Report on Flexural Live Load Distribution Methods for Evaluating Exisiting Bridges

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This report provides a synthesis of the topic of flexural live load distribution and its applicability to concrete bridges. Flexural live load distribution is critical to describing how loads are transmitted through a bridge system. This report is intended to provide engineers, including load rating engineers, with basic guidance on the methods and tools available for determining live load distribution behavior of in-service bridges. Included in the report are descriptions, a brief history, and background of the flexural load distribution phenomena and a summary of design and analysis methods used to describe the phenomena in practice. A series of case studies are presented in the latter part of the report to serve as a comparison summary of commonly used live load distribution methods and their performance in describing the behavior of in-service structures. The report also provides performing bridge load ratings with a practical synopsis of the various methods available for determining the live load distribution factor. While this report is limited to flexural live load distribution, it provides the foundation for a future committee guide on the in-service evaluation of concrete bridges.

Keywords: bridge analysis; bridge load rating; distribution factor; equivalent beam analysis; finite element; grillage analysis; live load testing; load resistance; transverse flexural load distribution.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Maintenance of an aging transportation infrastructure, including concrete bridges, is essential to the sustainability of resources and economic prosperity. With a national inventory of more than 600,000 bridges in the United States, 66 percent of which are concrete, maintenance and preservation represent a challenge for transportation agencies (Federal Highway Administration 2014). For these agencies, the challenge is to avoid or minimize bridge replacement and rehabilitation in the face of increased traffic volume and truck loads, along with dwindling financial resources.

Transportation agencies are responsible for ensuring both the safety and functionality of these bridges, and meeting this challenge requires a realistic measure of the actual behavior and in-service performance. This characterization of behavior is essential to determine the actual load-carrying capacity or remaining capacity of a bridge, which is typically determined through a processed called load rating. Load rating of a bridge defines the expected resistance or capacity based on its existing condition state and operating environment. As with bridge design, a challenge that exists for describing a bridge's capacity is the complex system interaction that exists amongst the superstructure components. For example, in a beam-slab bridge, the complexity is derived from the coupled interaction of two-way plate behavior within the bridge deck and the one-way beam behavior inherent to the girders. For both design and evaluation, a methodology for transverse distribution of loads, or live load distribution, is typically used to represent this phenomenon and provide a method to quantify relative load sharing behavior within the system.

In practice, this phenomenon is typically defined using prescriptive formulas that simplify the complex behavior into simple factors, but in recent decades, several refined methods for determining live load distribution have evolved. These methods provide alternative mechanisms to describe live load distribution behavior, which can often be more representative than the empirical methods included in most bridge design codes and specifications. The advantage of considering these methods is that they have the potential to describe the physical phenomenon and actual load distribution behavior, which in turn provides the bridge engineer with a mechanisms to make more informed decisions regarding load restrictions, maintenance, and replacement of existing bridges.

1.2—Scope

This report is intended for the bridge engineering community, particularly engineers responsible for bridge load rating, to provide basic guidance on the methods and tools available for determining live load distribution behavior of in-service bridges. The objective is to present guidance on available methods for determining live load distribution, including approximate formulas, structural analysis, or load testing. The selection of a particular method of analysis is presented within the context of the intended level of refinement and bridge type, such as slab, beam-slab, and box girder. Included in this report are descriptions, a brief history, and background of the flexural load distribution phenomena and a summary of design and analysis methods used to describe the phenomena in practice. This report provides an overview of criteria for transverse load distribution, including their limitations and acceptability; a summary and description of the use of refined methods of analyses for transverse load distribution; and load test methods. A series of case studies are presented in the latter part of the report to serve as a comparative analysis of commonly used live load distribution methods and their performance in describing the behavior of in-service structures.

While this distribution phenomenon is relevant to a variety of force effects, this report focuses exclusively on flexure. The treatment of shear is a topic of future work by the committee and will be part of a guide on the in-service evaluation of concrete bridges, but is beyond the scope of this report. For a treatment of shear load distribution, the