A STUDY ON PRESCRIPTIVE TO PERFORMANCE SPECIFICATION OF DURABLE CONCRETE IN CONSTRUCTION INDUSTRY

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Abstract - *A broad overview of performance-based specification of durable concrete is provided in the report. It explains briefly the situation of the concrete industry in India and the present concrete specification procedure. It is argued that in recent years, the essence of concrete manufactured in India has undergone significant transformation. While the use of ready mixed concrete from commercial facilities or captive plants has risen steeply, a number of mineral and chemical admixtures have begun to be used in concrete by the organized concrete industry. As a consequence, the age-old prescriptive criteria based on old practices may no longer be sufficient, so there is a need to move from prescriptive to performance requirements. The papers offer a few performance specification concepts and highlights their benefits. The basic elements of performance specifications are briefly defined, such as pre-qualification, sampling, testing methods, acceptance criteria development, and the bonus penalty system. It is suggested that in the near future, some pilot projects showing the advantages of performance specifications could be taken up in India.*

Key Words: Performance specification, Prescriptive specification, Durable Concrete, Chemical Admixture

1. INTRODUCTION

The National Ready Mixed Concrete Association (NRMCA) discusses performance specifications as part of its initiative to help the construction industry transition from prescription specifications to performance specifications (P2P). A performance specification is a set of instructions outlining the functional requirements for hardened concrete based on the application. The instructions should be clear, achievable, measurable and enforceable [1]. It became apparent that while performance, mainly for reliability, had an almost universal interest, there were few requirements that included any pure performance criteria. The desired durability would result in most specified exposure conditions that pertained to each country and then tabulated concrete mixture contents and limits those studies have shown. These include overall water-cement or water cement ratio limits, minimum cement content and acceptable air content ranges. Supplementary cement materials, such as fly ash, granulated ground blast furnace slag and silica fume, are almost universally used as additions or in blended cements. The use of statistical quality control to ensure consistent consistency at the lowest cost was presumed in all the specification documents.

It also became apparent that to many different individuals, the word "performance specification" means many things. This is not necessarily due to misinterpretation at all. This is because there is such a wide variety of options and relevant meanings, making it important that the word in any given sense be carefully described. In theory, the parties may agree to carry out work under the umbrella of the performance specification and yet have widely varying views on mutual expectations. The absence of reliable, consistent and systematic evaluation procedures for the assessment of concrete performance is often cited as a significant barrier to the implementation of performance specifications. Any of the tests available may be costly, take a long time to run and may not be as reliable as desired. For a concrete supplier faced with the need to build a performance mixture and to conduct prequalification testing, short bid times and fast construction starts create a difficult situation.

2. PRESCRIPTIVE SPECIFICATION

A prescriptive specification is one that includes provisions for the design and composition of the concrete mix methods and methods rather than specifying performance requirements. In project specifications, the intended performance requirements are often not clearly defined and the prescriptive requirements can conflict with the intended performance. Many of the project requirements include restrictions on the composition of the concrete mixture, such as the minimum quantity of cement, grade of cement, limits on the quantity of additional cement materials, the maximum ratio of water to cement materials (w/cm), limits on the grading of aggregates or the type of aggregate used, labels of admixture and mixtures. Mandatory dose, etc. In addition, compressive strength requirements or other properties may be implied but not explicitly defined in the specification. Quite frequently, depending on the constraints imposed on the composition of the mixture, these criteria cannot be fulfilled. A particular relationship exists for each set of materials between the proportions of the mixture, such as cement content and w/cm ratio, and the resulting strength and durability properties.

2.1 Prescriptive criteria for concrete cover, composition and strength

The cover of reinforced concrete structural members is set by the EN 1992-1-1 – Eurocode 2 [2]. In accordance with NP

ENV 13670-1 [3,] the uncertainty of this variable in relation to its execution is also taken into account. Thus, in addition to the minimum cover cmin and dur (mm), Eurocode 2 specifies the nominal cover cnom (mm). In order to take into account any expected deviation, c_{nom} is the value that should be considered for the construction project drawings and specifications [4].

$$c_{nom} = C_{min,\,dur} + \Delta C_{dev} \quad (1)$$

where ΔC_{dev} (mm) is the expected deviation which depends on the quality control, and in the Portuguese case [3] 10 mm was the established value, regardless of the level of quality control. The minimum concrete cover $C_{min,\ dur}$, may be interpreted as a 5% fractile characteristic value [5,6], where ΔC_{dev} = 1.645s being s the standard deviation of a concrete cover normal distribution. The standard deviation is in this case 6 mm, being the mean value of the nominal cover.

