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Concrete durability ☆

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Abstract

Concrete will be durable if the specifications under which it is procured require the appropriate limits and the concrete is produced to comply with the requirements. Thus the issue that must be resolved by the engineer is to anticipate the environment of service, identify the potentially deteriorative influences and their probable intensity, and prescribe proper precautions in the specifications and also prescribe therein appropriate contractor quality control measures and describe the quality assurance measures that will be taken by the owner. If these steps are taken in accordance with the guidance in the current ACI Manual of Concrete Practice, the concrete will be durable for the desired service life.

1. Introduction

Concrete that has been in service for a fairly long time can be inspected, tested, and evaluated; and the results analyzed; and a conclusion reached that thus far, it has been "durable" or it has not been. "Durable" is not an attribute of concrete in general, or of a given class or given levels of a set of properties, but is rather a conclusion reached about specific concrete subject to specific service environment. A concrete is "durable" if, in its environment, it has provided the desired service life, without excessive cost for maintenance and repair due to degradation or deterioration. Durability is not a property of concrete. Concrete that would be immune to the effects of freezing and thawing is of no higher "quality" than concrete that has no ability to resist freezing and thawing if it is to be used where it can never freeze in a critically water-saturated condition.

Thus the problem faced by the engineer who prepares specifications for concrete for particular work is to predict the deteriorative influences that could cause degradation of concrete in service in the environment at the project site over the intended service life of the concrete. Having done so he must then include in the specifications for the work not only all those requirements that are generic to all concrete construction of the class required for the particular project but also all those specific requirements needed to preclude or minimize the effects of the deteriorative influences at the site of the work whatever they are. These include: freezing and thawing, wetting and drying, heating and cooling, loading and unloading, cavitation, erosion, abrasion, acid attack, sulfate attack, other kinds of chemical attack, corrosion of steel, microbiological attack, penetration by marine borers, and others. Not only should consideration be given to these as aspects of the external environment but also, when relevant, the internal environment of the structure. I have been told of severe damage to prestressed concrete members in the roof of a building where it never freezes out doors but which was used to freeze food. The building was periodically disinfected with steam-while the roof members were frozen, saturated with water.

Once the internal and external microclimate (or microclimates) of the project have been reviewed for the presence or absence of deteriorative influences and the severity of those that were regarded as likely to exist is estimated, then one can think about what needs to be included as requirements in specifications. There may be a problem as to who should pay to sample the soil at the project site and supply to the specifier the values for sulfate (%SO_4) in the soil and ppm SO_4 in water that is likely to come into contact with the concrete in service, but the specifier must have this information or must specify how it shall be obtained and used to specify the

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type or types of cementitious materials and their proportions and the maximum water to cementitious material ratio (w/cm) of the concrete in the structure, or in those parts of the structure in contact with soil or water.

In effect, the specifier must know what it says in ACI 201.2R "Guide to Durable Concrete" [1] and prepare specifications, including relevant provisions for quality control (QC) by the contractor and quality assurance (QA) by the owner to ensure that what 201.2R says should be done, is done. If such is the case the specifications will include all the provisions that are needed—and no others—and will include provisions to ensure that the requirements are followed. If the specifications are correct, and are followed the concrete will be durable. If it is not, you either did not order what you should have ordered, or you did not get what you ordered.

The rest of what one needs to know about durability of concrete is in ACI 20 1.2R. As I write this, the issue of the ACI Manual of Concrete Practice that I have is for 2000 and version of ACI 20 1.2R is that approved in 1992 (re-approved 1997), a revision is in progress and when it becomes available, should be followed [1].

The Guide includes eight chapters;

1. Freezing and thawing (including effects of de-icing chemicals).
2. Aggressive chemical exposure (sulfate, seawater, acid, carbonation).
3. Abrasion (floors, pavements, studded tires, tire chains).
4. Corrosion of metals and other materials embedded in concrete.
5. Chemical reaction of aggregates (alkali-silica reaction, alkali-carbonate rock reaction).
6. Repair of concrete (bonding, curing, treatment of cracks).
7. Protective barrier systems.
8. References (7 pages).

2. Freezing and thawing

Concrete will be immune to the effects of freezing and thawing, even when critically saturated with water, if it is made with frost-resistant aggregate; a proper entrained air-void system, and is protected from such freezing until moderately mature (compressive strength of about 30 Mpa).

3. Chemical attack

Concrete will not be seriously damaged by sulfate attack if, for moderate severity, the cement is moderate sulfate resisting (Type II or equivalent) or for severe exposure, highly sulfate resisting Type V or equivalent; or for very severe attack, Type V plus effective pozzolan or ground blast-furnace slag.

For mild acid exposure use concrete of w/cm less than 0.4 and Type II cement, for severe acid exposure use an acid-resistant coating.

To limit carbonation to very slight penetration, use a w/cm of 0.4 or less and ensure good curing, keep embedded corrodible metal at least 50 mm below the surface.

4. Abbrasion resistance

For proper resistance to abrasion of floors, select an abrasion limit using an ASTM standard test and require compliance. For pavements use either a tough abrasion-resistant aggregate or low w/cm or both, and good curing. To avoid cavitation damage, avoid irregularities of concrete surface that induce cavitation.

5. Corrosion of embedded metal

To avoid corrosion of embedded metals either embed the metal to a sufficient depth, possibly as much as 75–100 mm, in well cured low w/cm concrete; or use a corrosion-retarding chemical admixture; or use corrosion-resisting metal (zinc coated, stainless steel clad, copper clad, or stainless steel).

6. Alkali-aggregate reaction

Deteriorative effects of use of alkali-reactive aggregate can best be avoided by use of innocuous aggregate. Many aggregates that have some degree of reactivity will be innocuous when used with low-alkali cement (Na_2O equivalent of 0.60% or less, % $Na_2O + 0.658x$% K_2O). If an alkali-silica reactive aggregate must be used with cement that is not low-alkali, damage can be avoided or minimized by using adequate amounts of a suitable pozzolan or slag.

7. Summary

Concrete will be durable; that is it will serve its intended purpose for the intended service life with only tolerable need for maintenance and repair, if the specifications were correct and were followed.

References

[1] ACI Committee 201. "Guide to Durable Concrete", ACI 201.2R-92 (Reapproved 1997) Manual of Concrete Practice, vol. 1. 41 pp. with references.