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Evaluation of Concrete Bridge Behavior through Load Testing – International Perspectives

Editors:
Eva Lantsoght and Pinar Okumus

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American Concrete Institute
Always advancing

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On the cover: Load test of a cable stayed bridge over Wisłok River, Poland. Photograph by Dr. K. Wilde.

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Preface

Load testing of concrete bridges is a practice with a long history. Historically, and particularly before the unification of design and construction practices through codes, load testing was performed to show the travelling public that a newly built bridge was safe for use. Nowadays, with the aging infrastructure and increasing loads in developed countries, load testing is performed mostly for existing structures either as diagnostic or proof tests. For newly built bridges, diagnostic load testing may be required as a verification of design assumptions, particularly for atypical bridge materials, designs, or geometries. For existing bridges, diagnostic load testing may be used to improve analysis assumptions such as composite action between girders and deck, and contribution of parapets and other nonstructural members to stiffness. Proof load testing may be used to demonstrate that a structure can carry a given load when there are doubts with regard to the effect of material degradation, or when sufficient information about the structure is lacking to carry out an analytical assessment.

In recent years, both researchers and practicing engineers worldwide have been refining load testing methods to balance accuracy, cost, effort, and time, and have been addressing increasingly complex structures and situations. To exchange international experiences among a global group of researchers and compare load testing methods used internationally, ACI Committee 342 organized two sessions titled “Evaluation of Concrete Bridge Behaviour through Load Testing – International Perspective” at the 2017 ACI Fall Convention in Anaheim, CA. This Special Publication contains several technical papers from experts who presented their work at these sessions, in addition to papers submitted for publication only.

This Special Publication combines contributions from different regions of the world, and in particular from Denmark, Germany, the Netherlands, Poland, Spain, Sweden, and from different regions in the United States. The technical papers consider both theoretical and practical aspects of load testing, discuss different levels of bridge behaviour assessment such as visual inspections, modelling, and load testing. They introduce the reader to the codes and guidelines that may only be available in some countries. The impact of differences in live loads, design codes, reserve capacities, age of structures, construction practices between Europe, and North America on assessment of concrete bridges is reflected by case studies. Recent developments with regard to codes and standards around the world for load testing are discussed, and open questions for future developments are highlighted by the authors.

The wide variety of concrete bridge structures investigated included short-span reinforced concrete slab bridges, older reinforced concrete earth-filled arch bridges, bridges that have been damaged and/or retrofitted, and modern prestressed concrete bridges with new materials. Reasons why load testing is required also vary and include apparent damage, opportunities created by decommissioned bridges, necessity to carry super heavy vehicles, use of unique materials or geometry, and absence of design plans. Results of testing bridges under static or dynamic service loads create knowledge on expected service performance and allow load ratings, while testing decommissioned bridges to near collapse or collapse reveals true capacity and the level of conservatism in design assumptions. Several papers highlight vehicles or rigs designed specifically for reuse in standardized load testing. Others use recent technology such as 3-D scanning or digital image correlation to collect data, in addition to traditional methods such as strain gauges. As such, this Special Publication provides a global perspective on strategies for assessing the in-service performance of concrete bridges, and an overview of the state-of-the-art with regard to load testing internationally.

Overall, in this Special Publication, authors from different backgrounds and geographical locations share their experiences and perspectives on load testing and its impact on understanding concrete bridge behaviour. The coeditors, Dr. Pinar Okumus and Dr. Eva Lantsoght, are grateful for the contributions of the Special Publication authors and sincerely value the time and effort of the authors in preparing the papers in this volume.