The Portuguese specification [7] is included in the Portuguese standard NP EN 206-1's National Annex. As a result, it is this document that specifies the minimum nominal cover, which includes the minimum cover and its deviation, and determines the requisites of the composition of reinforced concrete members [4].

The limits defined in [7] form the prescriptive methodology for a design working life of 50 years (target period) under environmental exposure, taking structural class 4 into account. According to this specification, the same prescribed limits of the concrete composition and 10 mm added to the 50 years cover allow for a design working life of 100 years – structural class 6. In addition to concrete cover, the maximum w/c ratio, minimum cement dosage, cement type, and minimum strength class are all prescribed limits [4].

3. PERFORMANCE SPECIFICATION

The test methods and acceptance criteria that will be used to enforce the requirements should be clearly specified in the performance specifications. Some testing may be required for pre-qualification, while others may be required for on-the-job acceptance. The specifications should allow the contractor and producer to provide a mix that meets the performance criteria in any way they see fit. In addition, the contractor and producer will collaborate to create a mix design for the plastic concrete that meets additional requirements for placement and finishing, such as flow and set time, while ensuring that the performance requirements are not compromised. Performance specifications should avoid requirements for means and methods, as well as limitations on the concrete mixture's ingredients or proportions. Performance-based design and specification is an alternative solution to prescriptive durability design. On the as-built structure, main durability-related parameters should be calculated to account for the impacts on the durability of construction processes and workmanship efficiency. However, most performance-based specifications include only the main characteristics to be evaluated at the stage of design or at the point of delivery of the concrete and do not provide an evaluation of the compliance of the completed structure or its components. This largely defeats the purpose of performance-based approaches, in the opinion of the authors, which is to check that the structure as designed meets the specification and design specifications.

Lobo et al. [8] Performance specifications are defined as 'a set of clear, measurable, and enforceable instructions outlining the application specific functional requirements for hardened concrete.' They emphasize that performance-based specifications clearly separate and assign risk and responsibility among the owner/designer, concrete producer, and builder [9], Prescriptive specifications, on the other hand, place the primary risk on the owner/designer. Risks and responsibilities between the concrete supplier and the builder are clearly defined by specifying and testing the concrete at the point of supply, and then after placement and early hardening in the structure [10].

3.1 Performance Testing

Performance testing requires the development and 'proving in practice' of reliable and meaningful test methods and the imposition of suitable performance limits. In some cases, the appropriate limit may come from service life models — e.g., deriving a chloride diffusion coefficient such as from the Life-365 model [11]. In other situations, particularly where service life models are not well established, the limits which come from the best judgement and experience, when better models are developed, in order to change or enhance these limits. In addition, performance tests can be used in various ways. Typically, they are used prior to construction for pre-qualification of mixes, where the concrete manufacturer performs tests to show that the required concrete meets the performance limits; in this situation, it is clear that only the 'potential' material (in the sense of the material's ability to potentially be durable) is proven, as the mixes are pre-construction mixes that are normally tested. The other use for performance testing is for quality control (QC) during construction, where there are two possible options: first, checks on concrete mixes as supplied or delivered before they are actually installed in the structure, similar to current routine concrete strength tests; Secondly, in both cases, when the real structure is checked using in-situ tests or samples extracted from the structure and tested in a laboratory, the goal is to determine the actual consistency of the structure as-built. There is a clearer relation between the test outcome and the predicted output of the structure itself for actual in situ testing.

Furthermore, the tests used for these various purposes may be different, even if they assess the same basic performance aspect. A diffusion coefficient, for example, can be measured on 'laboratory' concrete for pre-qualification purposes, whereas a resistivity/ conductivity test can be used in-situ for quality control. Many of the tests are concerned with concrete penetrability (the ability of the concrete to be penetrated by gases, liquids and ions under different transport mechanisms). Various performance-based test methods have also been developed in various parts of the world (reviewed in chapter 4 of the State of-the-Art Report of RILEM TC-230 PSC [12,13] to be published later in 2015). RILEM TC-230 PSC also makes the point that, in some instances, Deterioration modelling may not be required for the implementation of a performance-based approach. For example, in the evaluation of freeze–thaw resistance, the performance test results in the acceptance of the concrete mix if the loss of mass is less than a certain value. There is no appropriate model to integrate the result, and long-term experience is essentially the 'criterion' against which the test results are measured [13].

