4.99	4.81	5.00	0.1407	0.26	0.019800	1.8170	1.3562
12	4.87	4.96	4.77	4.68	4.82	0.1214	0.08	0.014733	0.5354	1.1699
				Average	4.74			0.129175		
				$s_{x\ bar}$	0.14046					

		Critical h value =	2.38
s_r =	0.10375	Critical k value=	1.96
$(s_R)^*$ =	0.16674		
s_R =	0.16674		

Table 9 - Asphalt Binder Content Data for Mixture #8

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	5.84	5.99	5.74	5.99	5.89	0.1225	0.16	0.015000	1.0035	1.0703
2	5.64	5.81	5.74	5.60	5.70	0.0954	-0.03	0.009092	-0.1786	0.8332
3	5.82	6.05	5.87	5.65	5.85	0.1646	0.12	0.027092	0.7425	1.4384
5	5.81	5.48	5.85	5.48	5.66	0.2027	-0.07	0.041100	-0.4396	1.7716
6	5.91	5.86	5.92	5.84	5.88	0.0386	0.16	0.001492	0.9574	0.3375
7	5.57	5.77	5.90	5.68	5.73	0.1398	0.00	0.019533	0.0209	1.2214
8	5.68	5.65	5.76	5.57	5.67	0.0785	-0.06	0.006167	-0.3782	0.6862
9	5.87	5.91	5.88	5.90	5.89	0.0183	0.16	0.000333	1.0035	0.1595
10	5.82	5.84	5.82	5.84	5.83	0.0115	0.10	0.000133	0.6350	0.1009
11	5.47	5.28	5.37	5.56	5.42	0.1214	-0.31	0.014733	-1.8828	1.0607
12	5.44	5.57	5.37	5.56	5.49	0.0968	-0.24	0.009367	-1.4836	0.8458
				Average	5.73			0.144042		
				$s_{x\ bar}$	0.162839					

Critical h value = 2.34
Critical k value= 1.94

$s_r =$ 0.114432
$(s_R)^* =$ 0.190624
$s_R =$ 0.190624

Table 10 - Asphalt Binder Content Data for Mixture #9

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	5.87	5.81	5.65	5.86	5.80	0.1018	0.13	0.010358	1.4246	1.0724
2	5.64	5.64	5.63	5.59	5.63	0.0238	-0.04	0.000567	-0.4757	0.2508
3	5.82	5.89	5.57	5.54	5.71	0.1760	0.04	0.030967	0.4056	1.8541
5	5.63	5.72	5.59	5.74	5.67	0.0716	0.00	0.005133	0.0200	0.7549
6	5.68	5.51	5.56	5.53	5.57	0.0762	-0.10	0.005800	-1.0816	0.8024
7	5.46	5.41	5.67	5.53	5.52	0.1130	-0.15	0.012758	-1.6599	1.1901
8	5.65	5.66	5.71	5.71	5.68	0.0320	0.01	0.001025	0.1577	0.3373
9	5.76	5.48	5.60	5.73	5.64	0.1287	-0.03	0.016558	-0.2829	1.3558
10	5.75	5.62	5.56	5.68	5.65	0.0814	-0.02	0.006625	-0.1728	0.8576
11	5.71	5.68	5.63	5.58	5.65	0.0572	-0.02	0.003267	-0.2003	0.6022
12	5.90	5.90	5.74	5.81	5.84	0.0776	0.17	0.006025	1.8652	0.8179
				Average	5.67			0.099083		
				$s_{x\ bar}$	0.090775					

Critical h value = 2.34
Critical k value= 1.94

$s_r =$ 0.094908
$(s_R)^* =$ 0.122457
$s_R =$ 0.122457

Table 11 – Evaluation of Within-lab Variances

Mix #	Largest Variance/ Sum of Variances	Critical Value
1	0.1853	0.3264
2	0.2122	0.3264
3	0.3296	0.3264
4	0.2594	0.3264
5	0.2111	0.3264
6	0.2067	0.3264
7	0.1710	0.3264
8	0.2853	0.3480
9	0.3125	0.3480

Table 12 – Variance Table (including outliers)

Mixture #	Mixture Type	Average % Binder	Components of Variance		Variance	
			Within-Lab	Between-Lab	Within-Lab	Between-Lab
1	12.5 Fine	6.42	0.012981	0.011821	0.012981	0.024802
2	OGFC	5.34	0.013993	0.092448	0.013993	0.106441
3	12.5 Coarse	6.46	0.016653	0.010530	0.016653	0.027182
4	OGFC	7.11	0.019079	0.014228	0.019079	0.033307
5	9.5 Coarse	6.88	0.004801	0.001566	0.004801	0.006367
6	19.0 Fine	6.20	0.017255	0.005582	0.017255	0.022837
7	19.0 Coarse	4.74	0.010765	0.017038	0.010765	0.027802
8	OGFC	5.73	0.013095	0.023243	0.013095	0.036338
9	9.5 Coarse	5.67	0.009008	0.005988	0.009008	0.014996

Table 13 – Modified Asphalt Content Data for Mixture #2 (elimination of laboratories 5 & 9)

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	5.47	5.28	5.60	5.41	5.44	0.1329	-0.02	0.017667	-0.1693	1.1920
2	5.51	5.09	5.26	5.44	5.33	0.1888	-0.14	0.035633	-1.0344	1.6929
3	5.80	5.61	5.78	5.72	5.73	0.0854	0.27	0.007292	1.9935	0.7658
4	5.61	5.55	5.52	5.44	5.53	0.0707	0.07	0.005000	0.5078	0.6341
6	5.44	5.60	5.73	5.57	5.59	0.1190	0.12	0.014167	0.9215	1.0674
7	5.31	5.31	5.45	5.36	5.36	0.0660	-0.11	0.004358	-0.7899	0.5921
8	5.35	5.21	5.25	5.51	5.33	0.1337	-0.13	0.017867	-0.9968	1.1987
10	5.36	5.47	5.37	5.49	5.42	0.0670	-0.04	0.004492	-0.3009	0.6010
11	5.35	5.29	5.33	5.45	5.36	0.0681	-0.11	0.004633	-0.8087	0.6105
12	5.59	5.51	5.42	5.69	5.55	0.1150	0.09	0.013225	0.6770	1.0313
				Average	5.46			0.124333		
				$s_{x\ bar}$	0.132932					

Critical h value = 2.29

Critical k value= 1.93

s_r = 0.111505

$(s_R)^*$ = 0.164304

s_R = 0.164304

Table 14 – Variance Table (excluding outliers)

Mixture #	Mixture Type	Average % Binder	Components of Variance Within-Lab	Components of Variance Between-Lab	Variance Within-Lab	Variance Between-Lab	Standard Deviation Within-Lab	Standard Deviation Between-Lab	Coefficient of Variation Within-Lab	Coefficient of Variation Between-Lab
1	12.5 Fine	6.42	0.012981	0.011821	0.012981	0.024802	0.113935	0.157488	1.8	2.5
2	OGFC	5.34	0.012433	0.014562	0.012433	0.026996	0.111505	0.164304	2.1	3.1
3	12.5 Coarse	6.46	0.016653	0.010530	0.016653	0.027182	0.129046	0.164871	2.0	2.6
4	OGFC	7.11	0.019079	0.014228	0.019079	0.033307	0.138127	0.182501	1.9	2.6
5	9.5 Coarse	6.88	0.004801	0.001566	0.004801	0.006367	0.069287	0.079791	1.0	1.2
6	19.0 Fine	6.20	0.017255	0.005582	0.017255	0.022837	0.131360	0.151119	2.1	2.4
7	19.0 Coarse	4.74	0.010765	0.017038	0.010765	0.027802	0.103753	0.166740	2.2	3.5
8	OGFC	5.73	0.013095	0.023243	0.013095	0.036338	0.114432	0.190624	2.0	3.3
9	9.5 Coarse	5.67	0.009008	0.005988	0.009008	0.014996	0.094908	0.122457	1.7	2.2

Table 15 – Pooled Variances and Standard Deviations

Mixture #	Number of Labs in Data Analysis	Number of Samples in Data Analysis	Variance	
			Within-Lab	Between-Lab
1	12	48	0.012981	0.024802
2	10	40	0.012433	0.026996
3	12	48	0.016653	0.027182
4	12	48	0.019079	0.033307
5	12	48	0.004801	0.006367
6	12	48	0.017255	0.022837
7	12	48	0.010765	0.027802
8	11	44	0.013095	0.036338
9	11	44	0.009008	0.014996

Pooled Variances:	0.012942	0.024438
Standard Deviations:	0.113763	0.156325

Table 16 – Precision Statement for Asphalt Binder Content

Test Method	Standard Deviation (1S)		Acceptable Range of Two Test Results (D2S)	
	Within-lab	Between-lab	Within-lab	Between-lab
% Binder, (ignition oven & plant mix)	0.1138	0.1563	0.32	0.44

