

# **Report on Performance-Based Requirements for Concrete**

Reported by ACI Innovation Task Group 8



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## Report on Performance-Based Requirements for Concrete

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*This report discusses the differences between performance and prescriptive requirements for concrete, and provides information on developing performance requirements as an alternative to the current prescriptive requirements in codes and specifications. Performance-based requirements allow the contractor and concrete producer to be more innovative in concrete applications, providing an element for sustainability of concrete construction. The essential elements of a performance-based requirement are reviewed, which include the desired performance characteristics, sampling and testing procedures to verify these characteristics, and acceptance criteria. Because acceptance criteria are crucial elements of effective performance specifications, factors to consider in developing criteria that distribute risks to the owner and members of the construction team are also discussed. Considerations for implementing performance-based requirements on a project are presented and development of performance-based requirements for durability emphasized. Alternative performance-based requirements are proposed for the prescriptive durability requirements in ACI 318.*

**Keywords:** acceptance criteria; bonus-penalty provisions; building code; durability; in-place tests; performance specification; prescriptive specification; quality assurance (QA); responsibility; sampling; sustainability; test methods.

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### CHAPTER 1—INTRODUCTION

#### 1.1—Background

**1.1.1 Prescriptive and performance specification**—As defined by ASTM, a “specification” is an explicit set of requirements to be satisfied by a material, product, system, or service (ASTM 2010). In the concrete construction industry, the primary types of specifications are materials specifications and construction specifications. The former provide minimum requirements for composition and properties, and the latter form part of the contract between owner and contractor. Specifications can be of the “prescriptive” or “performance” type. A prescriptive specification for concrete focuses on the properties of raw materials; mixture proportions; batching, mixing, and transport of fresh concrete; and a range of construction operations from placing to curing. Prescriptive specifications rely on observed or implied relationships between the details specified and the desired final, in-place, or end-product concrete performance. Under a prescriptive specification, the desired end-product performance may or may not be described. A performance specification, however, defines required results, the criteria to judge performance, and verification methods without requirements for how the results are to be obtained. An alternative name used by some agencies is end-result specification (ERS). The Federal Highway Administration (FHWA) has invested considerable resources to promote the use of performance-related specifications (PRS) in its projects (FHWA 1998). The PRS approach is intended to ensure the completed product will perform as specified.

Prescriptive and performance specifications have been in existence as long as code requirements and specifications for concrete have existed. For example, in 1910, the National

Association of Cement Users (NACU), the forerunner of ACI, adopted its “Standard Building Regulations for Reinforced Concrete” (NACU 1910). These regulations provided alternatives for concrete strength:

“Concrete composed of materials meeting the requirements of these regulations, mixed in proportion of one part of cement and six parts of aggregate (fine and coarse), shall develop a compressive strength of 2000 pounds per square inch in 28 days when tested as 8-in. diameter cylinders 16 in. long under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. When the proportion of cement is increased, using the best quality of aggregates, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, as determined by actual tests, but this increase shall not exceed 25 per cent.”

Thus, it is seen in this early document governing concrete construction, there were elements of prescriptive and performance requirements.

In 1936, ACI adopted the “Building Regulations for Reinforced Concrete (ACI 501-36T),” which serves as a basis for many provisions that are still in use today (American Concrete Institute 1936). ACI 501-36T permitted a performance-based alternative to the prescriptive water-cement ratio ( $w/c$ ) requirements for different design strengths. Alternative mixture proportions were permitted by prequalifying a mixture on the basis of test data correlating strength to  $w/c$ . Four different  $w/c$  values had to be tested, and the  $w/c$  approved for production was that value corresponding to a compressive strength that was:

- 20% greater than the design strength when design strength was less than 2500 psi (17 MPa); and
- 15% greater than the design strength when design strength was 2500 psi (17 MPa) or above.

These requirements are the forerunner of today’s “required strength” based on standard deviation of historical data. Once the proposed mixture was approved, no substitutions in materials were permitted without additional tests.

For durability, ACI 501-36T included that, “All concrete exposed to the weather shall have a minimum ultimate 28-day compressive strength of not less than 3000 lb per sq. in.”

According to ACI 501-36T, design professionals were responsible for on-site inspection of construction, including maintaining records of “the quality and quantity of concrete materials, the mixing and placing of the concrete, and the placing of the reinforcing steel.”

Today the responsibility for site verification of concrete production has shifted away from the licensed design professional toward the concrete producer. The licensed design professional, however, is still responsible for review or approval of the submitted mixture ingredients and proportions.

Other changes in the concrete industry since these early codes were written include:

- Recognition that for many applications concrete strength is not the only characteristic considered in developing an acceptable concrete mixture for a project;
- Portland cement is not the only cementitious material;