Quality Materials for Highway Construction

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Materials used in highway construction must meet appropriate quality requirements if the highways are to provide the service that is expected of them. If materials that are inadequate for their intended purposes are used, at the least an unjustified gamble is taken; at the worst structures can fail disastrously with loss of life. On the other hand, it is wasteful to require materials to have properties that provide performance at a level far above that which will ever be demanded of them.

The key to both quality and economy lies in the establishment, use, and insistence upon *appropriate* requirements for quality. Where do we get such requirements and what do we do with them? *Research* on materials provides the knowledge that relates determinable properties of materials to their performance and permits development of standardized methods for determining the relevant properties of individual samples. This knowledge and these test methods permit writing appropriate quality requirements in *specifications. Testing* provides assurance that the materials used comply with requirements of the specifications. This discussion intends to suggest certain important relationships between research, specifications, and testing, so that the objective of quality materials in economical construction may be attained to the greatest extent possible.

Although research has as yet provided only partial answers to many of the questions of the relation of properties and performance, and although few, if any, standardized tests are so well established as to need no improvement, the state of development in these fields is nevertheless greatly superior to that which existed only a very few years ago. Consequently, modern specifications, based on current knowledge, and requiring the use of the latest test methods, provide greater assurance of adequacy and economy than previous specifications did. Engineers, producers, consumers, and the public in general should realize that

specifications properly should differ from time to time and from place to place at the same time. The same requirements are not necessarily appropriate for concrete in a massive dam, in a highway pavement, and in a marine seawall; nor necessarily for pavements in Maine and Mississippi. The specifications for materials that represent the best conclusions we can draw today from research results will be different tomorrow when research provides additional knowledge. Finally, engineers, scientists, suppliers, and contractors, should all realize that once a specification requirement has been established and a contract entered into, the specification must be enforced. The fact that, for example, some gravels proposed for use as concrete aggregate that have 19 per cent loss in the magnesium sulfate soundness test contribute greater resistance to weathering of concrete than some others with 17 per cent loss is entirely irrelevant to any discussion of the rejection of a sample with 19 per cent and the acceptance of another sample with 17 per cent, if the aggregate is purchased under a specification and contract requiring not over 18 per cent loss.

Materials for use in portland cement concrete for highway construction include cement, water, aggregates, air-entraining admixtures, and other classes of material. Regardless of the degree to which all these may comply with quality specifications, it should be remembered that the quality and success of the structures depend as much on their proper *proportioning,* and control in use, as on their initial quality. On the other hand, if the materials themselves are inferior, no degree of care in proportioning and use can be relied upon to make up for this fundamental inferiority. Good materials can be used so as to make inferior structures, but inferior materials cannot be so used as to guarantee quality structures.

PROPERTIES VS. PERFORMANCE OF MATERIALS

The relationship between properties of materials and their performance in service has been of concern to thoughtful users for as long as construction materials have been used. I presume that engineers concerned with the selection of foundation materials like to recall that some 2,000 years ago it was pointed out that it was a wise man who built his house upon rock, while it was a foolish man who built his house upon the sand. It is the function of materials research to explain the causes of success and failure of materials in service, to note the properties of materials that are related to these causes and to provide the methods of testing materials. The status of our knowledge of concrete and concrete aggregates has been reviewed first in 1935, then in 1943, and most recently in 1955 by ASTM Committee C-9, in a series of Special Tech-

nical Publications. The 1955 report was prepared by a committee of which L. E. Gregg was the chairman. This publication, entitled, "Significance of Tests and Properties of Concrete and Concrete Aggregates," is described as "A resume of present information on the significance of the properties of concrete and concrete aggregates and tests by which they are studied and determined." This volume of 387 pages includes papers by 45 authors. All of the properties and methods of testing concrete and concrete aggregates that are used in specifications and many not so used are discussed.

The specifications prepared by the American Society for Testing Materials represent the best assemblage of requirements for quality that can be written for nationwide use. Other agencies modify these requirements to take care of local conditions. For example, the ASTM Specifications for Concrete Aggregate, Designation C 33, includes in its scope the statement:

"These specifications are regarded as adequate to insure satisfactory materials for most concrete. It is recognized that, for certain work or in certain regions, they may be either more or less restrictive than needed." The Corps of Engineers for its Civil Works construction regularly uses fixed specification limits only for grading, uniformity of grading, and uniformity of surface moisture content, and conducts detailed field and laboratory studies before advertising for bids so that sources that will yield ample quantities of suitable aggregates are listed in the specifications.

