

Structural Tolerances

The Problem and the Approach

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Increased public and political interest in highway construction as a result of the Interstate Highway Program has created an atmosphere in which inspectors and engineers are becoming more reluctant to exercise "engineering judgment" in acceptance or rejection of work. Under such conditions it becomes more important to develop a "statistical basis" or "tolerance curve" as specification controls, recognizing that laboratory precision cannot be economically obtained under jobsite conditions.

•THE PROBLEM of permissible construction tolerances has plagued mankind from prehistoric time when he first acquired the capability of adapting the materials of his environment to serve better his needs or his convenience. The controversy which could result between the maker and the purchaser of the first stone wheel can be well imagined. How much out-of-round would be permitted? How smooth must the rim be? How much off-center could the axle hole be placed? These questions had to be resolved by compromise on tolerances that would satisfy the needs of the purchaser and would be within the capabilities of the maker to produce. This might be called "engineering judgment" and some sort of refinement of this process has followed the construction industry from the stone ages to the present.

The magnitude of the Interstate Highway Program has focused attention on every aspect of the highway construction industry. The huge expansion of plant and personnel required since 1956 to accommodate this program has undoubtedly contributed to a condition which resulted in imperfections in construction that might not have occurred in a normal program. The public and political interest inherent in such a program has probably resulted in a tendency to magnify some of the imperfections out of proportion to their real significance in producing a satisfactory finished product.

The specifications under which most highway structures are built comprise single values, minimum or maximum as the case may be, for strengths, dimensional tolerances, and other controls that govern the acceptability of materials or workmanship. These have been accepted for many decades as values that cannot be quantitatively or qualitatively departed from.

The increased layman interest, which has arisen due to Congressional investigations and so-called exposés by news media, has caused some politicians, laymen, engineers and contractors to question whether an absolute line can or should be drawn between the acceptable and the unacceptable. A "tolerance curve" or a "statistical approach" has been suggested as a possible solution. If such an approach is used, research must be relied on to determine the limits governing unquestioned acceptance, qualified acceptance subject to correction or penalty, and absolute rejection.

Before the hot light of publicity was focused on every project, many responsible engineers were inclined to accept minor noncritical departures from specification on the basis that no willful departure from specifications had occurred and that the value and integrity of the end product had not been impaired. Now engineers and inspectors appear to be more unwilling to risk the exercise of any engineering judgment, due to the unpredictability of the findings of a possible inspection in depth.

Senator Jennings Randolph, speaking before the A. G. C. meeting in 1963 in New York, urged that a research task force attack the problem of creating a statistical approach to determine values governing Federal approval. He declared that highway elements cannot be constructed to the exactitude obtainable under laboratory control and do not need such exactitude. He cited increased cost, without corresponding benefit, of the application of the rigid single-value specification system which may result in acceptance or rejection of work with very minor difference in functional capability. Many contractors and engineers subscribe to Senator Randolph's views. Probably most laymen find it a reasonable approach. Nearly all of the institutes in the principal fields of construction have recognized the problem and have programs under way which they hope will ameliorate the situation. An important effort is being made by the ARBA with the U. S. Bureau of Public Roads.

Inherent in the statistical approach is the necessity for establishment quantitatively and qualitatively of ranges of values instead of absolute single values in specifications. Such statistical values can only be developed by intelligent research. The code adopted by the American Welding Society for acceptance of welds is considered to be a possible pattern for other processes. The code defines all imperfections that occur in welds. Some imperfections are causes for absolute rejection of a weld and some imperfections are acceptable if the size or frequency does not exceed certain limits. The permissible sizes and the permissible aggregate of imperfections within specified lengths are defined. By this code it may be determined without question which welds are acceptable, which may be corrected or which must be rejected. Perhaps research may point the way to similar codes for other construction processes.

A step forward was taken when AASHO included in the draft copy of Guide Specifications Section 105.3, "Conformity with Plans and Specifications," the following clause: "Less than exact or complete conformity, especially with those values that are not critical with regard to expected performance of the completed work, may be tolerated in instances where obtaining exact or complete conformity would not be economical." The intent of this clause reaffirms the principle of exercise of engineering judgment. However, it contains no reassurance or protection for the inspector who fears that his judgment may be questioned. Only a statistically developed range of permissible tolerances can give such assurance.

The problem rests with us; it is costing contractors and owners money that must come only from the public treasury. Its solution will result in increased efficiency and economy in the construction field. It is hoped that this symposium may make some small contribution to its solution.