Assessment and Analysis of Test Data

Presented by SARF

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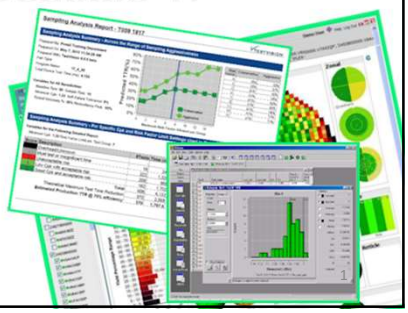
COLTO: Section 8200
Quality Control (Scheme 1)



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Standard Specifications for Road and Bridge Works for State Road Authorities
Section 8200: Quality Control (Scheme 1)

8201: Scope

This section describes one scheme for determining, by means of tests and measurements and by applying judgement plans, whether certain requirements specified in the specifications in regard to the properties of materials and workmanship are being complied with.

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8202: Judgement Plans, General

Two types of statistical judgement plans are used:

Judgement Plan A:

- Used for judging measurements of the levels and thicknesses of pavement layers.
- In accordance with this method the compliance of the individual results only with the specified requirements is determined.
- The variability of test results is not computed.

Judgement Plan B:

- Used for judging measurements of in situ densities, the strength of concrete, and other certain properties.
- The variability of the values of tests is calculated and applied where acceptance limits for sample means are determined.

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8203: Definitions

Lot:

- A lot is a sizeable portion of work or quantity of material which is assessed as a unit for the purposes of quality control.
- A lot is selected to represent material or work produced by essentially the same process and from essentially the same materials.

Random Sample:

- A random sample is a group of “n” test measurements at “n” separate test positions or on “n” sample portions obtained from the lot in a unbiased manner.
- Random sampling shall mean stratified random sampling.

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8203: Definitions

Sample mean :

The arithmetic mean of a set of test results constituting the sample.

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

Sample standard deviation:

$$s = \sqrt{\frac{\sum_{j=1}^{n} (x - \bar{x})^2}{n-1}}$$

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8203: Definitions

Specification Limit L_s:

The limit value of the property of any product outside which not more than a certain specified percentage (φ) of the population of values representing an acceptable product property is allowed to lie.

Acceptance Limit L_a:

The limit value of the sample mean within which the lot will be accepted.

Rejection Limit L_r:

The limit value of the sample mean outside which conditional acceptance cannot be considered.

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8203: Definitions

Outliers:

Where, in a sample, one or more test results differ significantly from the other values obtained, this difference could be ascribed to an assignable cause, in which case such test result shall be regarded as an outlier and disregarded when assessing the lot.

φ (%):

φ is the maximum percentage of a statistical population of values of a product property permitted to lie outside the specification limits where the product may still be regarded as being acceptable.

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8204: General Requirements

(a) Determine the lot size:

(i) Road Construction Layers:
Where production is on a continuous basis, a lot shall normally mean the product of one day's work and shall not exceed the product of two full days' work.

(ii) Concrete:
Lot size is determined by the engineer, and vary considerably.

(iii) Other:
Lot size is determined by the engineer

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8204: General Requirements

(b) Random Sampling:

- All samples shall be taken in a stratified random pattern.
- Use shall be made of tables of random numbers.
- Follow the instructions in TMH5: sampling for Road Construction.

(c) Sample sizes:

- The engineer will, in advance, determine sample size “n”.
- The larger the sample the more reliable the result.
- No sample size may be smaller than those given in sub clause 8205(a) and 8206(a).

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8204: General Requirements

(d) Outliers:

- Where a test result deviates greatly from the remainder of the lot it shall, if possible, be re-examined by further testing.
- If there is reasonable evidence to suggest that the test result is erroneous, it shall be regarded as an outlier, rejected and replaced with a fresh test result.
- Where repeating a test or re-examining a test result is impossible, Method 1 shall be used for identifying outliers for all work, except basecourse and asphalt work. Method 2 shall be used for identifying outliers for basecourse and asphalt work.