Table 17 – Gradation Data for Mixture #1; #16 Sieve

Laboratory Number	Test Results, x 1	2	3	4	Average	s	d	s^2	h	k
1	41.7	42.5	41.9	39.7	41.5	1.2152	-1.86	1.47667	-1.7901	1.3095
2	43.8	42.8	43.2	41.6	42.9	0.9292	-0.46	0.86333	-0.4415	1.0013
3	41.2	41.9	43.1	43.1	42.3	0.9394	-0.98	0.88250	-0.9472	1.0123
4	42.2	44.4	43.8	45.6	44.0	1.4142	0.69	2.00000	0.6663	1.5240
5	41.6	42.9	43.1	42.0	42.4	0.7165	-0.91	0.51333	-0.8750	0.7721
6	45.3	45.8	43.4	45.1	44.9	1.0424	1.59	1.08667	1.5332	1.1234
7	44.3	43.5	45.2	44.0	44.3	0.7141	0.94	0.51000	0.9071	0.7696
8	43.4	43.7	43.0	42.8	43.2	0.4031	-0.08	0.16250	-0.0803	0.4344
9	42.8	43.9	44.6	44.3	43.9	0.7874	0.59	0.62000	0.5700	0.8485
10	43.4	44.5	44.4	45.4	44.4	0.8180	1.12	0.66917	1.0757	0.8815
11	43.6	42.8	41.0	42.2	42.4	1.0954	-0.91	1.20000	-0.8750	1.1805
12	44.0	42.7	43.8	43.8	43.6	0.5909	0.27	0.34917	0.2569	0.6368
				Average	43.3			10.33333		
				$s_{x\ bar}$	1.0381					

Critical h value = 2.38
Critical k value= 1.96

s_r = 0.927961
$(s_R)^*$ = 1.312816
s_R = 1.312816

Table 18 – Aggregate Precision Values per Mixture and Sieve Size

Mix #	Sieve Size	% Passing	Acceptable Range of Two Test Results	
			W/L (% passing)	B/L (% passing)
1 12.5 F	19.0	100.0	0.417	0.417
	12.5	95.0	2.869	3.343
	9.5	88.9	3.904	4.543
	#4	72.5	4.375	5.672
	#8	56.1	3.848	5.046
	#16	43.3	2.598	3.676
	#30	34.2	1.944	3.002
	#50	22.4	1.320	2.553
	#100	10.3	0.903	2.478
	#200	7.3	0.768	2.336
2 OGFC	19.0	100.0	0.000	0.000
	12.5	90.3	4.643	6.959
	9.5	62.8	6.973	10.309
	#4	19.5	3.400	5.108
	#8	6.5	0.671	1.351
	#16	4.8	0.425	0.767
	#30	3.9	0.348	0.576
	#50	3.2	0.293	0.495
	#100	2.2	0.283	0.332
	#200	1.4	0.239	0.298
3 12.5 C	19.0	99.5	1.505	1.616
	12.5	95.7	3.326	3.392
	9.5	89.7	3.586	3.957
	#4	58.0	4.475	5.440
	#8	32.3	2.007	2.821
	#16	23.7	1.098	1.784
	#30	17.5	0.778	1.488
	#50	11.6	0.643	1.308
	#100	6.8	0.736	1.350
	#200	4.4	0.504	1.173
4 OGFC	19.0	100.0	0.202	0.202
	12.5	87.5	4.696	6.776
	9.5	59.7	7.205	9.938
	#4	24.4	3.746	4.673
	#8	12.2	1.003	1.951
	#16	8.3	0.555	1.750
	#30	6.2	0.592	1.641
	#50	4.7	0.416	1.589
	#100	3.2	0.366	1.442
	#200	2.3	0.355	1.140
5 9.5 C	19.0	100.0	0.000	0.000
	12.5	100.0	0.234	0.240
	9.5	99.0	0.926	0.986
	#4	84.7	1.821	2.282
	#8	51.5	1.478	2.614
	#16	34.7	0.858	1.366
	#30	26.2	0.705	1.465
	#50	19.1	0.499	1.506
	#100	10.0	0.544	1.626
	#200	4.9	0.462	1.242
6 19.0 F	19.0	99.4	1.566	1.714
	12.5	92.0	3.299	3.964
	9.5	86.4	4.259	4.795
	#4	69.6	4.987	5.260
	#8	52.9	3.845	4.410
	#16	38.6	2.590	3.108
	#30	29.1	1.755	2.369
	#50	20.3	1.256	1.869
	#100	10.8	0.810	1.364
	#200	5.5	0.545	1.049
7 19.0 C	19.0	99.1	2.101	2.126
	12.5	86.9	6.709	7.945
	9.5	77.0	7.053	8.851
	#4	46.2	4.835	7.525
	#8	26.5	1.742	3.312
	#16	20.3	1.116	2.091
	#30	16.5	0.934	1.758
	#50	12.3	0.675	1.429
	#100	8.2	0.477	0.956
	#200	5.5	0.411	0.697
8 OGFC	19.0	100.0	0.000	0.000
	12.5	92.7	4.566	5.734
	9.5	68.8	7.940	9.797
	#4	26.4	3.446	4.875
	#8	12.8	0.910	1.626
	#16	9.4	0.631	1.103
	#30	7.6	0.532	0.950
	#50	6.2	0.469	0.874
	#100	4.7	0.446	0.808
	#200	3.4	0.411	0.904
9 9.5 C	19.0	100.0	0.000	0.000
	12.5	99.4	0.962	1.174
	9.5	91.5	3.497	4.365
	#4	59.8	5.398	7.270
	#8	34.8	2.785	3.929
	#16	26.7	1.705	2.572
	#30	22.4	1.367	2.059
	#50	17.0	1.082	1.794
	#100	8.6	1.005	1.719
	#200	4.5	0.638	1.253

Table 19 – Comparison of Conventional Oven vs. NTO for Mean Binder Content

Lab #	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8	Mix 9	Average Difference	Std. Dev. Differences
1	0.14	-0.02	0.01	-0.08	0.02	-0.01	0.17	0.16	0.13	0.06	0.09
2	-0.04	-0.14	-0.09	0.01	0.04	0.14	-0.22	-0.03	-0.04	-0.04	0.10
3	-0.15	0.27	-0.01	0.27	0.04	-0.02	-0.18	0.12	0.04	0.04	0.16
4	0.06	0.07	-0.09	0.23	0.02	-0.05	0.07			0.04	0.10
5	-0.16		-0.10	-0.09	0.00	0.01	0.08	-0.07	0.00	-0.04	0.08
6	0.16	0.12	0.02	-0.10	-0.03	-0.19	0.01	0.16	-0.10	0.01	0.12
7	0.06	-0.11	-0.04	0.06	-0.07	0.04	0.01	0.00	-0.15	-0.02	0.07
8	-0.02	-0.13	-0.13	-0.22	0.12	-0.07	-0.09	-0.06	0.01	-0.07	0.10
9	-0.16		-0.08	-0.03	-0.03	-0.11	-0.12	0.16	-0.03	-0.05	0.10
10	0.05	-0.04	0.04	-0.07	-0.07	0.01	-0.05	0.10	-0.02	0.00	0.06
11	-0.10	-0.11	0.22	0.06	-0.04	0.08	0.26	-0.31	-0.02	0.01	0.17
12	0.16	0.09	0.24	-0.04	-0.01	0.16	0.08	-0.24	0.17	0.07	0.15
										Average	0.11
NTO	0.08	0.14	0.25	-0.08	0.02	-0.08	-0.09	-0.1	-0.15	0.00	0.13

Table 20 – Comparison of Conventional Oven vs. NTO for Within-lab Variance

Mix #	Mix Type	Aggregate Type	Variance		Difference
			Infrared	Conventional	Inf.-Conv.
1	12.5 Fine	FL Limestone	0.014	0.013	0.001
2	OGFC	GA Granite	0.043	0.012	0.030
3	12.5 Coarse	AL Lmstn, GA Gran	0.032	0.017	0.015
4	OGFC	FL Limestone	0.051	0.019	0.032
5	9.5 Coarse	FL Limestone	0.008	0.005	0.003
6	19.0 Fine	GA Granite	0.021	0.017	0.004
7	19.0 Coarse	GA Granite	0.050	0.011	0.040
8	OGFC	GA Granite	0.005	0.013	-0.008
9	9.5 Coarse	FL Limestone	0.012	0.009	0.003
				Avg. Difference	0.013

Table 21 – Statistical Analysis of Within-lab Variances for Conventional Oven and NTO

Mix ID	12 Lab Pooled Variance	Troxler NTO Variance	F Ratio NTO / 12 Lab	D.O.F. NTO	D.O.F. Conventional	Fcritical alpha = 0.05	F < Fcrit ?
1	0.0130	0.0144	1.11	3	36	2.87*	Yes
2	0.0124	0.0428	3.45	3	30	2.92	**No**
3	0.0167	0.0319	1.92	3	36	2.87*	Yes
4	0.0191	0.0506	2.65	3	36	2.87*	Yes
5	0.0048	0.0081	1.69	3	36	2.87*	Yes
6	0.0173	0.0208	1.21	3	36	2.87*	Yes
7	0.0108	0.0505	4.69	3	36	2.87*	**No**
8	0.0131	0.0046	0.35	3	33	2.90*	Yes
9	0.0090	0.0122	1.35	3	33	2.90*	Yes

