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Performance Approach for Concrete Durability

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Abstract - *Reinforced concrete structures are deteriorating prior to their expected design life when exposed to chloride or carbonation-induced environments. The reasons could be poor quality of construction, poor anticipation of exposure conditions etc. In prescriptive specification approach, it is assumed that if the strength is satisfactory, then the concrete would be sufficiently durable. However, research has shown that there is no simple or unique relationship between strength and any of the durability parameters. There is a need to assess and ensure durability of concrete by using quick and reliable durability parameters, by implementing performance specifications for the concrete.*

Key Words: Durability, Chloride ingression, Carbonation, Prescriptive approach, Performance approach

1.INTRODUCTION

The main limitation of concrete, even of good quality, is the presence of micro-cracks, voids and capillary pores through which chlorides, CO_2, moisture, etc., penetrate and initiate the deterioration process. Recent past experiences show that the reinforced concrete (RC) structures deteriorating prior to the expected design life when exposing to chloride or carbonation-induced environments [1].

In general, "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. Hence, the specification should be written in concise mandatory language with clear, measurable, and achievable requirements. In the present-day construction field, there are two types of specifications, (a) prescriptive and (b) performance.

1.1 REVIEW ON PERFORMANCE SPECIFICATIONS

Performance approaches are based on the measurement of material properties that can be linked to deterioration mechanisms under the prevalent exposure conditions. The measurement of properties of concrete used in actual structure helps to estimate the combined influences of material composition, construction procedures, and environmental influences on the durability of concrete. Thus, it can be used to form a logical basis for durability prediction and service life design. Performance-based approaches can be used in various stages of the construction of a structure such as design, specification, pre-qualification, and conformity evaluation of the as- built structure.

During 90s, Harrison proposed a framework for the development of performance-based specifications which essentially cover seven steps:

a) Definition of exposure class where the structure is being exposed.

b) Methodology/design criteria for defining the total service life,

c) Durability test checks to relate with output parameters,

d) Limiting values for checking the durability parameters,

e) Establishing limits of test applicability,

f) Determination of effective system for production and acceptance testing and

g) Implementation of specifications in full scale trials and long-term monitoring to con- firm limiting values determined [2].

In a similar way Somerville also described performance approach as an engineering approach to the durability design [3]. In recent years, a noticeable shift is observed from prescriptive to performance (P2P)-based specifications that shows whether the concrete has achieved the desired quality and resistance to deterioration through suitable tests.

Colin et al. describe performance specifications as a set of clear, measurable, and enforceable instructions that outline the application specific functional requirements for hardened concrete [3]. Many times, intended performance requirements are not clearly indicated in the prescriptive specifications, and the prescriptive requirements may conflict with the intended performance. Therefore, a shift from prescriptive to performance (P2P)-based specifications is the logical step in the evolution of the concrete industry.

1.2 PRESCRIPTIVE VS PERFORMANCE APPROACH

Nganga et al. presented a review of the "prescriptive" and "performance" based approach, where limitations of "prescriptive" approach are highlighted [5]. 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 implementation of new approach are the lack of tests that can be used routinely on site, nonavailability of data related to acceptable level of

performance, reluctance to adopt the approach by different parties. It is reported that awareness needs to be created among different parties involved to ensure the relevance and benefits of the approach.

Alexander et al. made a comparison between prescriptive and performance specifications [6]. It is reported that performance specifications aid to assess and assure the required quality level in a concrete structure for long term durability in each environment. Both strength and durability are related to water/cement ratio, internal bulk/core of concrete governs strength, and surface cover zone controls durability.

2. PERFORMANCE SPECIFICATIONS FOR DURABLE CONCRETE

Ho and Chirgwin attempted for the durable concrete by using performance specifications [7]. The quality of concrete was assessed by water sorptivity, a property related to the pore structure of concrete near the surface. Further, sorptivity considers the effect of curing. This property was chosen in addition to compressive strength, because, besides its relevance to durability, the test is simple to do and without any special requirement or equipment. With the additional durability requirement of water sorptivity, the incidence of damage due to rebar corrosion was expected to be greatly reduced.

