IN-LB	Inch-Pound Units
SI	International System of Units

Concrete Structure Design for Fatigue Loading—Report

Reported by ACI Committee 215

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Fatigue is a mechanical degradation process caused by repeated loads, such as traffic loading or wind loads on a bridge, that results in irreversible damage in concrete structures. Many types of concrete elements are subjected to repeated loads, such as airport and roadway pavements, bridge girders, bridge decks, wind turbines, and prestressed concrete railroad ties. This document provides information that will benefit practicing engineers interested in the design or rehabilitation of concrete structures subjected to high-cycle fatigue—that is, stress cycles in which the material behavior remains within the elastic range. The effects of repeated loads on plain concrete, reinforcing materials, and reinforced concrete systems are discussed based on a summary of available literature. This report does not contain detailed design procedures but rather should be considered a general resource providing a comprehensive overview of fatigue issues in reinforced concrete structures.

Keywords: design; fabric-reinforced cementitious matrix; fatigue; fiber-reinforced concrete; fiber-reinforced polymers; prestressed concrete; rehabilitation; reinforced concrete; reinforcing materials; service life.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Fatigue is a mechanical degradation process caused by repeated loads, such as traffic loading or normal wind loads on a bridge, that results in irreversible damage in concrete structures. Because individual application of these service loads would not cause significant deformation or damage, fatigue damage occurs gradually from the cumulative effects of thousands or millions of load cycles. This report does not discuss the effects of high-amplitude load cycles associated with extreme events such as an earthquake or unintentional overload.

Many types of concrete elements are subjected to repeated low stress loads; common examples include airport and roadway pavements, bridge girders, bridge decks, wind turbines, and prestressed concrete railroad ties. Although in-service fatigue failures of concrete structures and their components are rare, the fatigue behavior of reinforced concrete structures is important to consider for numerous reasons. For example, fatigue behavior can be a controlling parameter that determines the service life of concrete pavements. In other cases, fatigue damage can lead to increased cracking with resulting loss of stiffness and strength in concrete members under service loads, which can lead to failure. In statically indeterminate structural systems, changes in stiffness caused by fatigue will also influence the distribution of loads. In summary, fatigue behavior affects the serviceability, safety, and durability of concrete structures, and its effects should be recognized in design to ensure that in-service cyclic stress ranges remain at an acceptably low level.

Live load amplitudes applied to a structure tend to grow over time, while new structures are becoming more lightweight through greater design optimization and the use of high-performance materials; this increases the ratio of live to dead loads. As a result, the importance of transient, cyclic stresses in proportion to an element's total load capacity is likely to increase over the service life of a structure. Furthermore, increasing use of construction materials such as post-tensioned concrete, fiber-reinforced polymers (FRPs), and fiber-reinforced concrete (FRC) requires engineers to have a broad understanding of the fatigue characteristics of various materials and systems.

Although service loads nominally produce stresses that are within the elastic range of the material or structure, small defects or geometric discontinuities can result in local amplified stress concentrations that exceed the elastic capacity of the material and form small damage zones or nucleation sites. The preliminary stage of the degradation process, where the development of these damage zones occurs, is often referred to as the initiation period. As these loads may be repeatedly applied thousands or millions of times, the damage zones grow in size (propagation) or in number (accumulation), leading to changes in the behavior of the larger material or composite component. In reinforced concrete members, this damage manifests through the formation of cracks in the concrete, reinforcement, or at their interface. The result of propagation and accumulation is usually a net reduction in the effective cross section of the member, its reinforcement, or in the bond strength between the reinforcement and the concrete, typically resulting in a loss of member stiffness and strength.

Although real live loads vary greatly in magnitude and application time sequence, for the purposes of design, an equivalent constant amplitude load cycle (for example, a sine function) with a well-defined maximum and minimum stress or strain level is normally assumed. This constant amplitude fatigue model presents many advantages for fatigue analysis, including the use of *S-N* curves for presenting and interpreting fatigue life data. In those curves, *S* represents normalized applied stress or strain amplitude and is plotted on a vertical axis using a linear (or sometimes logarithmic) scale against *N*, which is the number of load cycles to failure