* By interpolation

Table 22 – Comparison of Conventional Oven vs. NTO for Aggregate Gradation

Mix #	Oven Type	Sieve Size									
		19.0	12.5	9.5	#4	#8	#16	#30	#50	#100	#200
1	Conventional	100.0	95.0	88.9	72.5	56.1	43.3	34.2	22.4	10.3	7.3
	NTO	99.9	95.4	89.3	73.0	56.8	43.6	34.5	23.0	10.5	7.3
	Difference	0.1	-0.4	-0.4	-0.5	-0.7	-0.3	-0.3	-0.6	-0.2	0.0
2	Conventional	100.0	90.3	62.8	19.5	6.5	4.8	3.9	3.2	2.2	1.4
	NTO	99.9	92.0	64.9	22.3	7.7	5.8	4.7	3.8	2.6	1.7
	Difference	0.1	-1.7	-2.1	-2.8	-1.2	-1.0	-0.8	-0.6	-0.4	-0.3
3	Conventional	99.5	95.7	89.7	58.0	32.3	23.7	17.5	11.6	6.8	4.4
	NTO	99.7	97.3	91.3	61.9	34.5	25.1	18.6	12.5	7.3	4.8
	Difference	-0.2	-1.6	-1.6	-3.9	-2.2	-1.4	-1.1	-0.9	-0.5	-0.4
4	Conventional	100.0	87.5	59.7	24.4	12.2	8.3	6.2	4.7	3.2	2.3
	NTO	100.0	85.1	56.6	22.9	12.0	8.3	6.3	4.8	3.2	2.2
	Difference	0.0	2.4	3.1	1.5	0.2	0.0	-0.1	-0.1	0.0	0.1
5	Conventional	100.0	100.0	99.0	84.7	51.5	34.7	26.2	19.1	10.0	4.9
	NTO	100.0	100.0	99.3	84.8	51.9	34.5	26.0	19.2	9.8	4.9
	Difference	0.0	0.0	-0.3	-0.1	-0.4	0.2	0.2	-0.1	0.2	0.0
6	Conventional	99.4	92.0	86.4	69.6	52.9	38.6	29.1	20.3	10.8	5.5
	NTO	99.2	94.2	88.1	70.3	53.3	39.1	29.9	21.2	10.8	5.5
	Difference	0.2	-2.2	-1.7	-0.7	-0.4	-0.5	-0.8	-0.9	0.0	0.0
7	Conventional	99.1	86.9	77.0	46.2	26.5	20.3	16.5	12.3	8.2	5.5
	NTO	98.5	86.6	76.7	45.9	26.1	19.9	16.1	12.1	7.9	5.1
	Difference	0.6	0.3	0.3	0.3	0.4	0.4	0.4	0.2	0.3	0.4
8	Conventional	100.0	92.7	68.8	26.4	12.8	9.4	7.6	6.2	4.7	3.4
	NTO	100.0	92.0	66.9	25.8	12.6	9.4	7.6	6.3	4.8	3.4
	Difference	0.0	0.7	1.9	0.6	0.2	0.0	0.0	-0.1	-0.1	0.0
9	Conventional	100.0	99.4	91.5	59.8	34.8	26.7	22.4	17.0	8.6	4.5
	NTO	100.0	99.5	91.2	57.7	33.6	26.1	22.0	17.0	8.3	4.4
	Difference	0.0	-0.1	0.3	2.1	1.2	0.6	0.4	0.0	0.3	0.1

Average Difference:	0.1	-0.3	-0.1	-0.4	-0.3	-0.2	-0.2	-0.3	0.0	0.0

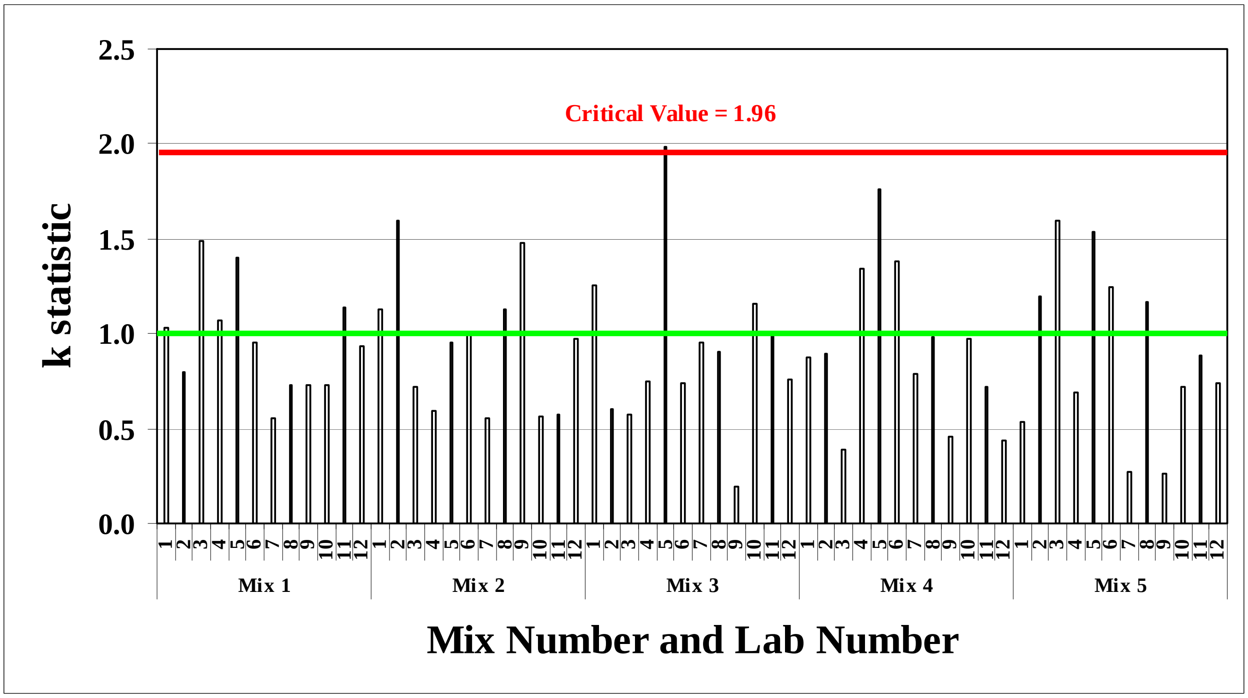

Figure 1 – Within-lab k Values by Mixture Number (1 – 5)

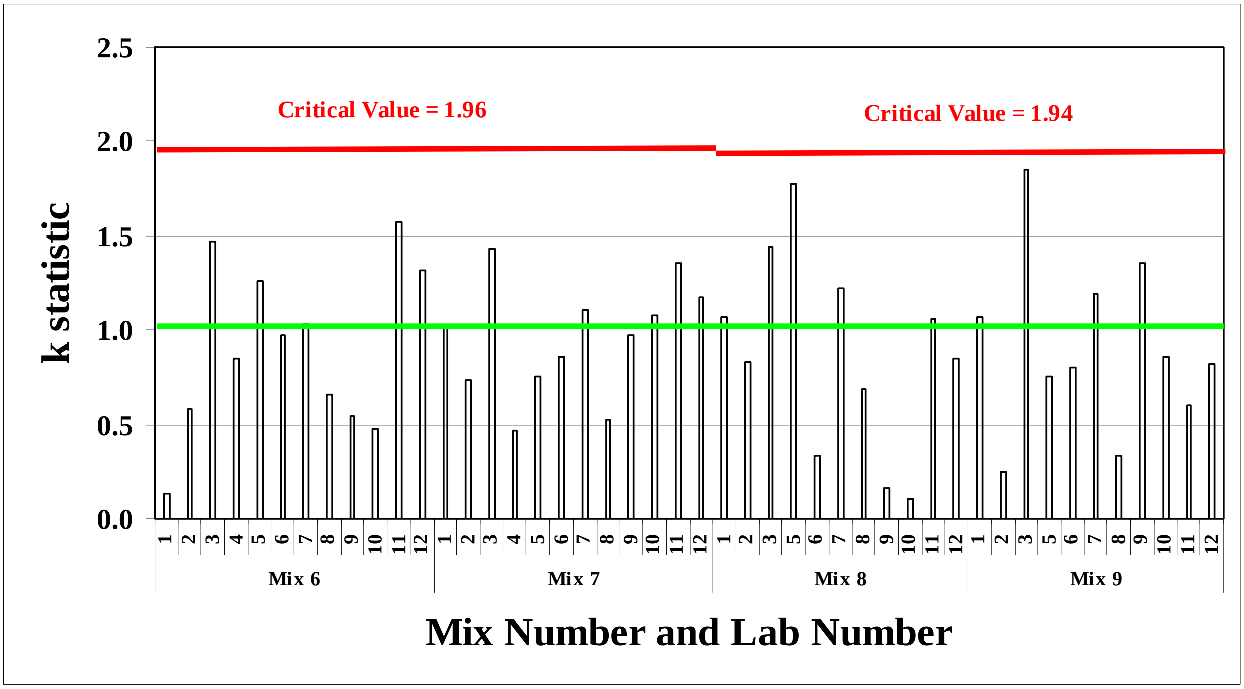

Figure 2 – Within-lab k Values by Mixture Number (6 – 9)