Karthik and Colin discussed the P2P criteria by carrying out a laboratory study on concrete mixtures optimized for better performance [8]. Both prescriptive (28-day compressive strength of concrete, maximum water to cement ratio [w/c], total cementitious content, slump, air entrainment) and performance (28-day compressive strength of concrete, use of SCMs, slump, air entrainment, charge passed in Coulombs (C) (<1500C), length change (drying shrinkage <0.04%) criteria were specified. Four concrete mixtures were selected, and all mixtures were designed for the required slump and air entrainment. It is reported that the specific performance criteria resulted in equal or better performance (lower shrinkage, better workability/lower admixture dosage, lower chloride permeability, etc.) as compared to prescriptive limitations in the specification.

Karthik et al. discusses on rapid index tests and specification criteria that can reliably classify concrete mixtures for resistance to chloride ion penetration within a testing period of approximately 56 days [9]. To simulate standard and service conditions, specimens were subjected to either immersion or to a cyclic wetting and drying exposure in chloride solution. Apparent chloride diffusion coefficients determined in accordance with ASTM C1556 were correlated with results of rapid index test methods that provide an indication of the transport characteristics of concrete.

Dhanya et al. describe the round-robin experimental investigation of durability parameters to identify the extent of variability in different durability test methods, with the purpose of selecting the best methods for durability design of concrete [10]. For the experimental study, two different concrete mixes prepared using the materials available locally at Chennai, India, and a total of nine institutions participated. Test results indicate that durability tests show much higher levels of variability (COV [coefficient of variability]: 25–80%) as opposed to compressive strength (COV: 10–11%) which suggests that the use of acceptance criteria applied to compressive strength may not work for durability parameters.

3. TYPES OF PERFORMANCE TESTING

Tests can be performed at various stages in construction.

1. Pre-qualification Tests: - Used by makers to show that a mixture, when put and relieved under specified or conditions, can meet the prerequisites and, if necessary, give input information to support life forecast. These tests regularly require huge lead time to finish and may incorporate tests required as contributions to support life models.

2. Identity Tests: - Test is carried out at the site before the mix is placed i.e., as soon as when the mix is delivered on the field of work. Identity tests are carried out to determine whether to accept the mix or not. The most common test is slump test and air content test. Also, the uniformity and the fresh density of concrete are tested on some places. AASHTO recommends a microwave test for finding the water content of the concrete which is delivered at the site. mainly implemented on New York.

3. Quality Assurance/Quality Control Tests: - In order to certify that the mix is up to the mark i.e., it satisfies the strength and other requirements of concrete specified. Also is to ensure that the correct method is followed at point of discharge of concrete mix and at the point of placing the fresh concrete.

4. In-Place Tests: - Includes the non-destructive tests (NDT) and performance tests that may carry out on cores taken from the concrete specimens. This test method is to confirm that all the practices taken while the production, placing and curing have resulted in achieving the performance requirements. This is for the End Result Specifications (ERS) usually used by several North American highway agencies such as the Ministry of Transportation Ontario (MTO). Based on the results the contractors and worker are complimented if result satisfy the requirements. Otherwise, they must give compensation for the same [11].

4. CONCLUSIONS

Durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration to remain its original form, quality and serviceability when exposed to its intended service environment. Durability study of concrete is very important for controlling the quality of any concrete. The main purpose of durability study on concrete is to record the durability performance of the concrete under different environment conditions.

Test methods for durability can encompass all the transport mechanisms in concrete. Very often, more than one phenomenon is operational in an actual durability problem, and the use of a single durability parameter cannot adequately express the quality of the concrete. For a successful performance specification, the choice of the durability parameter should reflect the actual deterioration mechanisms.

Performance approaches are based on the concrete properties which may be used as input parameters to predict durability of the specific structure under consideration. In India, the performance specifications were implemented for the Kolkata, Chennai, and Hyderabad metro.

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