

## A review on performance – based specification of durable concrete.

### Una revisión de la especificación basada en el desempeño del concreto duradero.

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#### ABSTRACT

Concrete is the most common and widely used building material because of its relatively low cost, flexibility, and adaptability. Recent historical experience indicates that with exposed to aggressive chloride or carbonation-induced conditions, the reinforced concrete (RC) structures deteriorate prior to the expected service life. This is because of the general assumption that the concrete must be sufficiently durable if the strength requirements are adequate. The variability of concrete arising from the actual concreting procedures, such as placement, consolidation, finishing, and curing, does not take this assumption into account. In other words, the concrete cast for compressive strength in the specimens shows no similarity to the concrete in the actual structure. This paper provides a thorough analysis of the advancements that are taking place to achieve the long-term reliability of RC structures based on performance specifications.

Keywords: reinforced concrete, service life, compressive strength, performance specification, durability, carbonation, chloride ions.

#### RESUMEN

El hormigón es el material de construcción más común y ampliamente utilizado debido a su costo, flexibilidad y adaptabilidad relativamente bajos. La experiencia histórica reciente indica que con la exposición a condiciones agresivas inducidas por cloruro o carbonatación, las estructuras de concreto reforzado (RC) se deterioran antes de la vida útil esperada. Esto se debe a la suposición general de que el hormigón debe ser suficientemente duradero si los requisitos de resistencia son adecuados. La variabilidad del hormigón que surge de los procedimientos reales de hormigonado, como la colocación, la consolidación, el acabado y el

curado, no tiene en cuenta este supuesto. En otras palabras, el hormigón moldeado para resistencia a la compresión en las muestras no muestra ninguna similitud con el hormigón en la estructura real. Este documento proporciona un análisis exhaustivo de los avances que se están produciendo para lograr la confiabilidad a largo plazo de las estructuras RC basadas en especificaciones de rendimiento.

Palabras clave: hormigón armado, vida útil, resistencia a la compresión, especificación de rendimiento, durabilidad, carbonatación, iones cloruro.

## INTRODUCTION

The presence of micro-cracks, voids and capillary pores through which chlorides, CO<sub>2</sub>, moisture, etc., penetrate and start the degradation process is the key disadvantage of concrete, even of good quality. Recent past experience indicates that with exposed to chloride or carbonation-induced conditions, the reinforced concrete (RC) structures deteriorate prior to the expected design life. Specification for concrete construction is a set of instructions from the owner/agency to the concrete contractor and forms the basis of a legal contract toward achieving the objectives of the owner/agency (Bhaskar et al.,2020). Hence, the specification should be written in concise mandatory language with clear, measurable, and achievable requirements (Colin et al.,2005). In the present-day construction field, there are two types of specifications, (1) prescriptive and (2) performance.

## PRESCRIPTIVE SPECIFICATIONS

The prescriptive specification is the provision of limiting values for compositions of concrete mixes and instructions on construction process execution. The commonly adopted "prescriptive specification or approach" is the one that includes clauses for means and methods of construction and composition of the concrete mix rather than defining performance requirements of concrete (Alexander et al, 2010). The durability requirements are incorporated as specific material requirements in the design process, particularly with respect to the minimum cement content, maximum w/c, minimum grade of concrete, etc. (Bhaskar et al.,2020). In other terms, with regard to the mix and material properties that are considered to ensure durable concrete, the design approach is prescriptive. If the concrete is mixed and placed, to ensure conformity with the design criteria and specifications, only the compressive strength is assessed. The most widely used current technique in the building industry is prescriptive specification or approach.

Based on the deteriorations of structures, it is understood that strength is not an adequate indicator because the test does not account for construction processing variables such as placing, compaction, and curing (Santhanam M.,2013, Bhaskar et al.,2020). However, this is done on standard samples, made, cured, and loaded under conditions that may not truly exist on the actual structure. It is well accepted that the potential durability should be

measured on the concrete system, in a manner that considers not only the concrete material itself but also the processing of the concrete during construction (Hooton,2005).

### PERFORMANCE SPECIFICATION

Here, "performance" means the in-place performance of the structure. That is, the performance of final structure is measured in terms of quick and reliable measures, known as durability parameters. The key to improve RC durability is that the as-built structures meet certain critical "performance" criteria with respect to possible deterioration mechanism (Alexander et al.,2005). Variables of construction manufacturing, such as placement, compaction, curing, etc., influence the consistency of the concrete surface area and have a direct effect on durability by regulating the movement of aggressive agents into the concrete from the setting. The key causes of concrete degradation are, therefore, the constituent materials, the near surface consistency of the finished concrete and the environmental aggressiveness. There is no chance of managing the climate and methods to enhance service life, but of focusing on concrete materials and construction efficiency. (Bhaskar et al.,2020) "Durability performance" specifications are therefore increasingly relying on a measurement of the transport properties of the surface or cover zone of the concrete. These developments are paving the way for crafting innovative "performance" specifications.