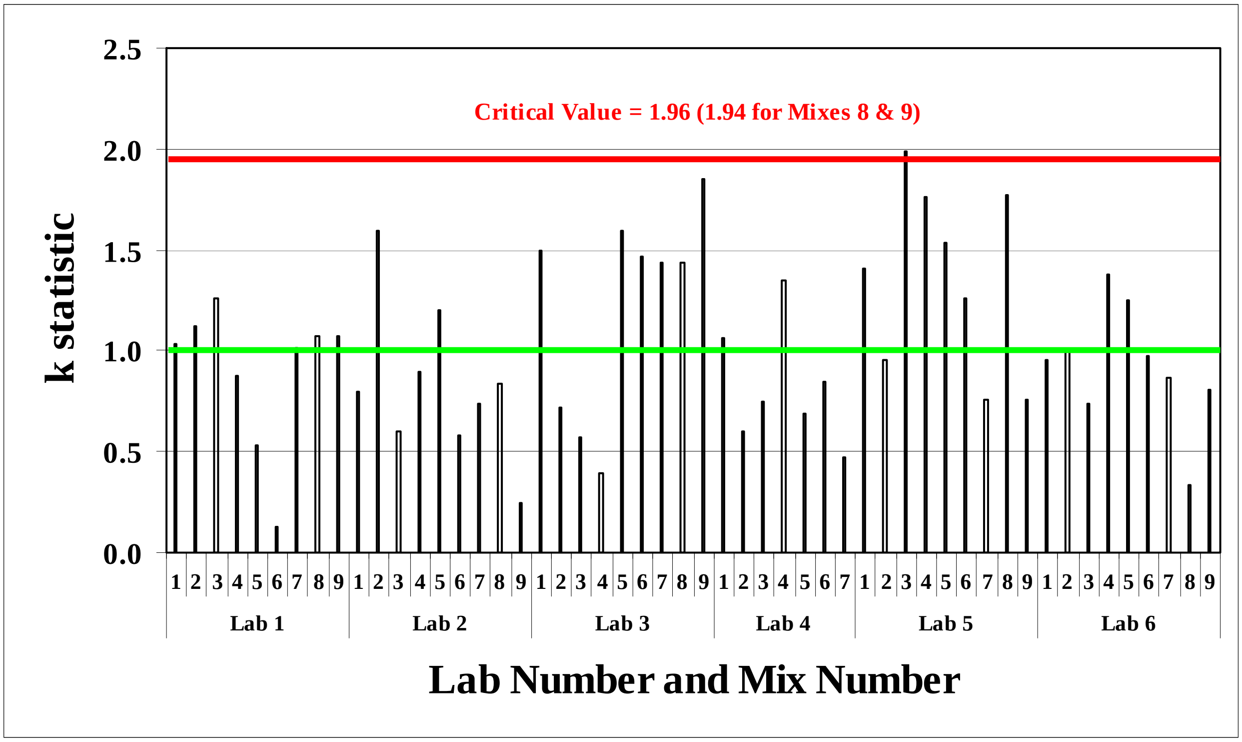

Figure 3 – Within-lab k Values by Laboratory Number (1 – 6)

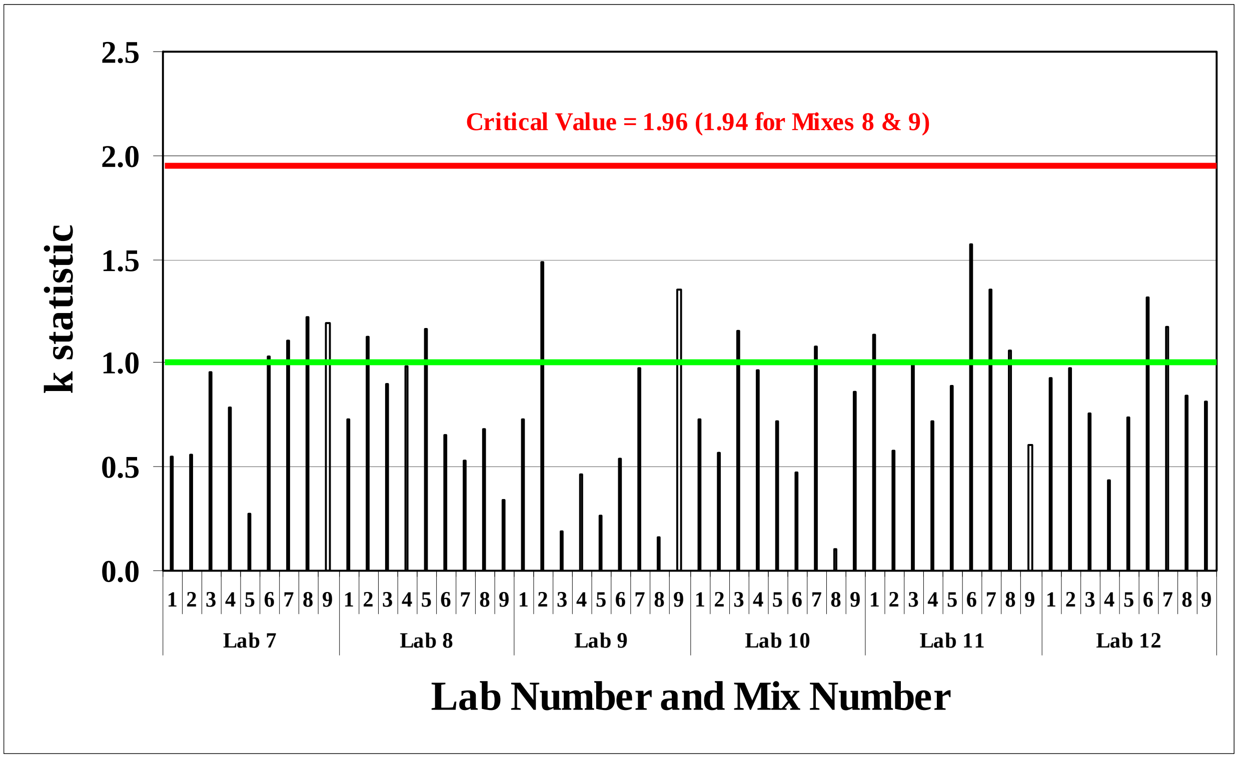

Figure 4 – Within-lab k Values by Laboratory Number (7 – 12)