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8204: General Requirements

(i) Method 1 (t-distribution, compare 2 means):

- Calculate T_0 from:

$$T_0 = (x_0 - \bar{x}_n) / s_n$$

where:

$\bar{x}_n$ = arithmetic mean of test results
s_n = sample standard deviation
x_0 = value of the test result differing most from the mean.

- Compare the value of T_0 with the value of T for the applicable value of n, from table 8204(d)/1.
- If the absolute value of T_0 is greater than T, than x_0 is an outlier.

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8204: General Requirements

(i) Method 1 (continued):

- Where S_n is very small, it may be cause for a value being wrongly classified as an outlier.
- For this purpose a minimum value S_n(min) shall be determined for S_n as follows:

$$S_n(\min) = \bar{s}_n \sqrt{\frac{(\chi^2_{0.99;n-1}}{n-1}}$$

where:

$\chi^2_{0.99;n-1}$ is obtained from table 8204(d)/2

$\bar{S}_n$ = mean value of S_n for the particular property as determined by records of previous work.

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8204: General Requirements

(ii) Method 2:

- In the case of basecourse and asphalt work the following procedure shall be used for identifying outliers where it is impossible to repeat a test or to reinvestigate a test result:
- Calculate the absolute value C_0 from:

$$C_0 = | x_0 - \overline{x}_n |$$

where:

x_0 represents the possible outlier
$\overline{x}_n$ = arithmetic mean of test results

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8204: General Requirements

(ii) Method 2 (Continued):

- Compare C_0 with critical value $C_{0,01;n} \cdot \sigma$:

where:

σ = standard deviation of the population derived from historical data.

- If $| C_0 | > C$, the test result x0 shall be regarded as an outlier, and shall be excluded from the sample.
- critical values for different values of n are given in table 8204(d)/3 for basecourse and table 8204(d)/4 for asphalt.
- Every outlier shall be discarded and replaced by another random test value.
- The sample mean $\overline{x}_n$ and the sample standard deviation s_n shall than be recalculated.

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8204: General Requirements

(e) Resubmission:

- In order to be able to determine theoretically whether there is a significant difference between two sets of test values (suffixed a and b), the Fisher F-test shall be conducted and, if necessary, also the t-test.

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8204: General Requirements

(e) Resubmission:

- Calculate the value of :

$$F = \frac{S_g^2}{S_k^2}$$

where:
S_g = the greater value of S_a and S_b(Standard deviations of a and b).
S_k = smaller value of S_a and S_b.

- Obtain the value for :

$$F_{0,05\ vg;vk}$$

from table 8204(e)/1
where:
v_g = sample size minus 1, from the sample with the largest standard deviation.
v_k = sample size minus 1, from the sample with the smaller standard deviation.

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8204: General Requirements

(e) Resubmission:

- Where $F > F_{0,05\ vg;vk}$ a significant difference occurs between the two sets of test values.
- Where $F < F_{0,05\ vg;vk}$ the difference is not necessarily significant, and the t-test shall also be conducted with a view to obtain a decision.

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8204: General Requirements

(e) Resubmission:

- Conduct the t-test:

$$s = \sqrt{\frac{(n_a - 1)s_a^2 + (n_b - 1)s_b^2}{n_a + n_b - 2}}$$

- Then calculate t:

$$t = |\bar{x}_a - \bar{x}_b| / s \cdot \sqrt{1/n_a + 1/n_b}$$

where:

$|\bar{x}_a - \bar{x}_b|$ = absolute value of the difference between $\bar{x}_a$ and $\bar{x}_b$

- The value of $t_{0,05;v}$ is obtained from table 8204(e)/2, where:

$$v = n_a + n_b - 2$$

- Where $t > t_{0,05;v}$ a significant difference between the sets of results is indicated.
- Where $t < t_{0,05;v}$ the difference in means is not significant.

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8205: Judgement Plan A

- For surface levels and layer thicknesses.

(a) Taking the levels:

- Level measurements shall be taken in a random pattern, before and after a layer has been constructed.
- Levels shall be taken at exactly the same point before and after construction.
- The number of measurements of layer thicknesses shall be at least 30 and that of surface levels at least 50.