4. DURABILITY OF CONCRETE

Concrete durability is defined as the ability of concrete to withstand weathering, chemical attack, and abrasion while retaining its desired engineering properties [14]. Water absorption, RCPT, and water permeability tests are used to determine the durability of concrete. There are several factors that influence the durability of concrete. High humidity and rain, UV resistance, chemical resistance, and seawater exposure Steel corrosion and chloride resistance, resistance to sulphates, Carbonation, Alkali-silica reaction (ASR) resistance [14]. The different ways to make concrete more durable as mix Design. The foundation of durability is a concrete mix design that is properly matched to the service conditions to which the concrete will be subjected. Construction joints are unavoidable in a concrete structure. Concrete placement, proper curing, and low permeability [15].

Concrete does not have the property of durability. Concrete that is immune to the effects of freezing and thawing has no higher "quality" than concrete that has no ability to resist freezing and thawing if it is to be used in a critically water-saturated condition where it will never freeze [16]. Thus, the problem faced by the engineer who prepares concrete requirements for particular work is to predict the degrading influences that could cause degradation of concrete at the project site during the concrete's expected service life in the environment. Having done so, he must then include not only all those requirements that are generic to all concrete class construction necessary for the particular project in the job specifications, but also all those specific requirements needed to avoid or mitigate the effects of the deteriorating factors at the work site, whatever they may be. These include freezing and thawing, wetting and drying, heating and cooling, loading and unloading, cavitation, erosion, abrasion, acid attack, sulphate attack, other types of chemical attack, steel corrosion, microbiological attack, marine borer penetration, and others. These should be considered not only as external world elements, but also, where applicable, the structure's internal environment. Significant damage was reported to pre-stressed concrete members in a building's roof where it never freezes outside but was used to freeze food. While the roof members were frozen and soaked in water, the structure was steam-disinfected on a regular basis [16].

4.1 Limit states for durability and service life design approaches

According to Walraven, the practical application of a performance-based approach for service life assessment and codification necessitates the following components [17, 12]: (i) limit state criteria; (ii) a specified service life; (iii) deterioration models; (iv) compliance tests; (v) a maintenance and repair strategy; and (vi) quality control systems.

Concrete durability limit state criteria should be quantifiable and have a clear physical meaning. The deterioration models should be mathematical in nature and include parameters that are directly or indirectly related to the performance criteria. Different levels of sophistication can be applied to performance-based durability design, such as the use of durability indicators, deterioration models, and full probabilistic approaches. Depending on their sophistication, performance-based design tools may include service life models with end-of-life criteria, as well as test methods for verifying concrete material properties. Engineers mostly work to codes of practice, so any usable approach must be codified. Structural codes, which include provisions for durability, are frequently out of date, so that new knowledge from research and practice takes a long time to find its way into the standards. ISO 13823 (2008) [18, 12] outlines a limit-state methodology as an example of performance-based durability design implementation. which is related to various approaches to service life design. The ideas in Fig. 1 have been taken up in the fib Model Code [19], with a number of approaches to durability design, or more broadly service life design. Two of them, viz. the 'deemed-to-satisfy' and the 'probabilistic' approaches, are briefly reviewed [12].

5. REVIEW ON PERFORMANCE BASED SPECIFICATION

One simple benefit of performance specifications is that they concentrate emphasis on the particular properties that are the most relevant for a given scenario. Conventional research Implementation. Even if one or more of these properties may not be applicable to the desired performance of the owner, it mostly focuses on slump, air content and 28-day cylinder power, whereas more relevant performance criteria may not be checked at all. The Equivalent performance concept defined in European standard EN 206-1 on concrete specification allows qualifying a concrete mixture that does not comply with prescriptive specifications, as long as its test performance is at least as good as a mixture that complies with standard limiting values.

The study's main goal in this context was to find a performance-based indicator to assess potential durability of concrete exposed to carbonation, which could then be used to compare potential durability of different concrete mixtures [22].

