Engineering Brief # 17

Date: June 21, 1977

In Reply Refer To: AAP-580

Subject: Engineering Brief No. 17, Statistical Quality Control Specifications

From: Chief, Airports Engineering Division, AAP-500
To: All Regions

Attn: Chiefs, Airports Division

Engineering Brief No. 17, Statistical Quality Control Specifications, reviews the concepts of conventional testing and acceptance procedures and explains the need for modifying our construction standards, contained in AC 150/5370-10, to incorporate acceptance of materials and construction based on statistical concepts. It also lists some of the concepts of a statistical quality control specification.

Any comments you may wish to offer will be appreciated.

ORIGINAL SIGNED BY:
LEONARD E. MUDD

Enclosure

ENGINEERING BRIEF NO. 17

STATISTICAL QUALITY CONTROL SPECIFICATIONS

AAP-580 is in the process of implementing specifications which are based on the concepts of statistical quality control. The revised standard for Item P-401, Bituminous Surface Course, provides for acceptance of the pavement, for density, on a statistically based specification. Other standards will be modified accordingly.

The question has often been asked, "Why is a statistical quality control specification necessary?" In an effort to answer this question a brief review of conventional procedures is presented.

A. Review of Conventional Procedures.

1. AASHTO Road Test Results

Although it has been known for a long time that variability existed in highway materials and construction processes, its significance was not fully understood until the results

of the AASHTO Road Test conducted in 1959 were evaluated. This test clearly demonstrated that even with well trained inspectors, well equipped laboratories and competent contractors, it was still not possible to meet all of the specifications all of the time. This can be seen in Table 1.

TABLE 1. AASHTO ROAD TEST

Embankment Construction Control

Loop Number	Percent Tests Within Specification: Field Moisture	Field Density
1	81	82
2	77	80
3	92	77
4	88	82
All Loops	83	80

Subbase Thickness Design (inches)	Percent Within Tolerances
4	90
8	84
12	91
16	66

As a result of the AASHTO tests it was concluded that failure to meet specifications all the time was no indication that the product would fail to perform as intended or provide an adequate service life. However, it did expose the lack of understanding of the specifications that were being used. The problem was not that inadequate facilities were being built, but that the knowledge of what was achievable was based on traditional methods of determining compliance, which were not able to provide accurate information about the quality of the product being received.

2. Single "Representative Sample" Concept

Sampling and testing of construction materials for conformance with specification requirements have always been an integral part of highway agencies responsibilities. The concept of single sampling is the basis of most highway agencies present sampling and testing programs. The idea persists that a single test on any small portion or so-called "representative sample" indicates the true quality of the material. If any test result is not within some arbitrary limits, the assumption is made that there is something wrong with the material, construction, sampling or testing. It should be recognized that one or two samples do not present a valid picture of the actual variability of the material characteristic being sampled. Based on the concepts of probability, either a passing or failing sample could occur by chance and be due to the inherent variation of

either the material or the sampling or testing practices. In addition most current specifications provide a sharp line of demarcation between passing/failing. This approach does not realistically represent the facts of life. The fact is that current specification requirements do not recognize the natural variability of materials or construction.

In order to obtain realistic information about material characteristics it appears that a sampling procedure which recognizes the inherent variation of these characteristics should be adopted.

3. Resampling

Such terms as check, investigational, confirmation, and referee samples have come into being to either confirm or document the cases where "failures" have occurred. In such a situation the material is usually accepted if the results of the sampling procedure indicate a passing test. From a statistical point of view there are several problems associated with this practice. The first problem is that the number of samples taken has a direct bearing on the specification limits which are established to determine acceptability. Another problem is that the act of taking a second sample, if the first one failed, results in a "conditional probability" situation which increases the chance of approving unacceptable material.

4. Substantial Compliance

Under most current specifications a sample, assumed to be "representative" of the material or construction, is tested. If the test result is within stated tolerances the material or construction passes and is accepted. If the test result is not within tolerances the material or construction fails to pass. Engineering judgement must then be applied and a decision made as to whether the material should be retested or whether it may be said to substantially comply" because the deviation will cause little impairment of performance. Substantial compliance has not been defined, and the degree of acceptable variation will differ from engineer to engineer and from job to job. It would appear to be to everyone's advantage (FAA, contractor, supplier, sponsor) if the specification clearly defined the degree of compliance which is desired before the field decision is made.

5. Sampling Location

The location at which a "representative sample" is taken is left to the discretion of the resident engineer. This fact makes the sampling process subjective and allows bias on the part of the engineer to be introduced. For example an engineer has to decide whether to sample from a location which visually "appears" to be satisfactory or unsatisfactory. The result of this decision places an unfair

proportion of "sampling risk" in the hands of one party or the other.

It would appear that a sampling procedure which gives every part of a material an equal chance of being selected, would be preferred by both the FAA, contractor and material supplier.

6. Specification Tolerances

Specification tolerances should be such that a contractor or material supplier, applying normal control procedures, will run a minimum risk of having acceptable material rejected. Present practice has often resulted in the use of engineering judgement when the desired quality and tolerance limits were set for a particular specification requirement. Although this has often resulted in satisfactory specifications it has occasionally placed a great deal of the risk of producing satisfactory material, which is later rejected, in the hands of the producer. This is because the inherent variability of the material characteristic being considered has not been properly taken into consideration.

A specification that has tolerances which more accurately reflect the inherent variability of the material being tested, should be preferred by all parties concerned,

B. Concepts of Statistical Quality Control Specifications.

Based on the above discussion we feel that a basic change in our acceptance sampling and testing procedures is indicated. Therefore, we propose to modify our construction standards to incorporate acceptance of materials and construction based on statistical concepts. Listed below are some of the basic concepts of statistical quality control specifications:

1. A test result is not the same as the property of the material being measured. The test result should be viewed as an estimate of the material property.

2. It is impractical to test all of the material or all of the end products on any construction project, therefore, a sampling plan must be employed. Samples may or may not adequately represent the total material process. Variations exist to some degree in whatever properties are measured. Not only do real variations exist, but apparent variations by errors in sampling and testing.

3. Statistical techniques, including random sampling, can be used to describe the probability that properties of the materials are within some desired range. However, it must be recognized that some material that is better than and some material that is worse than the desired range may be used in any sampling program.

4. Specifications must recognize variability and be written on a probability rather than on an absolute basis.

5. Statistical procedures cannot replace effective inspection. Proper inspection will always be needed to eliminate mistakes, either accidental or intentional.

6. Both the contractor and the contracting agency must have a clear understanding of how measurements will be made, when and how samples will be taken, and how the results will be interpreted.

In summary, the distinguishing elements of a statistical quality control specification are as follows:

1. Assures unbiased quality information.

2. Provides for objective evaluation of quality characteristics in terns of both central tendency (mean) and dispersion (standard deviation).

3. Acceptance decisions are made on a rational basis.

Statistically developed specifications are both practical and realistic because they provide a rational means for achieving the highest overall quality of the material or construction, while recognizing and providing for the variability of the process and the product.

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