(b) Calculating the deviations:

- Compute the difference between the specified level or thickness and the actual level of or thickness.
- Compute the mean thickness of the layer.

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8205: Judgement Plan A

(d) Assessing the results:

(i) Surface levels:

- The lot will comply with the requirements specified for surface levels if at least 90% of all surface levels are within the H_{90} tolerance specified in each case, before any level corrections are made.
- H_{90} 15mm – i.e. at least 90% of all surface levels measured are within 15 mm, plus or minus, of the specified levels.

(ii) Layer thickness:

- the layer will comply with the requirements specified for layer thickness if at least 90% of all thickness measurements taken are equal to or thicker than the specified thickness, minus the D_{90} tolerance specified in the relevant section, before any thickness corrections are made.
- D_{90} 20mm – i.e. at least 90% of all thickness measurements are equal to or thicker than the specified thickness, minus 20 mm.

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8206: Judgement Plan B

- For in situ densities, strength of concrete and certain other properties.

(a) Taking samples and testing properties:

- Determine the sample size (n) by taking into consideration the minimum sample sizes given in table 8206/2.
- Take the samples in a stratified random pattern as specified in sub clause 8204(b).

(c) Calculating standard deviation and the mean of sample values:

- Use the sample results for calculating the standard deviation S_n and the mean $\bar{x}_n$ of the sample values in accordance with definitions in clause 8203.
- Compute the mean thickness of the layer.

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8206: Judgement Plan B

(c) Calculating standard deviation and the mean of sample values (cont'd):

- Where it is resubmission, the first and second sets of sample results shall be used for determining a combined sample mean $\bar{x}_{ab}$, standard deviation S_{ab} and sample size n_{ab} as determined by:

$$n_{ab} = n_a + n_b$$

$$\bar{x}_{ab} = (n_a \bar{x}_a + n_b \bar{x}_b) / (n_a + n_b)$$

$$s_{ab} = \sqrt{\{(n_a - 1)s_a^2 + (n_b - 1)s_b^2 + N_a(\bar{x}_{ab} - \bar{x}_a) + N_b(\bar{x}_{ab} - \bar{x}_b)^2\} / (n_a + n_b - 1)}$$

where:

a = first set of test values
b = second set of test values
ab = combined properties

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8206: Judgement Plan B

(d) Determining the judgement limits:

(i) First submission:

- For the lower limit:

$$L_a = L_s + S_n \cdot k_a$$

- Accept the lot if the sample mean $\bar{x}_n$ is equal to or greater than the acceptance limit L_a, otherwise reject the lot.

- For the upper limit:

$$L'_a = L'_s - S_n \cdot k_a$$

- Accept the lot if the sample mean $\bar{x}_n$ is equal to or greater than the acceptance limit L'_a, otherwise reject the lot.

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8206: Judgement Plan B

(d) Determining the judgement limits (Continued):

- For a double limit specification:

$$L_a = L_s + S_n \cdot k_{ad}$$
$$L'_a = L'_s - S_n \cdot k_{ad}$$

- Accept the lot if the sample mean $\bar{x}_n$ falls between the lower acceptance limit L_a and the upper acceptance limit L'_a or is the equal to either one, otherwise reject the lot.

- k_a (single limit) can be obtained from table 8206/4 while k_{ad} (double limit) can be obtained from table 8206/5.

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8206: Judgement Plan B

(d) Determining the judgement limits (continued):

(ii) Resubmission:

- For the single limit specification:

$$L_a = L_s + S_{ab} \cdot k_a$$
$$L'_a = L'_s - S_{ab} \cdot k_a$$

- Accept the lot if $\bar{x}_{ab} \geq L_a$ in case of a lower limit specification and if $\bar{x}_{ab} \leq L_a$ in case of an upper limit specification, otherwise reject the lot.

- For a double limit specification:

$$L_a = L_s + S_{ab} \cdot k_{ad}$$
$$L'_a = L'_s - S_{ab} \cdot k_{ad}$$

- Accept the lot if $L_a \leq \bar{x}_{ab} \leq L'_a$, otherwise reject the lot.

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