A requirement in an aggregate specification based on a property or characteristic of aggregates is without meaning or purpose unless variation in the property may be expected to have a significant effect on the performance or cost of the concrete. Most specifications for aggregates begin by enumerating the kinds of materials of which acceptable aggregates may consist—sand, gravel, crushed stone, crushed slag—and then proceed to set requirements. Often the first property for which requirements are given is grading. Grading is a property that has a direct effect on economy and ability to control uniformity of concrete. Some specifications require not only that the grading be between given limits but also that successive samples not vary abruptly from one another within these limits—or that the grading of subsequent samples not deviate excessively from that of the sample employed in selecting proportions for the concrete mixture. The remaining features of most aggregate specifications consist of requirements designed to prevent the use of materials that are of inferior quality or that contain excessive quantities of materials likely to produce certain specific harmful effects on the concrete. In only a few cases has research provided a basis for

specifications to restrict or forbid aggregate constituents by type of material. Certain substances, notably gypsum, sugar, salt, deadburned magnesite or dolomite, and certain forms of relatively soluble silica, fall in this class. When even very small amounts of sugar get in concrete, the concrete will not harden. Salt in appreciable quantity in reinforced concrete exposed to moisture movements may be expected to cause harmful corrosion of the reinforcing steel. Gypsum will dissolve, react with cement aluminates, and produce expansion. Dead-burned magnesite or dolomite will hydrate slowly and produce expansion. Various forms of soluble silica when used with high-alkali cement in concrete subjected to moisture movements may produce expansion.

Almost all other specification requirements relate to the physical condition and physical properties of the aggregate particles rather than to the substances of which they are composed—the particles shall generally be hard, sound, dense, and resistant to abrasion. These qualities are dealt with in various ways but usually by setting limits on the proportion of particles that are so soft as to be broken in the fingers (clay lumps), that can be scratched by a brass point, that will float on a liquid of a given specific gravity, and limits on the amount of material that is lost in an abrasion test or a sulfate soundness test or a freezing and thawing test.

In some regions and for some kinds of construction certain of these considerations may be appropriately ignored while others must be given even greater attention than they receive in the ASTM specification. Resistance to freezing and thawing is of vital importance for highway work in severe climates; it is of little or no importance for concrete that will not be exposed to freezing either because of the climate in which used or the type of structure to be built. Similarly where serious deterioration has taken place due to chemical reactions involving sulfates or alkalies special specification provisions are appropriate and necessary to guard against repetition of such trouble.

IMPROVING PRESENT AGGREGATE SPECIFICATIONS

Many who have been engaged in concrete research believe that present aggregate specifications can be improved by changes in two directions that may seem to be opposite to each other: first developing better techniques for evaluating the fundamental properties of the actual rock and mineral particles of which aggregates are composed, and second developing better techniques for evaluating the performance of aggregates when actually used in concrete. A geologist trained in the study, classification, and description of the properties of rocks and minerals can, if he is informed of the properties that affect performance in

use, examine aggregate samples and report on the kinds and conditions of rocks and minerals present and on the influences that these may be expected to have on performance in service. Such petrographic examinations are being increasingly used in selecting quality materials for highway construction. Petrographic examination is covered by an ASTM recommended practice and is mentioned in the ASTM aggregate specifications.

An example of the second sort of improvement is the use of laboratory freezing and thawing tests of concrete specimens to evaluate concrete aggregates. It is now rather generally agreed that, while a rough separation can be made between most sorts of aggregates that can be used to make durable concrete, and those that would be expected to give trouble in concrete exposed to freezing and thawing, by the use of tests such as the sulfate soundness test, there are too many exceptions and ambiguities. Some aggregates that look good when tested in an unconfined condition behave poorly in service when confined in concrete. These usually are also found to behave poorly when tested in concrete in the laboratory. In this connection, as far back as 1925, research done here at Purdue led to the conclusion set forth in *Engineering Experiment Station Bulletin 24* that "The surfaces of concrete roads demand durable aggregates and tests for soundness of aggregates are generally adopted. The freezing and thawing test . . . while inconvenient, appears to be more significant than other tests."

The proper approach to quality materials for highway construction demands that all materials used meet appropriate quality requirements. It recognizes that failure to do so is dangerous, but it also recognizes that setting quality requirements higher than is appropriate is wasteful. Appropriate requirements can only be based on knowledge provided by research and on the use of test methods developed by research. Appropriate quality requirements may properly be different for different work at different places at the same time and may properly change for the same work at one place at different times. Once the quality requirements have been selected, written into a specification, and a contract has been entered into, conscientious testing and vigilant inspection are needed to provide assurance that the actual materials used meet the stated requirements.