Research and Development in Applications of Quality Control to Highway Construction

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The previous author has presented the tools of quality control, the statistics. I will discuss the research program of the Office of Research and Development, Bureau of Public Roads, in the statistical approach to quality control.

Dr. Irick in his paper, "Basic Concepts of Statistical Quality Control," has talked of the variability of materials, the variability of tests, and the variability of people. If the information he has given us, along with other information of like nature which has been developed in research projects, is considered, it is apparent that it is time to review our methods of specification writing and to implement research which will establish methods of including these variables in highway specifications.

Present specifications, in some instances, do take cognizance of such variables by allowing tolerances on specified values. However, such tolerances are based more often on engineering judgment than on statistically valid data. Even where tolerances are allowed in the 100 percent conformance specifications, it has been customary for the engineer to use engineering judgment in accepting or rejecting an item of construction when some test results are outside of specification limits. He has based his judgment upon his knowledge of materials and tests and of the criticalness of the particular item to the performance of the highway. Engineering judgment has produced good construction. However, in the case of postconstruction inspection and literal interpretation of the specifications, this use of judgment is being questioned. It is imperative that new methods of control of highway construction be studied and methods developed which will accurately express the construction requirements and evaluate compliance to the specifications.

Mr. Robert F. Baker, director of the Office of Research and Development, has appointed a task group of technical specialists to develop
research in the statistical approach to quality control. The task group has studied the work of others in this area, has consulted with engineers who are knowledgeable in quality control and statistics, and has prepared a plan and a program for obtaining information which will enable the writing of specifications based upon research data.

The plan of the task group encompasses the following:

1. The education of the industry as to the need for the statistical approach to quality control.
2. The developing of guides for research to establish statistical parameters.
3. The correlation of a nationwide program of research.
4. The gathering and dissemination of data for use by the states.
5. The design and implementation of experimental projects by which the findings of the research program will be evaluated.

The nationwide program of research is underway. Correlation of this program is being carried out by the task group and detailed guides for various aspects of the program have been prepared. These guides are being distributed to the states for their use.

In nearly all research, it is necessary to start from a basic assumption. In this program, the task group has made the assumption that present acceptable highway construction is good construction and can be used as a basis or pattern for future construction. The entire research project then is dependent upon the designing of methods of measuring presently acceptable construction in terms or values which may be translated to specifications which can be used to control future construction.

Before we can translate values to a specification, we must decide what is needed in a specification. The task group believes that a specification should be designed to fulfill these four basic functions:

1. To provide a standard guide for the contractor to use in preparing his bid.
2. To outline the required characteristics of materials, products, or completed work.
3. To provide guidelines for construction methods which are necessary to the production of desired results.
4. To state the basis for acceptance, which should include sampling and testing methods.

To fulfill its purpose, a specification must be complete and it must be enforceable. To be complete, a specification must contain a detailed listing of the identifying or quality control characteristics and acceptable limits of variation for measurable properties. It must also state definitely the method of test, the point and method of sampling, and the sampling
frequency or pattern. Most important of all, the specification must state definitely the basis for acceptance or rejection of the material or work.

The task group, in their study of specifications and methods of expressing them, have, so far, concerned themselves only with the establishing of the required characteristics of materials and processes and the basis of acceptance or rejection of each. The statistical method appears to be a suitable tool for both of these processes. The required characteristics of the materials and processes can be measured and expressed in the statistical terms of $\bar{X}$ and $\sigma$ which were defined by Dr. Irick. These statistical terms or parameters can then be used to compute limits and design sampling and testing programs which will adequately evaluate the quality of the material or process.

To generate interest in this project, members of the task group met with representatives of each state and bureau personnel during the months of November and December 1963. The plans and procedures of the project were explained at each meeting.

Each state has been invited to undertake one or more projects in which it will evaluate some portion of its present construction. The task group will coordinate these projects so that a nationwide effort will result. Several states in different areas of the United States will work with portland cement concrete, several others with asphalt mixes, others with pavements, etc. It is hoped, in this way, to obtain statistical parameters defining various materials and processes which will be transferable throughout the country.

The task group has written detailed guides for several of the areas of construction and hopes to complete this work in the near future. The basic pattern of each guide is the same and outlines the general research as follows:

1. The state will select a material or an item of construction for which it wishes to establish the parameters and to develop acceptance limits and sampling plans.
2. For each material or process selected, the significant quality control characteristics will be listed.
3. A sampling plan will be designed which will assure randomness of sampling. Methods of sampling and testing will be specified. These should be AASHO or ASTM standards where possible.
4. The sampling plan will be applied to the material or item of acceptable construction. A minimum of 50 duplicate samples from each of 3 projects is recommended. If previous knowledge of the value of sigma for the process or material is available, a smaller number of samples may be warranted; however, this number must be calculated using the approximate sigma.
5. Each duplicate sample should, where possible, be divided into two equal samples. This is for the purpose of making an analysis of variance which, with the duplicate samples, will make it possible to calculate the sampling and testing variances.

6. Obtain measurements of selected characteristics on each sample portion by routine standard test methods.

7. Compute the average $\bar{X}$ and the overall variance, the sampling variance, the testing variance, and $\sigma$ for each characteristic.

8. For the purpose of writing specifications, each specified characteristic must be rated or classified as to its importance to the proper functioning of the highway for the purpose of establishing a confidence level for control. The task group has tentatively selected 90 and 95 percent as the levels of control for minor and major items.

This general guide and the more detailed guides for each construction element or material will be transmitted to the states as patterns for the research project. It is not necessary that each state follow these guides. However, the members of the task group have found from discussion with state personnel that sampling and testing procedures are almost as numerous as states. It is hoped that some uniformity of procedure may be established for this project. If standard procedures are not used in this project, it is very important that this be noted when the results are reported. It is also important that the analysis of variance be performed in order that more of the material and process variables be transferable. If a state has an estimate of its sampling and testing variance, it can add material variance from known sources and write valid specifications.

Guides for writing specifications under this system will be developed. However, before general recommendations of this approach to specification writing can be assured, it will be necessary to evaluate the method through the construction of experimental projects. Sample specifications will be written using the parameters established in this project. Limits will be calculated and a sampling plan designed for the levels of control chosen for each item. Studies will be made of the relationships among level of control, performance, and cost. It is planned that several of these projects will be constructed during the summer of 1965.

The task group is also charged with the responsibility of gathering information concerning the variation of materials and processes of highway construction from all possible sources. This information will be solicited from all agencies concerned with such construction and from any other agency who may have applicable data. This information will
be analyzed and disseminated to the states. The task group has computer programs written for the purpose of computing the average and sigma and also for performing the analysis of variance. These programs will be made available to the states upon request. Information as to coding of the data will be distributed shortly.

The task group has its plans and guides for the first phase of the project, the data gathering phase, nearly complete. Now the states must collect the necessary data if this project is to succeed. Much planning and study is still necessary before the final phases of specification writing and construction of evaluation projects may be undertaken. However, the enthusiasm with which this project has been received, all over the country, would seem to assure its accomplishment in a relatively short time.