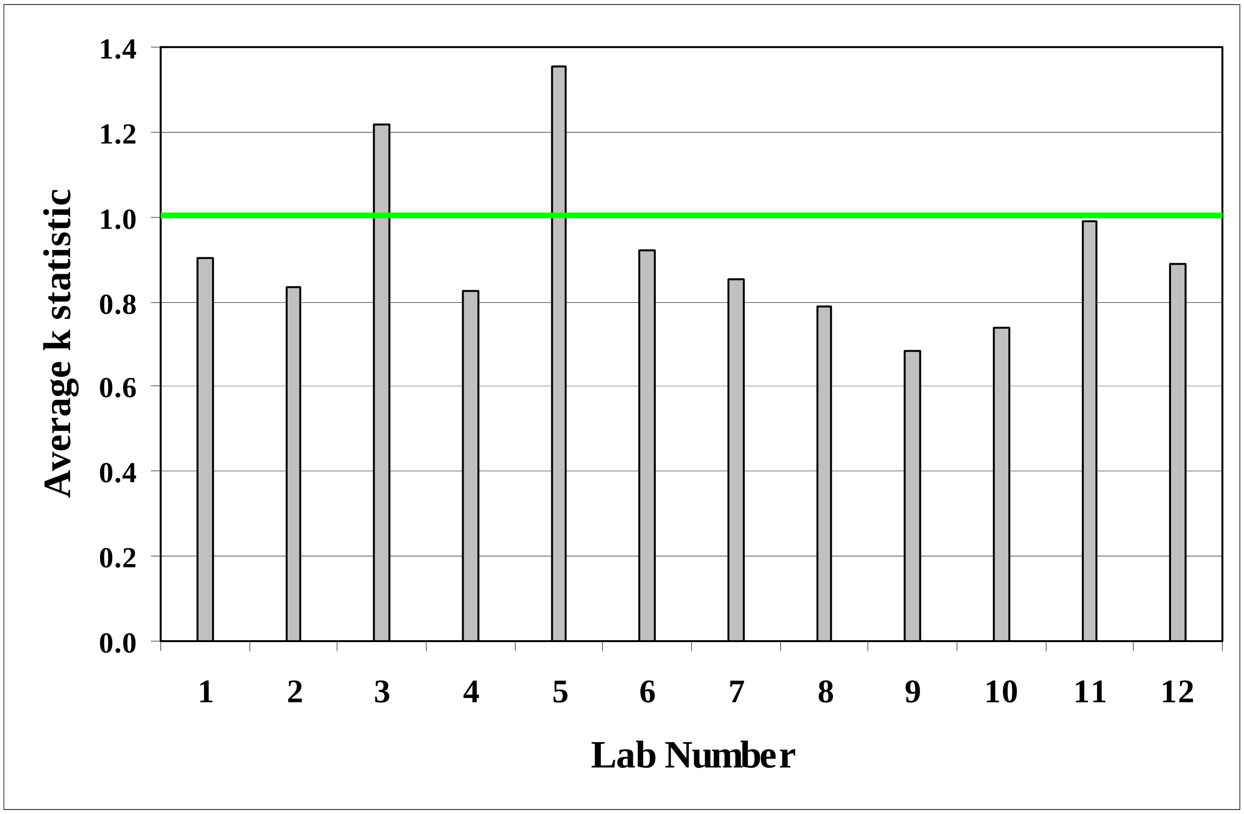

Figure 5 – Average k Value by Laboratory Number

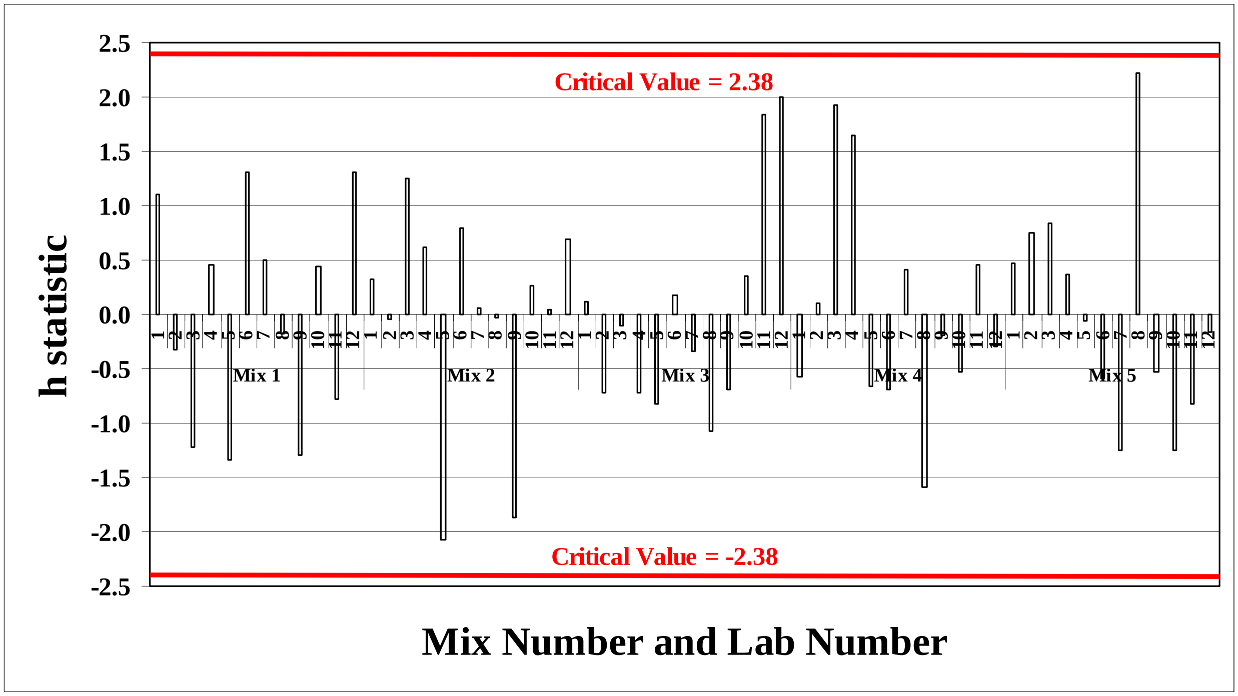

Figure 6 – Between-lab h Values by Mixture Number (1 – 5)

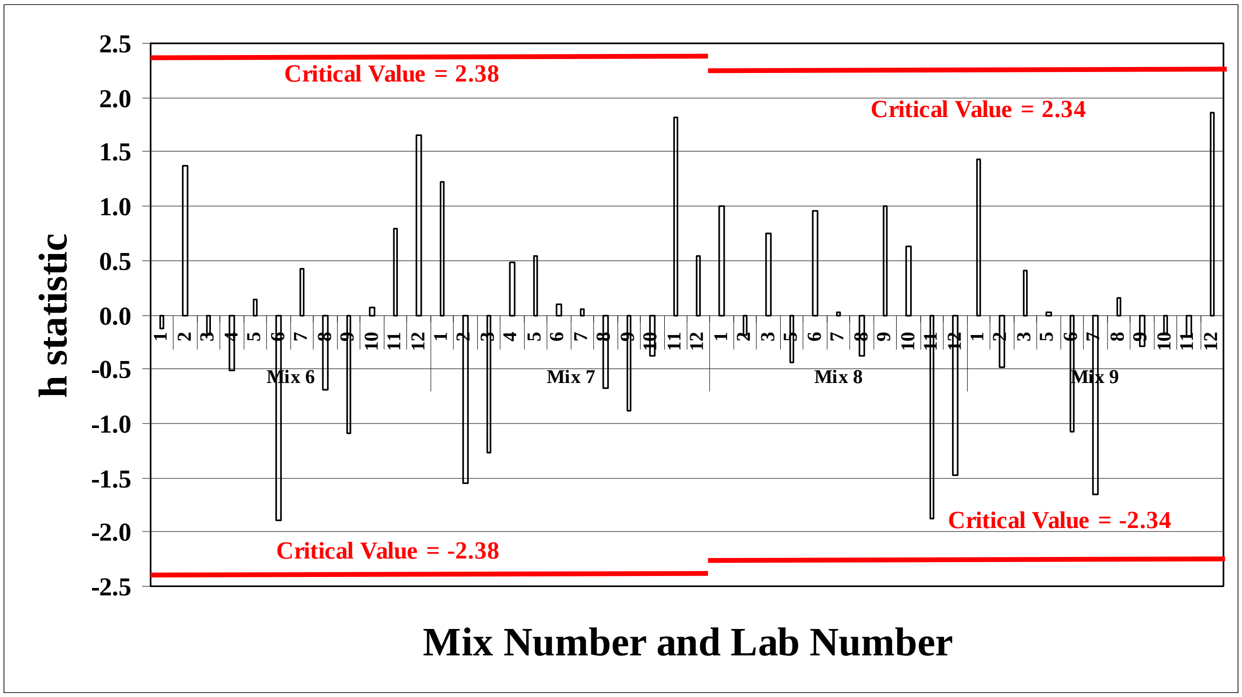

Figure 7 – Between-lab h Values by Mixture Number (6 – 9)

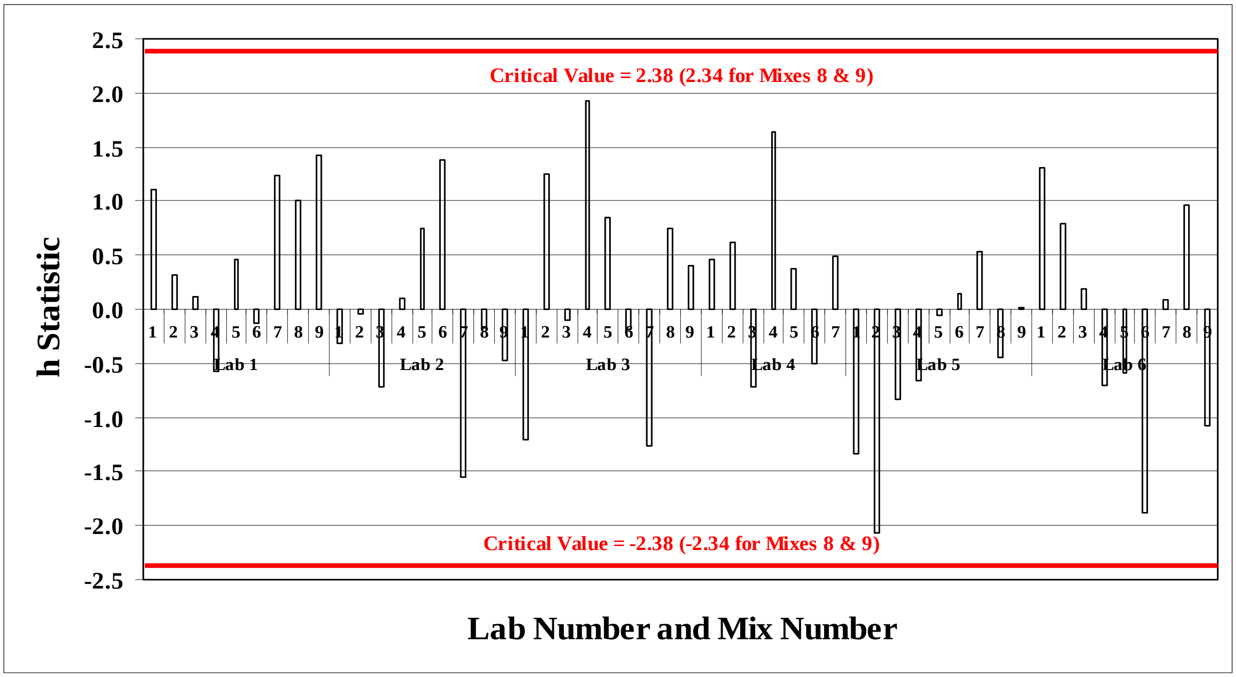

Figure 8 – Between-lab h Values by Laboratory Number (1 – 6)

