Oklahoma Department of Transportation

Use of Contractor's Test Results for Acceptance Purposes
Construction Control Directive No. **20020215**

February 15, 2002

Scope: To establish the procedure required to utilize the contractor's test results for acceptance purposes on contracts which contain the QA/QC Special Provision.

The Department maintains the responsibility to ensure that all materials used in the work are inspected and in conformity with the specifications. The contracts, which contain a QA/QC Special Provision, associate a value to the contractor's ability to furnish materials conforming to the specifications. In order to accept the contractor's material test results, which will ultimately determine his pay, it is essential that the Department verify the validity of those results.

The statistical process to validate the contractor's material test results is enclosed. This process compares the Department's results-which are considered valid-to the contractor's results. If the contractor's test results have been validated by this process, those results may be used alone, or in conjunction with, the Department's test results for acceptance purposes. Although this validation process will allow the intermingling of test results for a lot, every effort should be made to use one or the other. Intermingling should only occur when test results have been lost, or not acquired, and a test result is needed to achieve the four tests per lot.

Should the Residency office elect to use any or all of the contractors test results for acceptance and payment purposes(gradations and asphalt cement content and not roadway densities for example or, other combinations), the following procedure shall be used:

1. Samples of materials to be tested by the contractor and used for acceptance purposes are to be split with the Residency. The sampling and splitting process shall be performed by a certified technician and in the presence of Department personnel. Each split sample received by the Residency shall be marked (tagged) with the date, time, lot and sub-lot number and stored at the Residency office. Stored split samples may be discarded only after a lot is completed, the contractor's test results are established as valid,

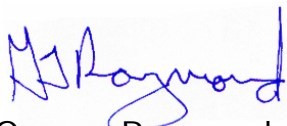and the lot is accepted by the Department with no deductions.

2. The contractor's test results shall <u>not</u> be utilized for the initial plant startup requirements and shall only be used: a) after test strips have been performed and final adjustments have been made to the plant production and b) when the contractor is actively adhering to his approved Quality Control Plan(includes maintaining up-to-date process control charts).

3. Of the initial split samples, test results shall be obtained by the Residency for the first four sub-lot samples. These four sub-lot test results shall be compared to the associated test results obtained by the contractor using the statistical process attached. Should the results of this statistical process reveal that the contractors tests are valid, the contractor's test results may be used for acceptance and payment purposes from that point forward or, until there is reason to suspect that out-of-specification material is being produced by the contractor. Should the results of this statistical process reveal that the contractors test results are not valid, acceptance and payment shall be based on the test results obtained by the Residency from the split samples. Use of the Residency's test results for acceptance and payment purposes shall continue until the contractor's test results can again be validated.

4. Comparison of the contractor's test results and the Department's test results shall occur on twenty-five percent(one sub-lot per lot) of the total sub-lot samples, independent of the process in No. 3 above. If during this comparison it is found that the contractors results cannot be validated, the Residency's test results shall be obtained from the stored split samples for the effected lot and be used for acceptance and payment purposes. Use of the Residency's test results for acceptance and payment purposes shall continue until the contractor's test results can again be validated.

5. The validation process should start anew anytime the contractor's results are found to be invalid, a change is made to the material(new mix design, change of material, etc.), or any other

situation which may give the Residency reason to suspect that the contractor's test results are skewed. Engineering judgement should be utilized when evaluating the validation process. For example, if the contractor's results for asphalt concrete oil content are determined to be invalid, the contractor's lab mold density results should also not be used since lab molded density is dependant on the oil content of the mix, etc.

6. The contractor must agree to split samples with IAS personnel.

It is the intent of this Directive that all parties responsible for Quality Assurance of construction materials(Contractor's QC, Residency, Independent Assurance) communicate and coordinate their actions and efforts to ensure quality materials are utilized on the project. If the Residency is contemplating utilizing the contractor's test results, all of the conditions and procedures indicated in this Construction Control Directive shall be discussed with the contractor at the pre-construction conference.

If the Residency does not wish to use the contractor's test results for acceptance purposes under this procedure or, the Residency has determined that the contractor's test results are invalid, the Residency <u>must</u> commit to furnishing acceptance test results to the contractor within the second working day after the material is sampled. If this information is conveyed to the contractor by phone message or fax, it is strongly suggested that the date, time and contractor's contact person who received the test results be documented in the project records.