In general, the pattern of construction practice is to implement "prescriptive specifications" where mix design parameters such as water to binder (w/b) ratio, cement material, and the construction procedures to be followed are given with limiting values. The main disadvantage is that the limiting values do not take into account the impact of modern construction materials that improve the concrete properties, which can be easily obtained at a low cost. Therefore, modern construction should be driven by considerations of concrete durability rather than strength alone, in order to create environmentally sustainable concrete structures. (Bhaskar et al.,2020) In recent days, the trend is moving toward "performance-based specifications", which shows that whether the concrete has achieved the desired durability-based quality or not. This helps to ensure that the finished product has sufficient quality and value, which ensures that the output of the final structure is calculated in terms of simple and accurate steps. This paper provides a thorough analysis of advances in the "performance-based specifications" for the achievement of improved RC structure durability.

### CONCRETE DURABILITY

The durability of concrete is an ability to withstand environmental deterioration. It is the ability of a material/structure to withstand its design service life for which it is designed, without significant deterioration (ISO 16204,2012). American Concrete Institute (ACI 201.2R,2017) defines concrete durability as its resistance to weathering action, chemical attack and other degradation processes while the British Standard (BS 8110,1997) defines a durable concrete is one that is designed and constructed to protect embedded reinforcement

from corrosion and should perform satisfactorily in the working environment for the life-time of the structure. To give increased importance to durability considerations (IS 456,2000) (reaffirmed in 2016) has strengthened the provisions pertaining to durability that are in line with other international standards.

The key to concrete durability is the achievement of a tight and highly impermeable pore structure (Swamy RN, 2008, Basheer et al,2001) It is to be noted that concrete durability is mainly related to the transport properties and its chemical composition (Neville and Brooks, 2010,Yu and Bull,2006). The deterioration mechanisms such as sulfate attack, alkali aggregate reaction, carbonation, corrosion of rebar, etc. are related to the ease with which a fluid or ion can move through the concrete. Penetrability involves different mechanisms and is quantifiable in terms of different transport mechanisms such as permeation, sorption, diffusion, migration, and convection (Richardson M, 2002, Otieno et al,2011]. It can be said that for long – term durability of any structure, the “specifications” used in any construction project/activity play an important role.

#### IMPLEMENTATION OF PERFORMANCE – BASED SPECIFICATION

Performance specifications are intended to determine and ensure, in the service environment of the structure, the appropriate degree of concrete quality in relation to long-term durability. Primary risk in a prescriptive specification is placed on the owner and designer; performance specifications separate and allocate risk and responsibility more clearly (Taylor,2004). Through independently defining and measuring the concrete as supplied and the concrete as put into the structure, the risk and liability appropriate to the supplier of the concrete is separated from that appropriate to the builder who places the concrete. In addition, prescriptive specifications are specifically concerned with the provision of complete details of inputs (i.e., materials) and processes in an effort to ensure sufficient quality and that adequate monitoring and inspection levels are established. On the other hand, it would be appropriate to wait for the allotted time in a performance specification before the durability (or other performance) parameters are tested and payment could be made for construction. It was claimed that the two methodologies are inefficient in their purest forms and that an intermediate approach should be used to implement hybrid requirements (with greater focus on performance criteria). In this method, in the particular service context, the owner and designer decide on the required output standard and suggest appropriate 'index' or indicator tests that are used to prepare specifications. The supplier and contractor then have a concrete system that meets the index criteria (or limits) set out by the owner/designer (which is pre-qualified using tests performed before actual construction). The “concrete system” not only describes the mixture proportions, but it also encompasses the details of the concreting procedures adopted (Bhaskar et al.,2020).

Performance specifications as “a set of clear, measurable, and enforceable instructions that outline the application-specific functional requirements for hardened concrete.”

