Guide to Durable Concrete

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This guide describes specific types of concrete deterioration. Each chapter contains a discussion of the mechanisms involved and the recommended requirements for individual components of concrete, quality considerations for concrete mixtures, construction procedures, and influences of the exposure environment, which are all important considerations to ensure concrete durability.

This guide was developed for conventional concrete but is generally applicable to specialty concretes; however, specialty concretes, such as roller-compacted or pervious concrete, may have unique durability-related issues that deserve further attention that are not addressed herein. Readers should consult other ACI documents for more detailed information on special concretes of interest.

Keywords: abrasion resistance; acid attack; admixture; aggregate; air entrainment; alkali-aggregate reaction; calcium chloride; carbonation; cement paste; corrosion; curing; deicer; deterioration; durability; fly ash; freezing and thawing; mixture proportion; petrography; pozzolan; reinforced concrete; salt scaling; sea water exposure; silica fume; skid resistance; spalling; strength; sulfate attack; supplementary cementitious materials; temperature; water-cementitious material ratio.

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CHAPTER 1—INTRODUCTION AND SCOPE

Concrete is one of the most widely used construction materials in the world. This fact attests to concrete's performance as a versatile building material. Durability represents one of the key characteristics of concrete that has led to its widespread use. Durability of hydraulic-cement concrete is determined by its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment. Properly designed, proportioned, placed, finished, tested, inspected, and cured concrete is capable of providing decades of service with little or no maintenance. Certain conditions or environments exist that will lead to concrete deterioration. Attacking mechanisms can be chemical, physical, or mechanical in nature, and originate from external or internal sources. Chemical and physical attacking mechanisms often work synergistically. Depending on the nature of attack, distress may be concentrated in the paste, aggregate, or reinforcing components of the concrete (or a combination thereof).

The various factors influencing durability and the particular mechanism of deterioration should be considered in the context of the environmental conditions to which the concrete would be subjected. In addition, consideration should be given to the microclimate to which the specific structural element is exposed. Deterioration, or the severity of deterioration, of a given structure may be affected by its orientation to wind, precipitation, or temperature. For instance, exterior girders in a bridge structure may be exposed to a different and more aggressive environment than interior girders.

The concept of service life is increasingly used for the design of new structures. To provide durable concrete, the specific demands on the concrete in its intended use should be given careful consideration. Required service life, design requirements, and expected exposure environments (macro and micro) should be determined before defining the appropriate materials and mixture proportions necessary to produce concrete suitable for a particular application. The use of good materials and proper mixture proportioning will not necessarily ensure durable concrete. Appropriate measures of quality control, testing, inspection, placement practices, and workmanship are essential to the production of durable concrete. Properly designed testing and inspection programs that use trained and certified personnel are also important to ensure that durable concrete is produced. ACI has a number of certification programs that are applicable. This guide discusses the more important causes of concrete deterioration and gives recommendations on how to prevent such damage. Chapters on fresh concrete, freezing and thawing, alkali-aggregate reaction (AAR), aggressive chemical exposure, corrosion of metals, and abrasion are included. Fire resistance of concrete and cracking are not addressed in detail, because they are covered in ACI 216.1, 224R, and 224.1R, respectively.

Fresh or unhardened concrete can be consolidated and molded to the desired shape to serve its intended purpose. During this stage, a number of properties significantly influencing the durability of the hardened concrete are established. Pore structure development, air-void system formation, material mixing, placement and consolidation, curing, and minimizing or eliminating cracking of plastic concrete are all important to the ultimate durability of concrete.

Deterioration of concrete exposed to freezing conditions can occur when there is sufficient internal moisture present that can freeze at the given exposure conditions. Freezing-and-thawing damage is a serious problem, and is greatly accelerated by the use of deicing salts. Fortunately, concrete made with high-quality aggregates, a low water-cementitious material ratio (*w/cm*), a proper air-void system, and that is allowed to mature before being exposed to freezing and thawing, is highly resistant to freezing-and-thawing damage.

Although aggregate is commonly considered to be inert filler, this is not always the case in a concrete environment. Certain aggregates can react with alkali hydroxides from cement and other materials, causing expansion and deterioration.