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Statistical Comparison Process
Department Test Results versus Contractor's Test Results

In order to utilize the contractor's material test results for acceptance and payment, the Department must ensure that the contractor's results compare favorably with the Department's test results for the same lot of material. This comparison is made by the utilizing the following formula:

$$t = \frac{\left|\overline{X}_c - \overline{X}_g\right|}{\sqrt{\dfrac{1}{N_c} + \dfrac{1}{N_g}}\ \sqrt{\dfrac{(N_c - 1)\sigma_c^2 + (N_g - 1)\sigma_g^2}{N_c + N_g - 2}}}$$

where:

t	=	Called the t-statistic[1]. This value is compared to the critical value in Table 1. If this value is less than the critical value in Table 1, the contractor's test results are valid. If this value is greater than the critical value in Table 1, then there exists significant doubt as to the validity of the test results obtained by the contractor.
$\left\|\overline{X}_c - \overline{X}_g\right\|$	=	Absolute value of $\overline{X}_c - \overline{X}_g$
$\overline{X}_c$	=	The arithmetic mean of the contractor's test results.
$\overline{X}_g$	=	The arithmetic mean of the Department's test results.
N_c	=	The total number of contractor samples used in the analysis(two minimum)[2].
N_g	=	The total number of Department samples used in the analysis(two minimum)[2].
σ_c	=	The standard deviation of the contractor's test results.

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[1]This analysis assumes a producer's risk of 0.01.

[2]In this analysis, the contractor's sample results will be compared to the same split sample results obtained by the Residency. The number of contractor samples will always equal the number of Residency samples.

σ_g =   The standard deviation of the Department's test results.

Critical Values of the t-Statistic					
Degrees of Freedom $N_c + N_g - 2$	Critical t Value	Degrees of Freedom $N_c + N_g - 2$	Critical t Value	Degrees of Freedom $N_c + N_g - 2$	Critical t Value
2	9.925	14	2.977	26	2.779
3	5.841	15	2.947	27	2.771
4	4.604	16	2.921	28	2.763
5	4.032	17	2.898	29	2.756
6	3.707	18	2.878	30	2.750
7	3.499	19	2.861	31 to 40	2.704
8	3.355	20	2.845	41 to 60	2.660
9	3.250	21	2.831	61 to 120	2.617
10	3.169	22	2.819	121 to 250	2.597
11	3.106	23	2.807	250+	2.576
12	3.055	24	2.797		
13	3.012	25	2.787		

Table 1

Example for Initial Validation

In this example, the contractor will be placing asphalt concrete. The contract contains the QA/QC Special Provision and the Residency is contemplating using the contractor's test results for acceptance and payment. The contractor's pay for placing the asphalt concrete is based on four parameters: Asphalt Cement Content, Gradations, Air Voids, and Roadway Density. The first four sub-lots of production mix have been placed. Samples have been obtained and each sample has been split with the Residency. Both the Residency and the contractor have independently performed testing on the their respective sample splits. The Residency has received the results from the contractor. Can the Residency use the contractor's results for acceptance and payment?

Asphalt Cement Content

Lot/Sub-lot	Contractor's Results	Residency's Results
1/1	4.1	4.3
1/2	4.5	4.3
1/3	4.6	4.4
1/4	4.5	4.3

At first glance, it appears that the contractor's results compare favorably with the results the Residency achieved. To determine if the results compare statistically, we need to use the t-statistic formula. Utilizing the statistical function of your calculator or Lotus 1-2-3 we get the following information:

$$\overline{X} = 4.4250$$
$$\overline{X}_g = 4.3250$$
$$N = 4$$
$$N_g = 4$$
$$\sigma = 0.2217$$
$$\sigma_g = 0.0500$$
$$N + N_g - 2 = 6$$
$$t_{critical}(Table\_1) = 3.707$$

Plugging this information into the t-statistic formula:

$$t = \frac{|4.4250 - 4.3250|}{\sqrt{\frac{1}{4} + \frac{1}{4}} \sqrt{\frac{(4-1)(0.2217)^2 + (4-1)(0.0500)^2}{4+4-2}}} = 0.880$$

Since 0.880 is less than 3.707, the contractor's results for asphalt cement content compare

favorably with the Residency's results and can be used for acceptance and payment.

Gradations

Gradation comparisons are performed slightly different. Each individual sieve must be compared to validate all the gradations.

Lot/Sub-lot	Sieve Size										
	25.0 mm	19.0 mm	12.5 mm	9.50 mm	4.75 mm	2.36 mm	1.18 mm	600 μm	300 μm	150 μm	75 μm
Residency 1/1	100	94	83	70	47	31	25	20	11	6	3.8
Residency 1/2	100	91	84	70	46	30	23	19	11	6	4.0
Residency 1/3	100	95	86	71	46	28	22	18	11	6	3.5
Residency 1/4	100	97	90	75	49	30	23	19	11	6	3.4
Contractor 1/1	100	95	83	68	45	30	24	19	11	6	3.5
Contractor 1/2	100	98	87	72	49	32	24	20	11	6	3.8
Contractor 1/3	100	98	92	76	48	29	23	19	11	6	3.3
Contractor 1/4	100	98	89	77	48	29	23	19	11	5	3.3

25.0 mm Sieve: Obviously there is no difference between the Residency's results and the contractor's therefore, no statistical comparison is needed.

