# Guide for Concrete Highway Bridge Deck Construction

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*The service-life performance of concrete bridge decks, including maintenance, repair, and rehabilitation needs, is directly related to the care exercised from the preconstruction through post-construction period. This guide provides recommendations for bridge deck construction based on considerations of durability, concrete materials, reinforcement, placing, finishing and curing, and overlays.*

**Keywords:** admixtures; aggregate; air entrainment; bridge decks; concrete curing; concrete finishing; concrete overlays; concrete placing; cracking; durability; polymer concrete; reinforcing bars; scaling; shrinkage; skid resistance.



## CONTENTS



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## CHAPTER 1—INTRODUCTION AND SCOPE

### 1.1—Introduction

The deck of a highway bridge serves both structural and functional purposes for the structure. As a structural component, it provides the load path to safely transfer forces from wheel loads to the supporting superstructure and substructure elements. It may also contribute, through composite action, to the performance of primary superstructure components. Equally, the construction and condition of a deck directly impacts serviceability or the ability of the structure to safely and efficiently carry highway traffic by providing smoothness, skid resistance, and resistance to deflections under wheel loads. The riding surface of a highway bridge deck should provide a continuation of the pavement segments that it connects. The surface should be free from characteristics or profile deviations that impart objectionable or unsafe riding qualities. The desirable qualities should persist with minimum maintenance throughout the projected service life of the structure.

Roughness, cracking, spalling, scaling, and poor skid resistance are defects that result when the many details that influence their occurrence are not given sufficient attention. Recognition of the interaction of design, materials, and construction practices, as well as environmental factors, is the important first step in achieving smooth and durable decks.

Many decks remain smooth and free from surface deterioration and retain skid resistance for many years. When deficiencies occur, they usually take one of the forms described in this guide. The contribution of various aspects of deck construction to defects is discussed and guidelines based on theory and experience presented that should reduce the probabilities of occurrence to acceptable levels.

### 1.2—Scope

This guide presents considerations to take in the design and a summary of construction practices for conventionally reinforced concrete highway bridge decks. Such decks are typically supported by multiple simple- or continuous-span steel or prestressed concrete girders, or integral reinforced concrete members. The service-life performance of concrete bridge decks, including maintenance, repair, and rehabilitation needs, is directly related to the care exercised from preconstruction through the post-construction period. Recommendations are presented for design and durability considerations, concrete materials, reinforcement, placing, finishing and curing, and the use of overlays.

Although some performance and durability factors discussed may be applicable, design and construction of prestressed bridge decks are presently beyond the scope of this guide. Thus, prestressing steel is not included in the reinforcement section. Guidance for the design of prestressed bridge decks is being developed elsewhere (Swartz and Schokker 2008).

## CHAPTER 2—DEFINITIONS

### 2.1—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," at http://terminology.concrete.org. Definitions provided herein complement that resource.

**crack, reflective**—a crack that forms in a bonded overlay or wearing course caused by upward extension of moving crack or joint in the substrate.

**washboarding**—undulations in the finished surface of a deck that cause vibrations of undesirable frequency and amplitude in passing vehicles.

## CHAPTER 3—DESIGN AND DURABILITY CONSIDERATIONS

### 3.1—General

Chapter 3 emphasizes design factors that may affect the resistance of a bridge deck to chemical and environmental exposure, including potential for freezing and thawing, deleterious chemical reactions with concrete constituents, or chloride-induced corrosion damage. The design considerations of this chapter are not concerned with the structural analysis of the bridge deck. Structural aspects of the design, however, can have implications in the development of internal stresses and subsequent cracking in bridge decks, which may negatively impact durability. The items discussed in this chapter are generally within the purview of the bridge designer, and should receive due consideration.

## 3.2—Concrete and reinforcement materials

Although the specific topics of material selection for concrete mixture proportioning and bridge deck reinforcement are covered in greater detail in Chapters 4 and 5, respectively, it is important to emphasize the influence of material selection during the design process on the long-term durability of a bridge deck. Most modern bridge deck designs generally employ some strategy for deterring corrosion and enhancing exposure-related durability. These may include the use of epoxy-coated, galvanized, or metallic-clad reinforcement; alternative reinforcement materials such as various grades of stainless steel, specialized steel alloy formulations; or fiber-reinforced polymer (FRP) reinforcement.