Performance based specifications" are reported to address requirements for the concrete's mechanical and functional properties." It is known that "performance-based specifications" are free from process restrictions, such as proportions of mixtures and construction methods (Colin et al.,2005). Better quality concrete can be obtained with greater skills in mixture proportioning, selection of better materials, and achieving reduced variability (Day KW, 2005, Bhaskar et al.,2020). Prescriptive specifications are suggested to give concrete manufacturers little benefit, as they restrict the spectrum of application of the latest technologies to mixture-proportioning techniques. The opinion is that prescriptive requirements in the development and use of concrete stifle creativity. It also mentioned that there is a position for prescriptive specifications where a particular project presents previously unprecedented challenges or opportunities and where a highly skilled and experienced technologist has been recruited to agree on a solution with the best producer available. In any other conditions, it will be well advised for the agencies of any large project to agree on a performance basis with a chosen supplier, regardless of national codes and local industry practices. Two separate specifications are stated for a satisfactory specification: (a) to provide an accurate measurement of the quality of concrete, and (b) to take immediate action in the event of a decrease in quality.

Traditional standards and specifications for concrete were largely prescriptive and sometimes hinder innovations (Hooton et al.,2005). Particularly, it is referred during the production of environment-friendly concretes by having minimum cement content with different replacement levels of SCMs (Bhaskar et al.,2020). Also made a review on international standards, especially on "performance-based specifications" and it was reported that the Canadian CSA A23.1-49 standard is among the most progressive performance standards (Hooton et al.,2005]. Concrete is believed to be a sustainable material (made from local materials) and the sustainability of concrete structures can be further increased by the use of higher levels of cement substitute materials and by improved durability performance design (extending service life), even in extreme aggressive environments. It is of the opinion that often, through imposing prescriptive restrictions on materials and precise proportions by not having durability performance specifications, standard specifications may be an impediment to these latter issues. Although there are many forms of aggressive exposures that may require a multitude of durability tests, the common element is that the permeability or low penetration resistance of concrete is needed for most aggressive exposures. To ensure durable concrete, the adoption of one or more penetration resistance tests is therefore necessary.

A review of the "prescriptive" and "performance" based approach, where limitations of "prescriptive" approach are highlighted (Nganga et al.,2011, Bhaskar et al.,2020). A shift to "performance-based approach" was suggested to address the prescriptive approach limitations. The provisions, benefits, and the limitations of performance approach is highlighted. The main challenges to adopting the new approach are the lack of on-site assessments that can be consistently used, the unavailability of data relating to an appropriate

standard of results, and the reluctance of the various parties to follow the approach. In order to ensure the relevance and benefits of the strategy, it is stated that knowledge needs to be generated among the various parties involved.

## CONCLUSION

Due to the early signs of deterioration of the RC structures, RC durability received greater attention during those days. A significant change from "prescriptive" to "performance"-based requirements is observed, especially in the construction of large infrastructure. This paper extensively explains the "prescriptive approach" as well as the "performance-based approach". It can be said that "performance- based specifications" can ensure that the quality and long-term durability necessary are achieved.

The current practice in concrete construction is focused on "prescriptive specifications," where variables such as water-to-binder ratio, cement quality, and curing conditions that are difficult to test on site are given limited values. Compressive strength is often used as a durability indicator but does not account for on-site building activities, such as placement, consolidation/compaction, curing, etc. The key drawbacks of the implementation of "prescriptive specifications" are the inability to take into account modern construction materials that improve the properties of concrete toughness, which can be easily obtained at a low cost. As the material requirements are not specified in "performance-based specifications," the contractor/concrete producers have flexibility in the selection of materials, allowing them to take advantage of locally available and low-cost materials. Innovation in the development of a concrete mix is encouraged. The consistency of the finished product (actual structure) will therefore be the main objective and quality can be calculated in terms of durability parameters. It has become evident that evaluating the durability of concrete is more difficult than evaluating strength. Therefore, it is suggested that in the near future, some pilot projects showing the advantages of performance specifications could be taken up in India.

## ACKNOWLEDGMENT

First and foremost, I sincerely thank the 'God Almighty' for blessing me with his grace. I wish to place on record my profuse sense of gratitude and sincere thanks to Dr. Elson John, Associate Professor, Department of Civil Engineering, Mar Athanasius College of Engineering, Kothamangalam for his guidance, constant supervision, encouragement and support throughout the period of this work. I owe my sense of gratitude and sincere thanks to Jessymol George, Assistant Professor, Department of Civil Engineering, Amal Jyothi College, Kanjirappally for her guidance, constant supervision, encouragement and support throughout the period of this work. Finally, I would like to acknowledge the heartfelt efforts, comments, criticisms, co-operation and support given to me by my dear friends during the preparation of the project.

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Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 10(X), 2022:  
<http://dx.doi.org/>

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Received: 15<sup>th</sup> February 2021; Accepted: 04<sup>th</sup> May 2021; First distributed: 04<sup>th</sup> May 2021