19.0 mm Sieve:
$$\overline{X}_c = 97.250$$
$$\overline{X}_g = 94.250$$
$$N_c = 4$$
$$N_g = 4$$
$$\sigma_c = 1.500$$
$$\sigma_g = 2.500$$
$$N_c + N_g - 2 = 6$$
$$t_{critical}(Table\_1) = 3.707$$

Plugging this information into the t-statistic formula:
$$t = \frac{|97.250 - 94.2500|}{\sqrt{\frac{1}{4} + \frac{1}{4}} \sqrt{\frac{(4-1)(1.500)^2 + (4-1)(2.500)^2}{4+4-2}}} = 2.058$$

Since 2.058 is less than 3.707, the contractor's results for the 19.0 mm sieve compare favorable with the Residency's results. Without showing all of the calculations here, the results of the remaining sieves are as follows:

12.5 mm Sieve	t=2.058
9.50 mm Sieve	t=0.737
4.75 mm Sieve	t=0.447
2.36 mm Sieve	t=0.264
1.18 mm Sieve	t=0.361
600 µm Sieve	t=0.522
300 µm Sieve	t=0
150 µm Sieve	t=1.000
75 µm Sieve	t=1.102

Since all of the t-statistic results for each sieve are less than 3.707, the contractor's gradation results compare favorably with the Residency's results and may be used for acceptance and payment.

Air Voids

Lot/Sub-lot	Contractor's Results	Residency's Results
1/1	2.5	2.6
1/2	4.3	3.0
1/3	4.0	3.9
1/4	3.3	3.9

Given the above test results for air voids, we obtain the following information:

$$\overline{X} = 3.525$$
$$\overline{X}_g = 3.350$$
$$N = 4$$
$$N_g = 4$$
$$\sigma = 0.8016$$
$$\sigma_g = 0.6577$$
$$N + N_g - 2 = 6$$
$$t_{critical}(Table\_1) = 3.707$$

Plugging this information into the t-statistic formula:

$$t = \frac{|3.525 - 3.3500|}{\sqrt{\frac{1}{4} + \frac{1}{4}}\ \sqrt{\frac{(4-1)(0.8016)^2 + (4-1)(0.6557)^2}{4+4-2}}} = 0.338$$

Since 0.338 is less than 3.707, the contractor's test results for air voids compare favorably with the Residency's results and may be used for acceptance and payment.

Roadway Density

Lot/Sub-lot	Contractor's Results	Residency's Results
1/1	92.4	96.6
1/2	92.1	94.5
1/3	90.5	95.6
1/4	91.3	94.4

Given the above results for roadway density, we obtain the following information:

$$\overline{X_c} = 91.575$$
$$\overline{X_g} = 95.275$$
$$N_c = 4$$
$$N_g = 4$$
$$\sigma_c = 0.8539$$
$$\sigma_g = 1.0372$$
$$N_c + N_g - 2 = 6$$
$$t_{critical}(Table\_1) = 3.707$$

Plugging this information into the t-statistic formula:

$$t = \frac{|91.575 - 95.275|}{\sqrt{\frac{1}{4} + \frac{1}{4}}\ \sqrt{\frac{(4-1)(0.8539)^2 + (4-1)(0.10372)^2}{4+4-2}}} = 5.508$$

Since 5.508 is greater than 3.707, there exists significant doubt as to the validity of the contractors results. The contractor's results for roadway density should not be used until their test methods or sampling methods can be analyzed to determine the cause for the discrepancy with the Residency's results. Once the discrepancies have been analyzed and

addressed, this process for validation must be repeated if the Residency wishes to utilize the contractor's roadway density results for acceptance and payment.

The residency should use judgement in accepting any of the contractor's results even though they may be validated by this process. If during the validation process you find that all of the parameters(gradations, air voids, roadway density) compare favorably except the asphalt cement content parameter. It would be wise not to accept the air voids and roadway density test results from the contractor given that these results are contingent on the asphalt cement content of the material. It should also be noted that this comparison could also give the Residency cause to analyze their sampling and test methods.