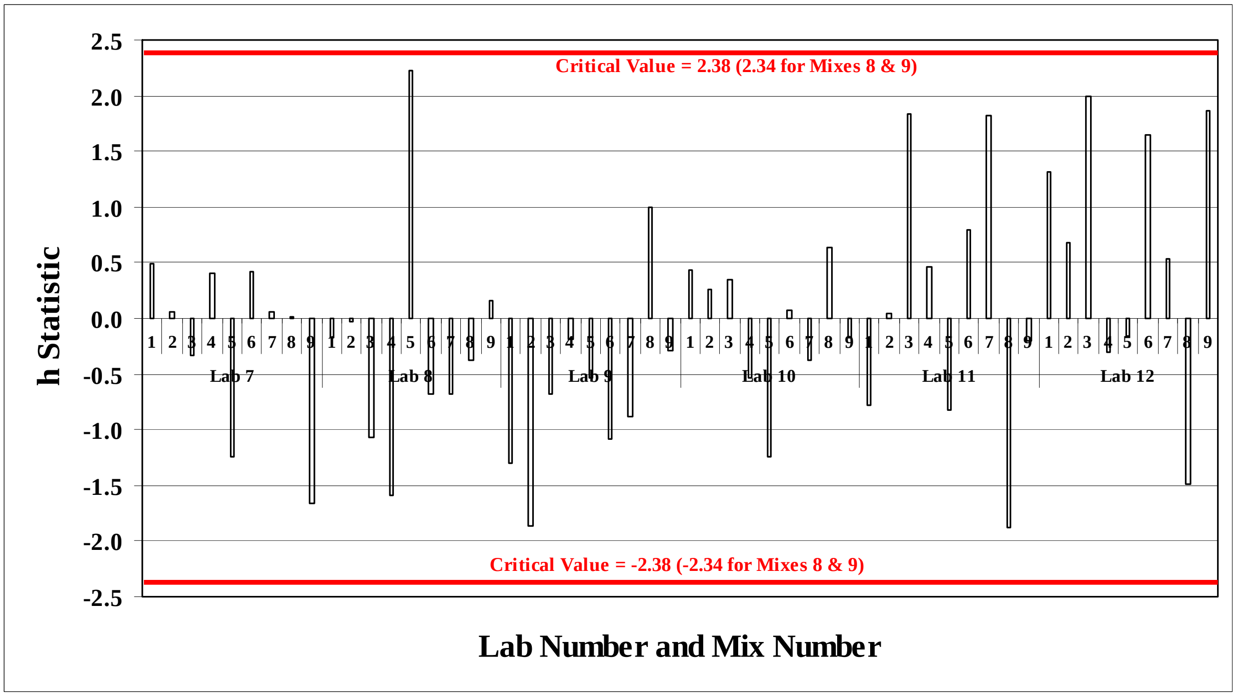

Figure 9 – Between-lab h Values by Laboratory Number (7 – 12)