The analyzed concrete mixtures of the analysis met the same prescriptive requirements as the reference concrete mixtures in order to be used as reference concrete mixtures (Eq. binder content and water/Eq. binder ratio). However, they demonstrated very different potential durability. In the description of the reference concrete mixture, this difference in output must be taken into account. For example, by specifying a higher minimum Eq, a satisfactory level of potential durability has to be ensured. The content of the binder and lower water maximum/Eq. The binder ratio for the mixture of reference concrete. The essence of performance-based approaches is measurement and verification, appropriate durability indicators that represent the deterioration mechanisms expected during the service life of a structure, provided they are measurable on pre-qualification mixes and on the actual structure, can be a powerful tool in achieving desired perform.

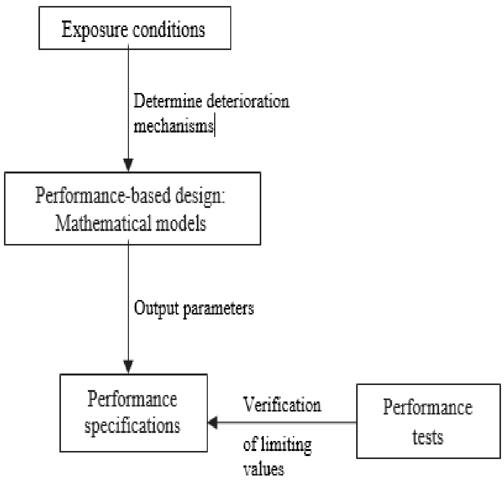

Fig -1: Schematic representation of the performance-based approach (Somerville [23])

Performance approaches [12] are slowly gaining acceptance in the concrete industry since they promote innovation, while the desired concrete performance during its service life and the as-built structural concrete properties can be specified prior to construction. However, at present there are not many instances in practice where actual in-situ or as-built properties are measured; such approaches, in the authors' opinion, cannot be regarded as fully performance-based. Performance-based approaches offer a logical means of design and specification of durability, as variables that affect durability are verifiable, such as concrete cover consistency and penetrability, and thickness (to prevent corrosion), although there are several other parameters relevant to durability. The benefits are various. First, the use of service life models allows RC systems to be planned and constructed with a service life that is at least notionally quantifiable, as desired by the owner. Secondly, as the specifications for material composition are not specified, concrete manufacturers have the flexibility to select materials which allow them to take advantage of locally available or more suitable materials. Thirdly, it promotes innovation. In order to ensure compliance with performance requirements, inspection of as-built properties of the building also enforces tighter quality control of construction activities.

A study of the convergence of prescriptive and performance-based [25] methodologies has been presented with respect to concrete mixes with different types of cement within the EN 197-1 standard [24]. The experimental results, started at the age of 28 days, show that, for carbonation, the tested compositions with fly ashes (CEM II/A-V and CEM IV/B-V) have half the resistance of the compositions with clinker (CEM I) and low percentage of lime filler (CEM II/A-L), even though the compressive strength does not follow this tendency. Based on the service life results, the prescribed compositions with fly ashes do not meet the required performances in most cases. These concrete mixes only respect the expected service lives of 50 years for class XC3 and of 100 years for the same exposure class with a safety factor approach. The compositions with CEM I and CEM II/A-L reach and go past the target periods for both exposure classes, except for class XC3 and a target period of 100 years with a probabilistic approach. When both performance-based approaches are considered, the results demonstrate that there is generalized convergence, with the exception of the target period of 100 years for exposure class XC3. The findings of this study highlight the importance of future discussion and research in order to improve the convergence of prescriptive and performance-based methodologies in the context of carbonation-induced corrosion [25].

6. THE ESSENCE OF PRESCRIPTIVE VS PERFORMANCE

The "Prescription to Performance" (P2P) [25] initiative aims to shift the emphasis of concrete specifications. A prescriptive specification focuses on the raw material properties, mixture proportions, batching, mixing, and transport of fresh concrete, as well as the entire range of construction operations from placement to curing. Prescriptive specifications are based on observed or implied relationships between the details specified and the final, in-place, or "End Product" or "End Result" performance of the concrete. The end product performance may or may not be described in a prescriptive specification. A pure performance specification, on the other hand, "begins with the end in mind," thoroughly specifying the end product's necessary performance characteristics while leaving the selection of materials, proportioning, and construction means and methods to the contractually bound party to comply with the specifications. Within a pure performance specification, the unique manufacturer-contractor team is responsible for selecting products and carrying out construction operations that produce the required concrete output.

