



Bridge Design - Concrete Decks

Course Number: CE-02-408

PDH: 2

Approved for: AK, AL, AR, FL, GA, IA, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868

Indiana Continuing Education Provider #CE21800088

Maryland Approved Provider of Continuing Professional Competency

New Jersey Professional Competency Approval #24GP00025600

North Carolina Approved Sponsor #S-0695

NYSED Sponsor #274

Course Author: Mathew Holstrom

How Our Written Courses Work

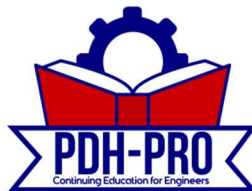
This document is the course text. You may review this material at your leisure before or after you purchase the course.

After the course has been purchased, review the technical material and then complete the quiz at your convenience.

A Certificate of Completion is available once you pass the exam (70% or greater).

If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).

If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.



CONCRETE DECKS

1.1 INTRODUCTION

Bridge decks are an integral part of the bridge structure by providing the direct riding surface for motor vehicles. In addition, bridge decks directly transfer load from the moving traffic to the major load-carrying members. This chapter provides a general description of the various concrete deck types, a discussion of the basic structural behavior of concrete decks, and an overview of major design and detailing considerations. Finally, a design example for a reinforced concrete bridge deck is provided. The example illustrates bridge deck design in accordance with the *AASHTO LRFD Bridge Design Specifications* (AASHTO, 2012) and the California Amendments (Caltrans, 2014).

1.2 CONCRETE DECK TYPES

There are two main types of concrete decks, cast-in-place, and precast. The most common type used in Caltrans is the cast-in-place reinforced concrete deck. The other type is used depending on the various conditions like location, traffic, cost, seismicity schedule, and aesthetics (Chen and Duan, 2014).

1.2.1 Cast-In-Place Concrete Decks

A cast-in-place concrete deck is a thin concrete slab, either using normal reinforcement or prestressing steel, usually between 7 and 12 inches, with reinforcing steel interspersed transversely and longitudinally throughout the slab. There are several advantages to using a reinforced concrete deck. One of the major advantages is its relatively low cost. Other advantages are ease of construction and extensive industry use.

Even though cast-in-place concrete decks have advantages, there are disadvantages using this particular type of deck, such as cracking, rebar corrosion, and tire noise. A large cost of bridge maintenance is in maintaining the riding surface (Fu, et al., 2000). Lack of deck crack control can lead to rebar corrosion and increased life cycle cost, not to mention a poor riding surface for the public.

1.2.2 Precast Concrete Decks

Precast concrete decks consist of either precast reinforced concrete panels or prestressed concrete panels. These panels can either serve as the final deck surface or as a temporary deck to allow placement of a final cast-in-place concrete deck. The advantage of a precast concrete deck is in the acceleration of the construction schedule. Precast panels allow for quicker placement, which, in principle, speeds up overall bridge construction.

1.3 DESIGN APPROACH

1.3.1 Structural Behavior of Concrete Decks

It is accepted and widely known that the primary structural behavior of a concrete deck is not pure flexure, but a complex behavior known as internal arching. Concrete slabs behave quite differently than concrete beams under a given load. Research has shown that when a concrete slab starts to crack, the load is initially resisted by a combination of flexure stresses and membrane stresses as shown in Figure 1.3-1 (Csagoly, et al., 1989). The stresses and strain create cracks in three dimensions around the wheel footprint. The way internal arching works is as cracks develop in the bottom of the slab and the slab's neutral axis shifts upward, compressive stresses develop above the neutral axis to resist further opening of the cracks. The concrete portion above the crack is in a purely elastic state. Therefore, what results is a domed shaped compression zone around the load.

The compressive membrane stresses do not resist the loading completely. There is a small flexural component that also resists the loading as well. But the controlling structural mechanic is the membrane compressive stresses created in the upper parts of the slab.

For the deck to fail, as the load is increased the deflection also increases. The section around the load becomes overstrained and this results in a cone-shaped section of failed concrete. Therefore, the primary failure mode is punching shear.

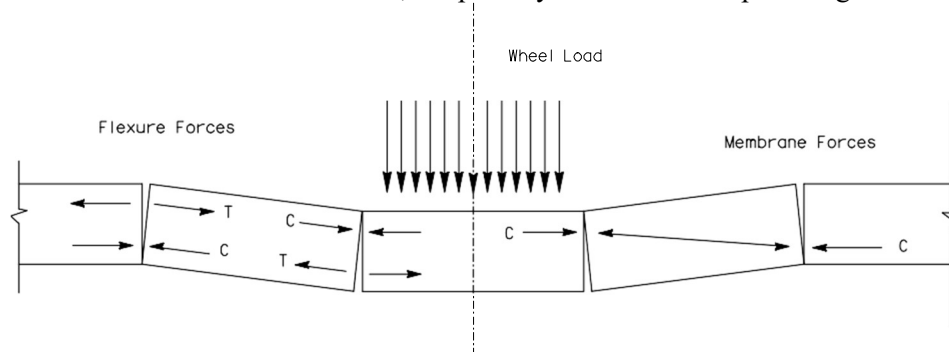


Figure 1.3-1 Concrete Deck Showing Flexure and Membrane Forces

1.3.2 Limit State

1.3.2.1 Service Limit State

Concrete decks are designed to meet the requirements for Service I limit state (AASHTO Article 9.5.2). Service limit state is used to control excessive deformation and cracking. According to the California amendment (CA Article 9.5.2), deck slabs shall be designed for Class 2 exposure, therefore,