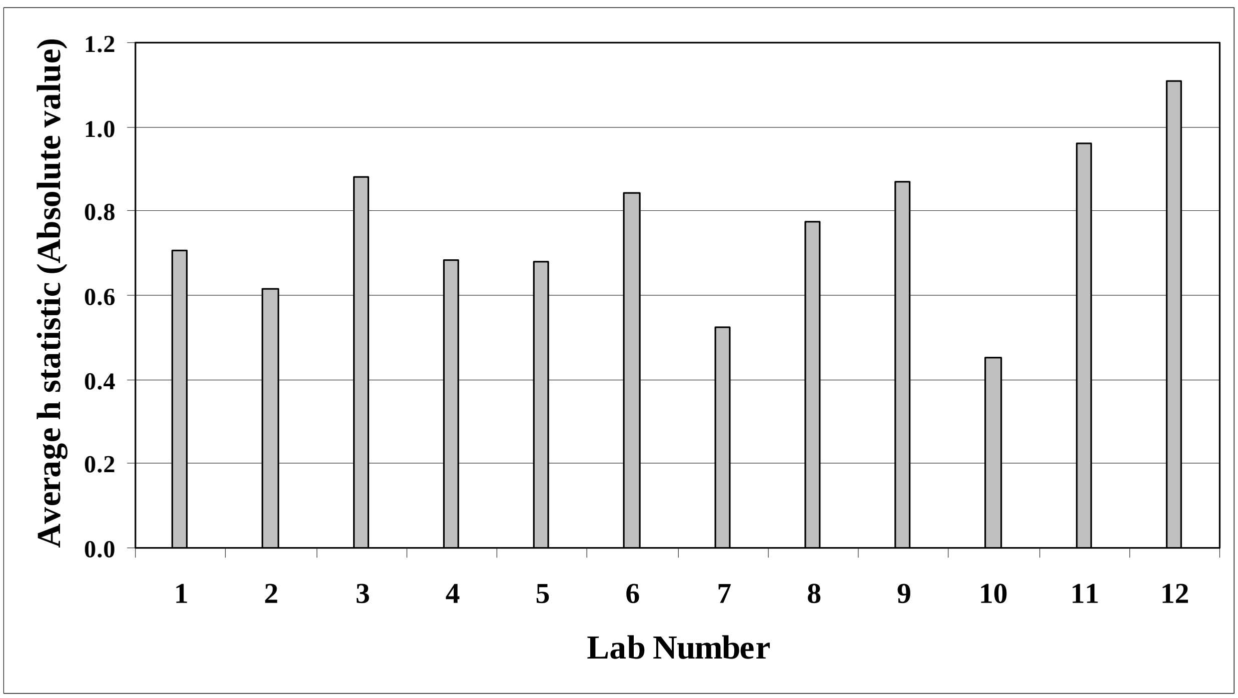

Figure 10 – Average h Value (Absolute) by Laboratory Number

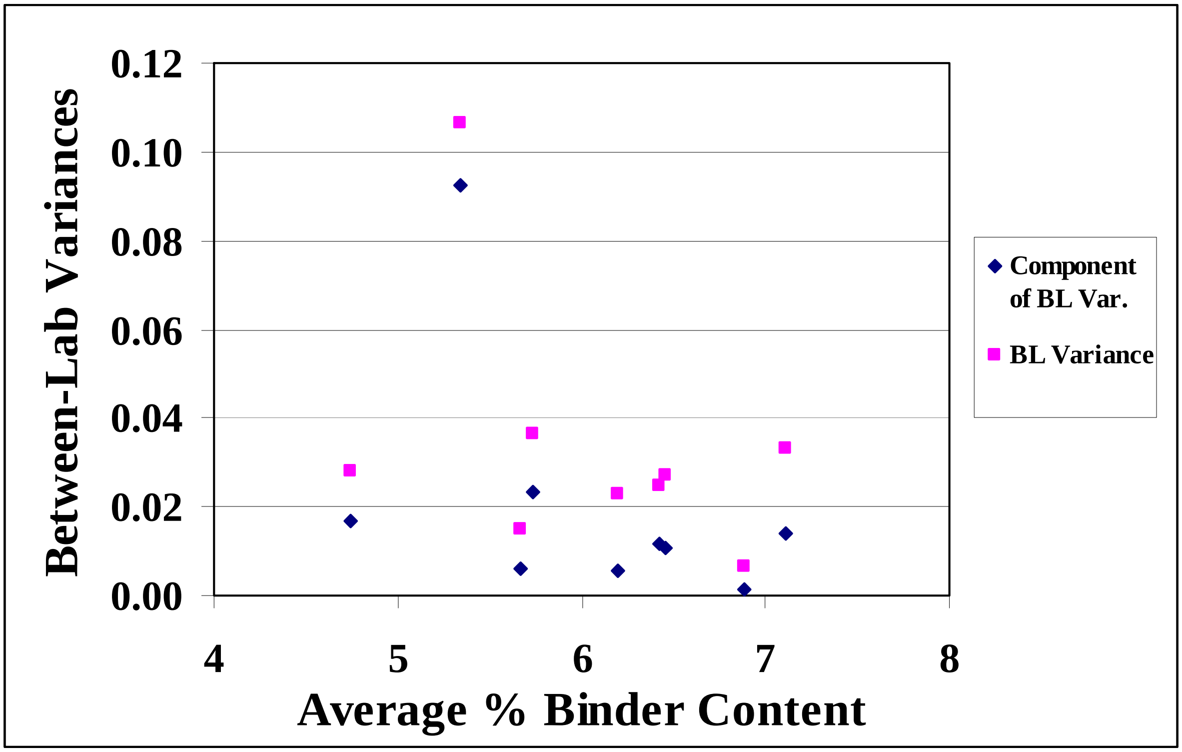

Figure 11 – Between-lab Variances vs. Average % Binder Content

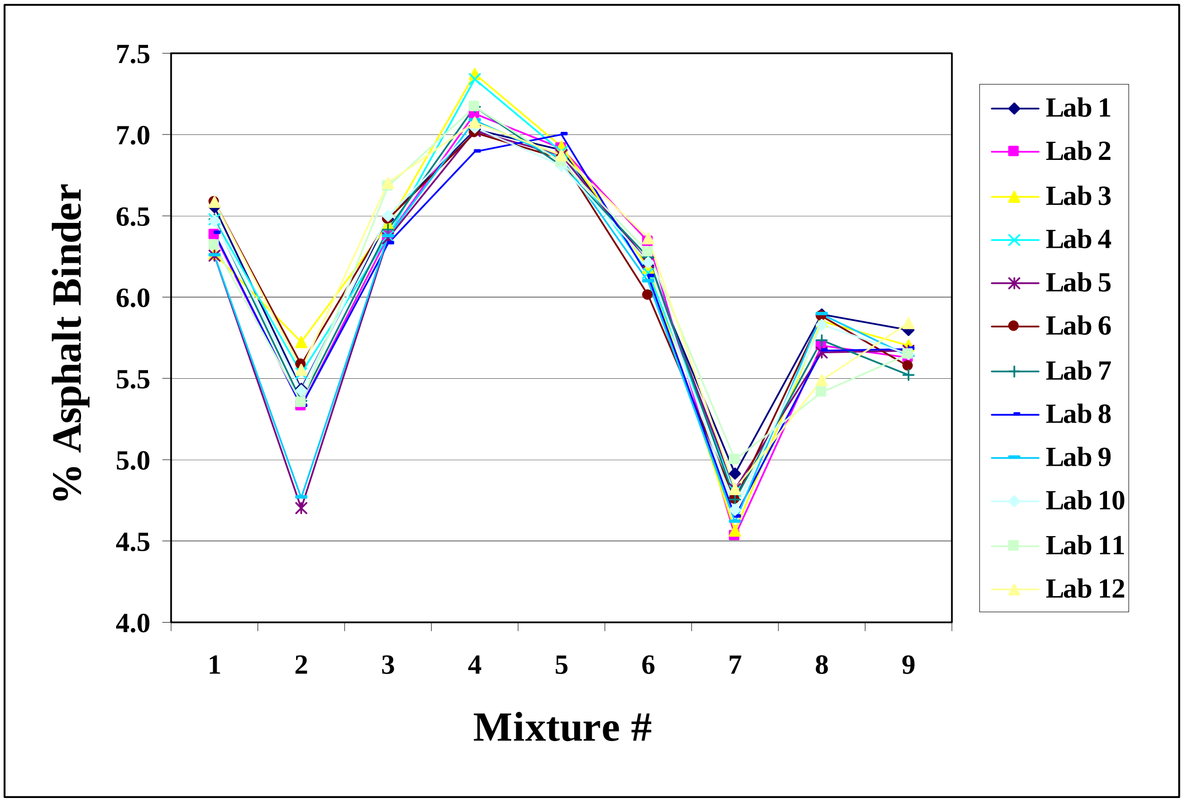

Figure 12 – % Asphalt Binder per Laboratory vs. Mixture Number

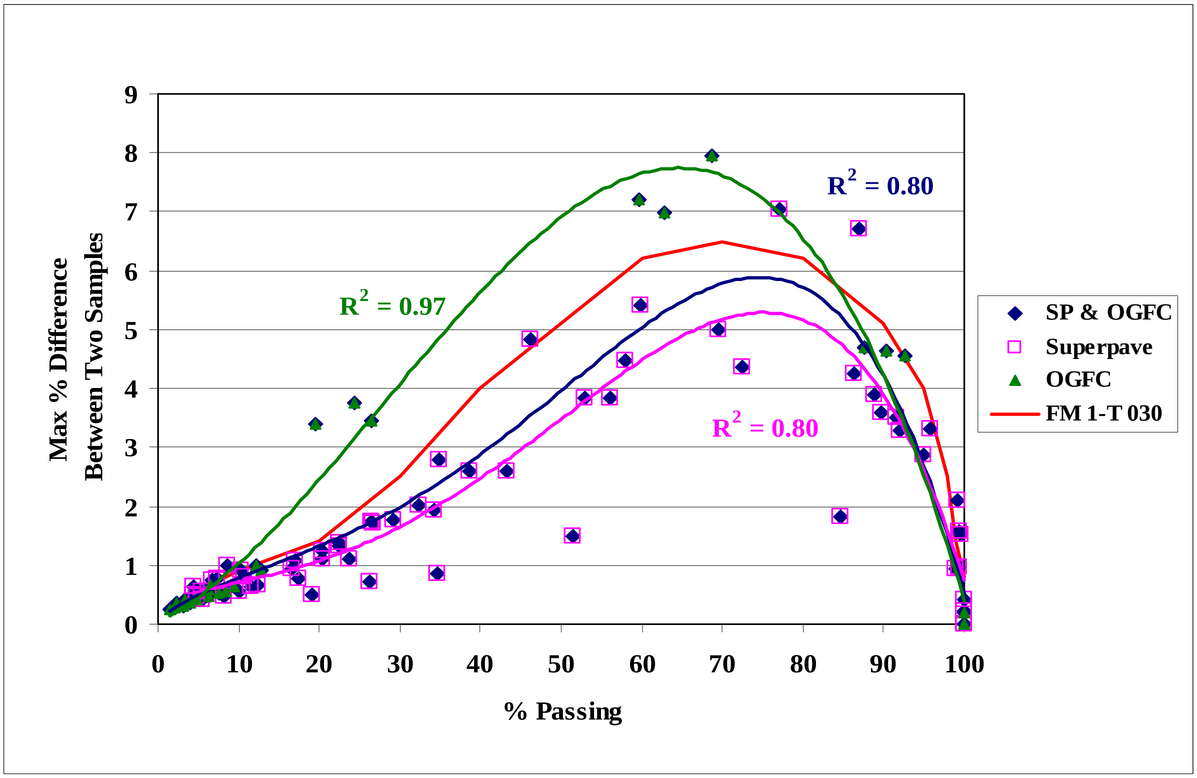

Figure 13 – Within-lab Variability Graph

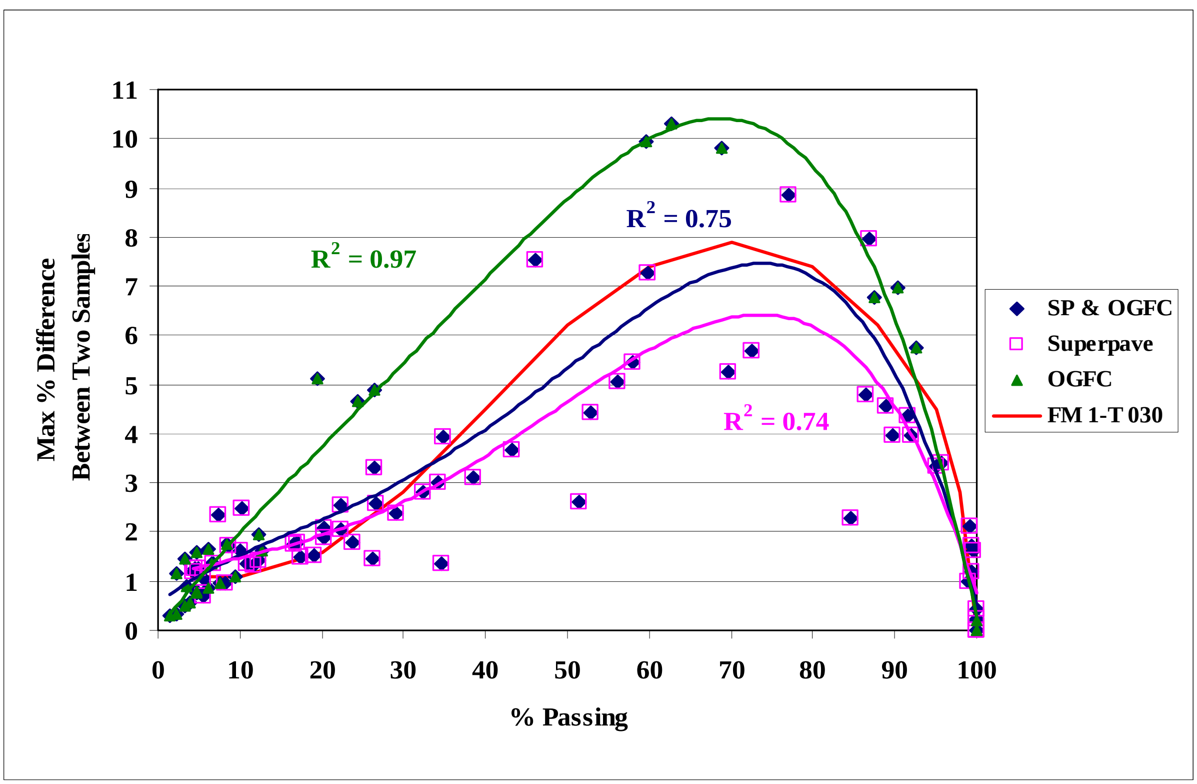

Figure 14 – Between-lab Variability Graph

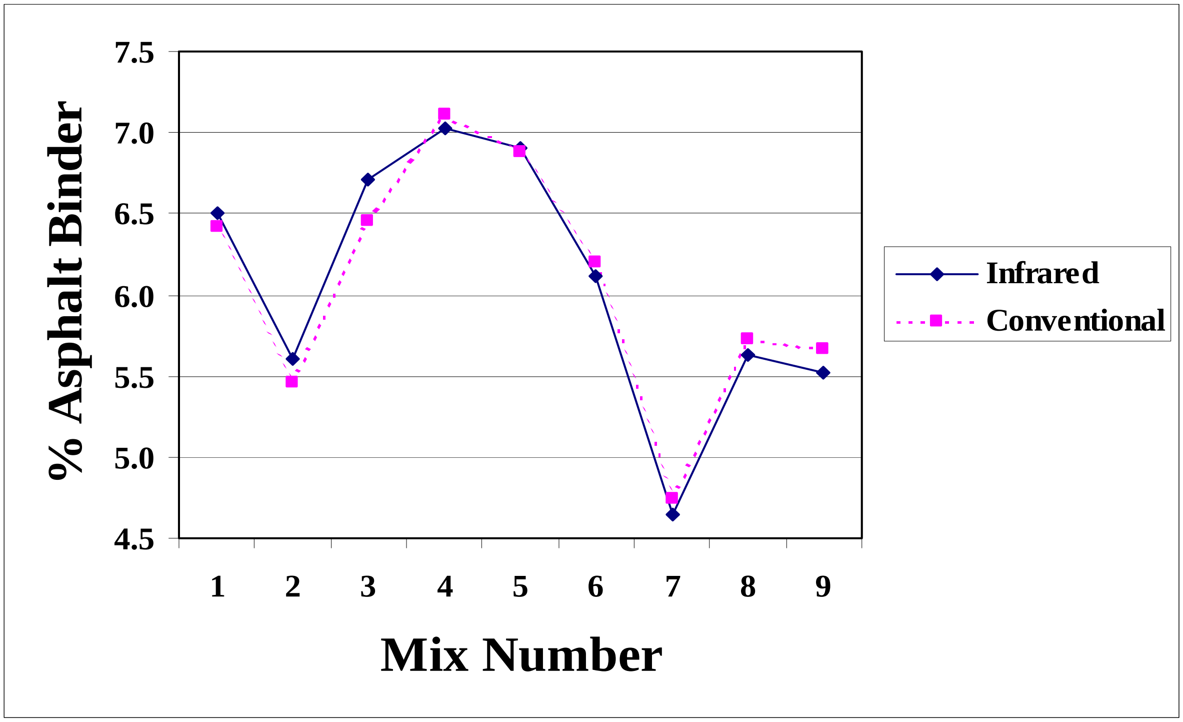

Figure 15 – Comparison of Conventional Oven vs. NTO for Mean Binder Content

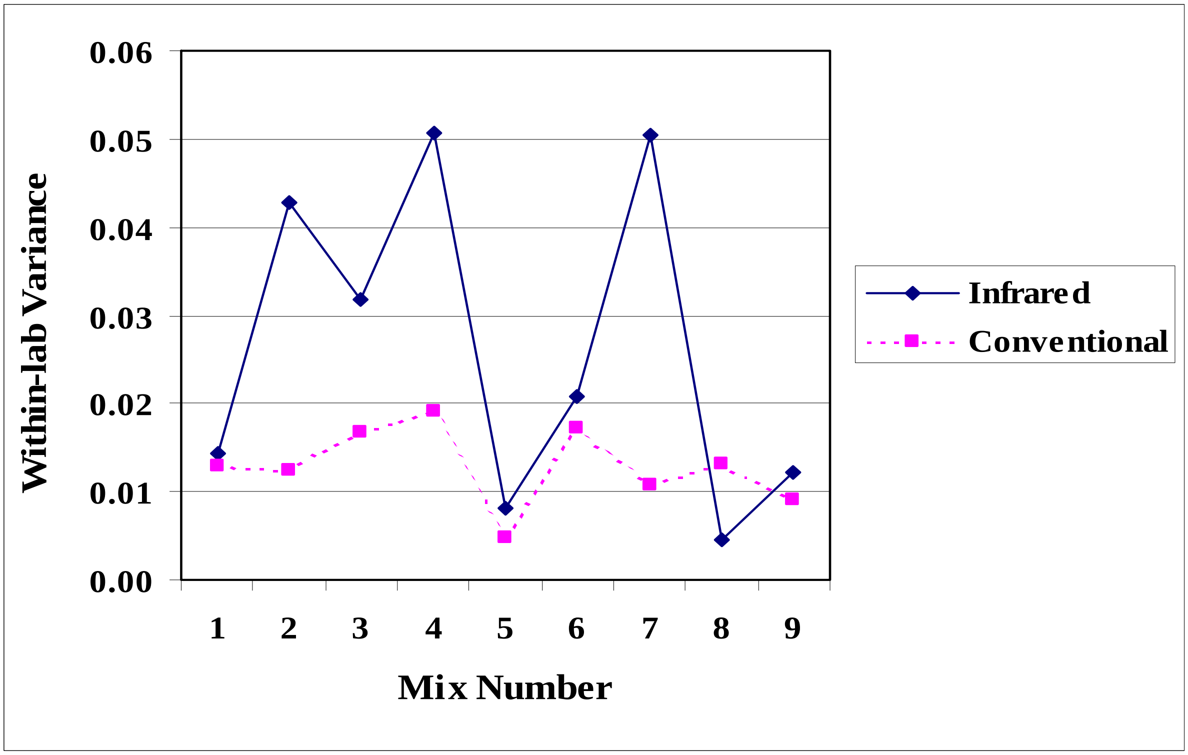

Figure 16 – Comparison of Conventional Oven vs. NTO for Within-lab Variance

APPENDIX

Florida Department of Transportation

JEB BUSH
GOVERNOR

State Materials Office
2006 NE Waldo Road, Gainesville, FL 32609
Phone (352)337-3100, Fax (352)334-1649

THOMAS F. BARRY, JR.
SECRETARY

March 2000

To: Participants in Ignition Oven Study

Thank you for your willingness to participate in this study to determine precision values for plant produced mix using the ignition oven. Your laboratory is one of twelve laboratories participating in a study that will determine the allowable difference between two test results for both “within laboratory” tests and “between laboratory” tests. The values will be determined for % asphalt cement content and certain sieve size gradations. The new precision values will encompass the variability inherent in sampling the truck as well as splitting the sample into the appropriate test size and the variability due to the operator and test equipment.

Over a period of one or two months you will receive seven large boxes of plant produced mix. Each box will contain a different type of mix. You are to heat the box in an oven at 300 °F for 3.0 hours in order to get the sample workable enough so that it can be properly quartered. Please do not vary from this time or temperature so as to be consistent with all other participants. Once heated, split out four samples to be tested in the ignition oven per FM 1-T 168 (attached). The weight of the split sample will be dependent on the mix type and will be written on the box. Next, burn the four samples independently in the ignition oven per FM 5-563 (attached). Use a correction factor of 0.0. Write the data on the attached worksheet as well as attaching the oven printout to the worksheet. Perform a washed gradation per FM 1-T 030 (attached). It is not necessary to calculate the % passing for each sieve, as this will be done at the State Materials Office.

It is very important that the same person perform the testing for all four samples of a particular mix type. However, it is not essential that the same person perform the testing for all seven mix types. If there are other trained personnel in the lab who routinely perform the ignition oven test, then it is encouraged to let him/her perform the testing on some of the seven mix types. This will allow the multi-operator between laboratory precision value to be adequately represented.