The key benefit of specifying the output of the end product is that a professional concrete. The manufacturer-contractor team is flexible in creating a particular mix of products and materials. Methods of construction that will accomplish the specified objectives of the owner designer. Therefore, performance specifications can work well when the producer-contractor team has the necessary requirements. Expertise; the specifications can be clearly articulated by the owner-designer, and suitable and reasonably reliable test methods are available to record the stated results. When there is a reliable link between the materials, means, and methods defined and the desired results, a prescriptive specification can function better. The simpler the concrete is, the more and less restrictive the results needed, the more likely a prescriptive specification is to be mixed and an easy and reliable way of defining concrete would be.

7. PERFORMANCE SPECIFICATION – BENEFITS AND ISSUES

The shift from prescriptive to performance-based specifications has numerous advantages, particularly in terms of encouraging innovation, including the use of new materials and processes [12]. As previously stated, performance specifications should allow concrete to be manufactured with the necessary properties to meet the desired service-life requirements in the specific environment. Ideally, this necessitates a thorough understanding of deterioration processes, the ability to model such processes and thus evaluate the specific properties required to provide adequate resistance, the ability to calculate these properties for the purpose of pre-qualifying mixes, and, ideally, the availability of appropriate in-situ tests to ensure that the properties are obtained in the standard process.

The primary advantages of shifting from prescriptive to performance-based specifications are as follows [10]:

- Performance-based approaches are a more logical way of improving concrete performance. [27,28,29]
- In their proper form, they help ensure that the as-built structure meets the design intentions;
- They allow for modelling and service life predictions;

The key to increasing reinforced concrete durability is to ensure that as-built structures meet critical performance criteria in terms of likely modes of deterioration. The goal is to ensure that the structure does not reach a "limit state" of serviceability during its service life [10]. The goal of performance-based specifications is to ensure that a reasonable likelihood of performance is achieved in terms of reliability. A shift from prescriptive to performance specifications is one of the most important steps needed to address existing flaws in reinforced concrete design and construction.

Major problems in the performance specification are as follows [26]:

- The specifier may be unsure of what those characteristics are or how to measure them. Reliable tests to quantify the desired outcomes may not be available. When compared to conventional tests, performance tests may be more expensive, time consuming, or necessitate more specialized knowledge.

- Materials, concrete production, concrete delivery, mix adjustments by contractor, placement, consolidation, finishing, adjustments to mix properties at surface, ambient conditions, moisture control, and temperature control all have an impact on end product properties. In a low bid (first-cost) contract, it may be difficult to reap life-cycle economic benefits.

- Tests that go beyond the standard slump, air, and cylinders are likely to be more expensive and complicated, and their precision must be factored into the specification.

- In cases where prescriptive specifications clearly limit the producer's responsibility to follow instructions, the shift to performance specifications and the associated responsibility for end results is a significant increase.

8. CONCLUSIONS

In the present-day construction field, there are two types of specifications are Prescriptive and Performance. A study of the current world literature on specifications makes it clear that performance is a hot topic and there is a worldwide concern about the durability of concrete. The performance specifications scheme reflects improvement over the prescriptive specifications of the age-old. Some Western countries have already begun to use performance-based specifications for some of their projects, and there is now example expertise to incorporate the new framework. The organized concrete industry is rising fast in India.

During the same time period that concrete was transitioning to an engineered material, many concrete producers shifted from being merely "truckers" who delivered concrete mixed according to a specified recipe to being well informed on concrete materials, including complex aggregate grading, chemical admixtures, and a wide range of cementitious materials. Other industry changes include the recognition that for many modern concrete applications, strength is no longer the only, or even the most important, consideration. Water content and aggregate size are not the only factors influencing slump, and w/c is not the only factor influencing permeability.

In the field, air content is easily defined and easily measured, but the durability of freezing thaw and scaling resistance are more dependent on the size and distribution of the air void in the paste than on the total volume of air in the concrete.

Chemical and mineral admixtures affect air, workability, setting time, bleeding, rate of strength gain, and early and later age strength. These same admixtures may or may not be mutually compatible. Simultaneously, it has become more difficult to write a prescriptive specification that can capitalize on these developments while avoiding their pitfalls. It has become clear that determining the durability of concrete is more difficult than determining its 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.

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