Eva Lantsoght and Pinar Okumus
Co-Editors

TABLE OF CONTENTS

ASSESSMENT OF SLAB BRIDGES THROUGH PROOF LOADING IN THE NETHERLANDS

Eva O. L. Lantsoght, Cor van der Veen, Ane de Boer and Dick A. Hordijk

Synopsis: A large subset of the Dutch bridge stock consists of reinforced concrete slab bridges, for which assessment often results in low ratings. To prioritize the efforts of the bridge owner, more suitable assessment methods for slab bridges are necessary. Research efforts over the past years resulted in the development of several methods, at levels requiring increasing costs, time, and effort for increasing accuracy. The last option, when an analytical assessment is not possible due to uncertainties, is to use proof load testing to evaluate the bridge directly. To develop recommendations for the proof load testing of reinforced concrete slab bridges for the Netherlands, different methods are combined: pilot proof load tests on bridges with and without material damage, a collapse test, tests on beams taken from an existing bridge and new beams with similar dimensions cast in the laboratory, and an extensive literature review. The result of this study is a set of recommendations that describe how to prepare and execute a proof load test, and how to analyze the results. This paper summarizes the research program about proof load testing from the Netherlands and gives an overview of the currently developed recommendations and topics for further research.

Keywords: field testing; flexure; measurements; proof load testing; reinforced concrete; shear; slab bridges

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INTRODUCTION

Existing bridges in the Netherlands

The expansion of the Dutch road network after the Second World War included the construction of a large number of bridges. These bridges are now approaching the end of their originally devised service life of 80 years. To evaluate if extension of the service life of these bridges is possible, and if they are suitable for carrying the current traffic, assessment of these structures is required.

A large subset of the Dutch bridge stock consists of reinforced concrete slab bridges. Of the bridges built during the 1960s and 1970s, 50% are reinforced concrete slab bridges. In later periods, the majority of bridges were prestressed prefabricated girder bridges. The reinforced concrete slab bridges are typically short span bridges in or over the highway, and can be a single span or multiple spans. A first assessment, based on the code provisions for the design of new structures (Vergoossen et al., 2013), showed that about 600 of these bridges do not fulfil these code requirements. In many cases, the shear capacity was insufficient. This observation resulted from the fact that the applied live loads according to NEN-EN 1991-2:2003 (CEN, 2003) are heavier than those used in the past, and that the shear provisions described in NEN-EN 1992-1-1:2005 (CEN, 2005) generally lead to lower shear capacities than the previously governing national code NEN 6720:1995 (Code Committee 351001, 1995).

Assessment based on Levels of Approximation

The *fib* Model Code 2010 (fib, 2012) introduced the Levels of Approximation concept for the first time. A low Level of Approximation is a conservative method that can be used, for example, for preliminary design. If the assessment requires a more accurate answer, a higher Level of Approximation is necessary. This higher Level of Approximation will require more time to set up the model, and increased computational time and effort as compared to a lower Level of Approximation. Belletti et al. (2015) recommend different Levels of Approximation for the shear and punching provisions (Belletti et al., 2015), as used in the *fib* Model Code 2012 (fib, 2012). Figure 1 illustrates the concept of using Levels of Approximation.

For the assessment of the shear capacity of reinforced concrete slab bridges, a method with Levels of Approximation was developed as well (Lantsoght et al., 2017a), called Levels of Assessment. In total, four Levels of Assessment were identified:

1. Level of Assessment 1 – Quick Scan method: the Quick Scan method (Lantsoght et al., 2013b; Lantsoght et al., 2016f) is a fast, spreadsheet-based calculation that mimics a hand calculation. The provisions of the Eurocodes NEN EN 1991-2:2003 (CEN, 2003) and NEN-EN 1991-2-2:2005 (CEN, 2005) are followed and extended with recommendations based on slab experiments (Lantsoght et al., 2013c; Lantsoght et al., 2014b; Lantsoght et al., 2015a; Lantsoght et al., 2015c). The result is a Unity Check: the ratio of the shear stress caused by the loads (self-weight, superimposed dead load, and live loads) to the shear capacity. If the Unity Check is smaller than or equal to one, no further refinement of the assessment method is required and the code requirements for the bridge are fulfilled. If the Unity Check is larger than 1, a higher Level of Assessment is necessary.