The use of better-quality concrete mixtures has gained favor, either separately from, or in conjunction with, alternative reinforcement strategies. Such strategies may include minimizing the water-cementitious material ratio (*w/cm*) of a concrete mixture or the use of mineral admixtures, such as fly ash, silica fume, slag cement, or metakaolin, to reduce permeability characteristics of the concrete. Many other admixtures are commercially available to address workability and placement characteristics, resistance to freezing and thawing, and increased corrosion resistance. Other products are available to reduce susceptibility to plastic and drying shrinkage.

Careful consideration should be given to the selection of deck materials. One common myth is that compressive strength is the single most important factor in specifying quality deck concrete. In fact, concrete bridge decks composed of concrete with excessively high compressive strength tend to be less flexible, have greater shrinkage potential, and have less ability to redistribute load and thermal- or shrinkage-induced strains. The result is a greater tendency toward cracking, which leads to premature deterioration from the ingress of moisture and aggressive chemicals, such as deicing salts. Recently, many agencies have considered performance-based specifications that rely more on measures of permeability than strength as criteria for acceptance.

Alternatively, reinforcing materials such as FRP bars, which are not affected by chlorides, can be considered viable alternatives to ferrous reinforcing bars. The use of FRP bars is governed by the American Association of State Highway Transportation Officials (AASHTO) LRFD design guidelines (AASHTO 1998) and by the Canadian Highway Bridge Design Code (CAN/CSA-S6-06) (Canadian Standards Association 2006).

## 3.3—Positive protective systems

**3.3.1** *Overlays*—The common forms of bridge deck deterioration, such as scaling, some types of cracking, and surface spalling, generally occur within the top 2 in. (50 mm) of a deck. Improper concrete placing and finishing practices often result in a lower-quality concrete in this area. Because it is subjected to the most severe exposure and service conditions, the top portion of the deck slab should have the best possible concrete quality. Consideration should be given to placing an overlay on the bridge deck when it is constructed. Many different types of overlays have been used successfully. Chapter 7 discusses several types of overlays in detail.

**3.3.2** *Other positive protective systems*—Because of the high cost of repairing corrosion-induced damage, several different protective systems are being used for bridge decks in severe deicing salt areas and for structures in marine environments. Other systems used to enhance durability or protect decks, some of which have been mentioned already, may include:

1. High-performance concretes that employ fly ash, silica fume, and slag cement as mineral additives for reduced permeability and protection against sulfate attack and alkali-silica reaction (ASR);
2. Shrinkage-compensating cements or shrinkage-reducing admixtures (SRA) in concrete for crack reduction;
3. Calcium nitrite, or other (anodic) corrosion-inhibiting admixtures, for increasing the threshold value of chloride concentration required for corrosion;
4. Waterproofing membranes with or without a bituminous concrete wearing surface for protection against chloride ion penetration;
5. Passive-current or impressed-current cathodic protection for preventing corrosion and stopping the corrosion of active systems;
6. Reinforcing steel coatings or cladding such as galvanizing, fusion-bonded epoxy, and stainless steel for extending the time to corrosion damage; and
7. Alternative reinforcing materials, such as solid stainless steel and nonmetallic FRPs, for extending the corrosion-resistant service life.

The performance of several different protection systems was evaluated as part of Strategic Highway Research Program (SHRP) and Federal Highway Administration (FHWA) studies (Pfeifer et al. 1987; Bennett et al. 1993; Weyers et al. 1993). As noted previously, selection of appropriate concrete mixtures is discussed in detail in Chapter 4. The ability of various types of reinforcement to resist corrosion is discussed in Chapter 5.

## 3.4—Arrangement and cover of reinforcement

**3.4.1** In the most common type of bridge deck—the slab-on-beam bridge using a 7 to 9 in. (175 to 230 mm) thick slab spanning between longitudinal girders—the primary reinforcement is placed transverse to the girders. To use this reinforcement most effectively from a structural point of view, practice places the reinforcement closest to the top and bottom slab surfaces. The "AASHTO Standard Specifications for Highway Bridges" (AASHTO 1998) provides simple empirical equations to represent the Westergaard analysis of bridge deck behavior. The primary reinforcement is selected on the basis of one-way slab action and pure flexure. Shear, bond, and fatigue are not considered in the procedure. None of the bridge deck durability studies have