Example for Re-validation

In the previous example for roadway density, we found that the contractor's results did not compare favorably with the Residency's results. The contractor-having this information-has analyzed his test procedures, discovered the apparent problem, and taken corrective action to bring his results in-line with the Residency's results. The Residency now wishes to give the contractor a "second chance". The re-validation process for roadway density begins again with the second lot of material:

Lot/Sub-lot	Contractor's Results	Residency's Results
2/1	92.6	93.1
2/2	93.2	93.4
2/3	93.6	93.6
2/4	93.8	93.6

Given the above results for roadway density, we obtain the following information:

$$\overline{X} = 93.300$$
$$\overline{X}_s = 93.425$$
$$N_c = 4$$
$$N_s = 4$$
$$\sigma = 0.5292$$
$$\sigma_s = 0.2363$$
$$N_c + N_s - 2 = 6$$
$$t_{critical}(Table\_1) = 3.707$$

Plugging this information into the t-statistic formula:

$$t = \frac{|93.300 - 93.425|}{\sqrt{\frac{1}{4} + \frac{1}{4}} \sqrt{\frac{(4-1)(0.5292)^2 + (4-1)(0.2363)^2}{4+4-2}}} = 0.4314$$

Since 0.431 is less than 3.707, the contractor's test results for roadway density compare favorably with the Residency's results and can be used for acceptance and payment from this point forward.

Example for Continuous Validation

The initial validation of the contractor's test results is only the first step in determining that the contractor's test results can be used for acceptance and payment. Validation must also occur continuously throughout the life of the project to ensure that sampling and testing conditions have not changed.   Although this comparison shall be performed on all the parameters of the QA/QC Special Provision, this example will only illustrate the process used for the asphalt cement content. The other parameters would be continuously validated similarly.

In this example, the contractor's results for asphalt cement were validated initially. Production has began on the asphalt mix and now 25% of the contractor's results must be validated. The Residency has chosen to randomly select one sub-lot out of each lot to meet the 25% requirement. In this case, sub-lot number 2 in lot 2 was selected.

Lot/Sub-lot	Contractor's Results	Residency's Results
1/1	4.1	4.3
1/2	4.5	4.3
1/3	4.6	4.4
1/4	4.5	4.3
2/2	4.6	4.3

This process is cumulative(accounts for all of the previous comparisons) until a change occurs such as a mix design change or, changes in sources of material. Given the above test results thus far, we obtain the following information:

$$\overline{X} = 4.460$$
$$\overline{X}_g = 4.320$$
$$N_c = 5$$
$$N_g = 5$$
$$\sigma = 0.2074$$
$$\sigma_g = 0.0447$$
$$N_c + N_g - 2 = 8$$
$$t_{critical}(Table\_1) = 3.355$$

Plugging this information into the t-statistic formula:

$$t = \frac{|4.460-4.320|}{\sqrt{\frac{1}{5}+\frac{1}{5}} \; \sqrt{\frac{(5-1)(0.2074)^2 + (5-1)(0.0447)^2}{5+5-2}}} = 1.476$$

Since 1.146 is less than 3.355, the contractor's test results continue to compare favorably with the Residency's results and can continue to be used for acceptance and payment.

Production of the material continues by the contractor and now the Residency obtains the results for the next randomly selected sub-lot:

Lot/Sub-lot	Contractor's Results	Residency's Results
1/1	4.1	4.3
1/2	4.5	4.3
1/3	4.6	4.4
1/4	4.5	4.3
2/2	4.6	4.3
3/3	4.1	4.0

Given the above test results thus far, we obtain the following information:

$$\overline{X}_c = 4.400$$
$$\overline{X}_g = 4.267$$
$$N_c = 6$$
$$N_g = 6$$
$$\sigma_c = 0.2366$$
$$\sigma_g = 0.1366$$
$$N_c + N_g - 2 = 10$$
$$t_{critical}(Table\_1) = 3.169$$

Plugging this information into the t-statistic formula:

$$t = \frac{|4.400-4.267|}{\sqrt{\frac{1}{6}+\frac{1}{6}}\;\sqrt{\frac{(6-1)(0.2366)^2+(6-1)(0.1366)^2}{6+6-2}}} = 1.195$$

Since 1.195 is less than 3.169, the contractor's test results continue to compare favorably with the Residency's results and can continue to be used for acceptance and payment.

This process would continue until the work has been completed or the residency elects to no longer utilized the contractor's test results. Had the contractor's test results been proven invalid after sub-lot 3/3, the Residency would obtain the test results from the stored split samples and acceptance and payment for lot 3 would be based on the Residency's test

results. Acceptance and payment would continue to be based on the Residency's test results from that point forward or, until the contractor's test results could again be validated.