$$\gamma_e = 0.75 \quad \text{(AASHTO Article 5.7.3.4)}$$

1.3.2.2 Strength Limit State

Concrete decks must be designed for Strength I limit state. Because concrete deck slabs are usually designed as tension-controlled reinforced concrete components, the resistance factor is $\phi = 0.9$ (AASHTO Article 5.5.4.2). Strength II limit state typically is not checked for deck designs. The permit vehicle axle load does not typically control deck design (CA Article C3.6.1.3.3).

1.3.2.3 Extreme Event Limit State

Most bridge decks include an overhang with a concrete barrier attached. Therefore, the deck overhang has to be designed to meet the requirements for Extreme Event II. The AASHTO (2012) requires bridge deck overhangs to be designed for the following cases (AASHTO Appendix A13.4):

Design Case 1: The transverse and longitudinal forces specified in AASHTO Appendix A13.2 - Extreme Event Load Combination II limit state.

Design Case 2: The vertical forces specified in AASHTO Appendix A13.2 - Extreme Event Load Combination II limit state.

Design Case 3: The loads, specified in AASHTO Article 3.6.1, that occupy the overhang- Load Combination Strength I limit state.

1.3.2.4 Fatigue Limit State

Concrete decks supported by multi-girder systems are not required to be investigated for fatigue (AASHTO Article 9.5.3).

1.3.3 Methods of Analysis

1.3.3.1 Approximate Method of Analysis

Caltrans traditionally designs concrete bridge decks as transverse strips as a flexure member. This method is called the Approximate Method of Analysis (AASHTO Article 4.6.2.1). The concrete deck is assumed to be transverse slab strips, which is supported by the girders. To simplify the design, it is assumed that the girders are rigid supports. The AASHTO specifications allow the maximum positive moment and the maximum negative moment to apply for all positive moment regions and all negative moment regions in the slab, respectively.

The width of an equivalent strip (interior strip) is dependent on the type of deck used, the primary direction of the strip relative to the direction of traffic, and the sign of the moment. AASHTO Table 4.6.2.1.3-1 only applies for interior strips and not for overhangs.

1.3.3.2 Refined Methods of Analysis

The Refined Methods of Analysis (AASHTO Article 4.6.3) as listed in AASHTO 4.4 are acceptable methods for analyzing concrete bridge decks. But these various methods are not typically used to analyze a standard bridge deck. A refined analysis method would be better suited for a more complex deck slab structure, which would require a more detailed analysis.

1.3.3.3 Empirical Method of Analysis

Empirical Design (AASHTO Article 9.7.1) is a method of deck slab design based on the concept of internal arching action within concrete slabs. But, until further durability testing of this design method is completed, the empirical design method is not permitted for concrete bridge deck design in California (CA Article 9.7.2.2).

AASHTO Table 4.6.2.1.3-1 Equivalent Strips

Type of Deck	Direction of Primary Strip Relative to Traffic	Width of Primary Strip (in.)
Concrete: ● Cast-in-place ● Cast-in-place with stay-in-place concrete formwork ● Precast, post-tensioned	Overhang Either Parallel or Perpendicular Either Parallel or Perpendicular Either Parallel or Perpendicular	$45.0 + 10.0X$ $+M: 26.0 + 6.6S$ $-M: 48.0 + 3.0S$ $+M: 26.0 + 6.6S$ $-M: 48.0 + 3.0S$ $+M: 26.0 + 6.6S$ $-M: 48.0 + 3.0S$
Steel: ● Open grid ● Filled or partially filled grid ● Unfilled, composite grids	Main Bars Main Bars Main Bars	$1.25 P + 4.0 S_b$ Article 4.6.2.1.8 applies Article 4.6.2.1.8 applies
Wood: ● Prefabricated glulam ○ Non interconnected ○ Interconnected ● Stress-laminated ● Spike-laminated ○ Continuous decks or Interconnected panels ○ Non interconnected panels	Parallel Perpendicular Parallel Perpendicular Parallel Perpendicular Parallel Perpendicular Parallel Perpendicular	$2.0 h + 30.0$ $2.0 h + 40.0$ $90.0 + 0.84L$ $4.0 h + 30.0$ $0.8 S + 108.0$ $10.0 S + 24.0$ $2.0 h + 30.0$ $4.0 h + 40.0$ $2.0 h + 30.0$ $2.0 h + 40.0$
S = spacing of supporting components (ft) h = depth of deck (in.) L = span length of deck (ft) P = axle load (kip) S_b = spacing of gird bars (in.) $+M$ = positive moment $-M$ = negative moment X = distance from load to point of support (ft)		



Purchase this course to
see the remainder of
the technical materials.