Please fax or mail the results as soon as you complete the testing for a particular mix type to:

Florida Department of Transportation
2006 NE Waldo Road
Gainesville, FL 32609
Attn: Greg Sholar

Fax: (352) 334-1649

Thank you again for your participation. Please call me at (352) 337-3278 if there are any questions.

Sincerely,

Gregory A. Sholar
Bituminous Engineer

Attachments: FDOT test methods (3 ea)
Sample worksheet (1 ea)
Blank worksheet (4 ea)

FDOT: IGNITION METHOD ROUND ROBIN STUDY
WORKSHEET SUMMARY

General Information	
Lab Name:	
Lab Location:	
Project No.:	
Technician:	
Date:	
Sample I.D.:	Lab No.:

Washed Sieve Analysis	
Tare Weight of Pan, g	
Initial Weight of Aggregate Sample, g	
Weight of Sample after Washing & Drying, g	
Wash Loss, g	
-200 from Sieve Analysis, g	
Total -200, g	

Ignition Test Data		
Chamber Temperature Setting, °C		
Basket Assembly Weight, g	(A)	
Basket Assembly + Sample Weight before test, g	(B)	
Initial Sample Weight, g (B - A)	(C)	
Basket Assembly + Sample Weight after test, g	(D)	
Final Sample Weight, g (D - A)	(E)	
Temperature Compensation, %		
Loss of Material, % of Mix (C - E)*100/C		
A. C. Content, % (from printout)		
Elapsed Time to Test Completion (min:sec)		

Note: Please attach furnace controller printout.

Sieve	Weight Retained (g)	Percent Retained (%)	Percent Passing (%)
1" (25.0mm)			
3/4" (19.0mm)			
1/2" (12.5mm)			
3/8" (9.5mm)			
No. 4 (4.75mm)			
No. 8 (2.36mm)			
No. 16 (1.18mm)			
No. 30 (600μm)			
No. 50 (300μm)			
No. 100 (150μm)			
No. 200 (75μm)			
Pan			
Total			

Comments: ______________________________

FDOT: IGNITION METHOD ROUND ROBIN STUDY

WORKSHEET SUMMARY

SAMPLE

General Information				Washed Sieve Analysis	
Lab Name:	State Materials Office			**Tare Weight of Pan, g**	
Lab Location:	Gainesville, FL			**Initial Weight of Aggregate Sample, g**	1850.1
Project No.:	Variability Study			**Weight of Sample after Washing & Drying, g**	1830.9
Technician:	John Doe			**Wash Loss, g**	19.2
Date:	03/08/00			**-200 from Sieve Analysis, g**	28.7
Sample I.D.:	Mix #1, Replicate #3	**Lab No.:**		**Total -200, g**	47.9

Ignition Test Data			Sieve	Weight Retained (g)	Percent Retained (%)	Percent Passing (%)
Chamber Temperature Setting, °C		538	**1" (25.0mm)**	0.0		
Basket Assembly Weight, g	**(A)**	3371.9	**3/4" (19.0mm)**	0.0		
Basket Assembly + Sample Weight before test, g	**(B)**	5371.9	**1/2" (12.5mm)**	98.2		
Initial Sample Weight, g (B - A)	**(C)**	2000.0	**3/8" (9.5mm)**	180.0		
Basket Assembly + Sample Weight after test, g	**(D)**	5222.0	**No. 4 (4.75mm)**	425.6		
Final Sample Weight, g (D - A)	**(E)**	1850.1	**No. 8 (2.36mm)**	245.4		
Temperature Compensation, %			**No. 16 (1.18mm)**	207.7		
Loss of Material, % of Mix (C - E)*100/C			**No. 30 (600µm)**	201.8		
A. C. Content, % (from printout)			**No. 50 (300µm)**	195.4		
Elapsed Time to Test Completion (min:sec)			**No. 100 (150µm)**	197.2		
Note: Please attach furnace controller printout.			**No. 200 (75µm)**	50.9		
			Pan	28.7		
			Total	1830.9		

Comments: