Introduction

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Chapter 1. Introduction

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ABSTRACT: This chapter introduces the general topic of load testing of structures. In this chapter, the reader can find a short background to the topic of load testing of structures, the scope of this book, the aim of this book, and a short discussion of the structure and outline of this book.

1 BACKGROUND

Load testing of bridges can be considered a very specialized topic as well as a very broad topic. One can consider it a very specialized topic, since it is one type of testing that is part of the bridge engineering profession. On the other hand, the amount of information and different views and practices in this book demonstrates that load testing is a broad topic and that load testing can be used to serve a large number of purposes.

Both new and existing bridges can be subjected to a load test. Two types of load tests can be distinguished: diagnostic load tests and proof load tests. This book separates these two topics in separate parts with best practices and examples of application. Diagnostic load tests are used to obtain direct information from a bridge in the field, to verify behavior or to update analytical models. Proof load tests are used to demonstrate directly that a bridge fulfils the code requirements.

For new bridges, diagnostic load tests are the most common type of load tests. In some countries, diagnostic load tests are required prior to opening of some or all new bridges to demonstrate that the bridge behaves in the way it was designed and to confirm the assumptions made in the analytical models used for the design. In the past, proof load tests on new bridges were used prior to opening to demonstrate to the traveling public that the bridge is “safe” for use. Safety in this context was defined as the bridge being able to carry a large number of heavily loaded trucks.

In existing bridges, diagnostic load tests can be used to update the analytical models developed for the assessment of the bridge. A diagnostic load test can be used to determine the transverse distribution of the actual structure, the actual stiffness of the structure, the amount of restraint at the supports, the effect of unintended composite action in non-composite sections, etc. This information can then be used to have a better understanding of the bridge behavior. Proof load tests on existing structures can be used to demonstrate that a given bridge fulfils the code requirements by applying a load that is representative of the factored load combination. Proof load tests can be interesting when there are large uncertainties on the structure and its behavior, caused by for example the effect of material degradation and deterioration on the capacity, the case of planless bridges, or caused by uncertainties on the structural behavior at larger load levels. Since they involve larger loads, proof load tests are more expensive and require a more extensive preparation than diagnostic load tests.

With an increasing need to assess existing structures, methods of field testing including load testing, monitoring of structures, and nondestructive testing have increased in importance over the past decades. The elements of the method of load testing that are discussed in this book are the general procedures regarding deciding on load testing, preparing load tests, executing load tests, and evaluating the results of a load test after the test. These elements are described in general terms, as well as separately for diagnostic and proof load tests, for which different considerations are important. This book contains a number of case studies, showing for specific bridges how these considerations are applied in practice and providing guidance and advice for practicing engineers that are preparing load tests. Besides the tried-and-tested methods for load testing, this book also discusses novel measurement techniques that can improve the practice of load testing in the future. Additionally, this book shows how load testing can move from a singular test to a method to evaluate the safety of a given bridge by linking the principles of load testing to concepts of structural reliability.

The field of load testing is moving from deterministic approaches based on rules of thumb to practices in which the proven safety after a load test can be quantified. Many researchers have worked on making this step over the past years, often in close collaboration with practicing engineers, bridge owners, and road authorities. With an increasing need to consider structures within their life-cycle and as part of a network, there is an incentive to place load testing within the framework of a decision-making process at the network level and to carry out load tests at the optimal time during the life-cycle of a structure. These principles are not present yet in the existing codes and guidelines for load testing, but are topics of research that are discussed in this book.

As the title indicates, this book discusses load testing of bridges. However, the same procedures can be applied to other structures. For this purpose, a chapter on load testing of buildings has been included. In the introductory chapters on the history of load testing and the current codes and guidelines, both bridges and buildings are discussed. The general principles for load testing of bridges and buildings are the same, but closing a building for a load test has a lower impact than closing a bridge, which results in driver delays and secondary costs. As such, in the past, loading protocols that last more than a day were common for buildings. Another element of particular interest for buildings is that a building may contain a large number of floor spans with similar dimensions. An open question here is how many spans should be tested to have a statistically relevant number of tests for the evaluation of all floor spans in the building. This topic is addressed in the part about load testing of buildings.

This book encompasses all bridge types: new and existing bridges. The presented case studies show cases of new bridges that were load tested upon opening because they are built with a novel material, and/or to verify the structural behavior of the new bridge. Other case studies show how load testing can be used for the assessment of existing bridges. The presented case studies of proof load tests all deal with existing structures with large uncertainties, where a proof load test is used to directly demonstrate adequate performance.

The scope includes all building materials. Most of the presented case studies are based on reinforced concrete road bridges, but some applications of steel bridges and prestressed concrete bridges are included as well. The case studies do not include timber, masonry, or plastic bridges, but the same principles can be applied to these building materials. In the chapters that deal with general considerations and methodology of load testing, topics of interest related to these building materials are highlighted, and references to relevant articles and reports are included for the reader.

The majority of the information and case studies in this book applies to road bridges, as such bridges make up the majority of the bridges in the transportation network. The chapter with examples of applications of diagnostic load tests from Europe also discusses dynamic load testing of railroad bridges. The same principles are valid for road and railroad bridges, yet the tolerances are different. During the preparation stage of a load test on a railroad bridge, the governing tolerances should be reviewed, and where necessary, the stop and acceptance criteria should be updated to reflect these tolerances. Most codes and guidelines for load testing focus on road bridges. However, the Spanish and French codes also give recommendations for load testing of pedestrian bridges. The applied load is then either dead loads or human pedestrians. One chapter deals with the topic of load testing of pedestrian bridges.

3 AIM OF THIS BOOK

Over the past decades, there have been a large number of developments related to improved methods for the assessment of existing structures. This evolution reflects the fact that our built environment is aging and requires suitable methods to evaluate these structures, which are different from the methods used for designing new structures. Topics that have been of interest in this regard are methods of field testing including load testing, monitoring of structures, and nondestructive testing techniques. This increased importance is reflected by the number of mini symposia, special sessions, paper collections, special publications, etc. that have been organized and developed over the past years.

This book aims at bringing together the available information and knowledge on the topic of load testing of bridges, and –to a smaller extent- other structures. The gathered knowledge includes practical experiences from load tests as well as research insights. It reflects the current state-of-the-art at an international level, and aims at showing the way forward in research related to load testing of bridges. The reader will notice throughout this book that local practices differ. Overall recommendations on which code or guidelines is the “best” for load testing are not included in this book, since a variety of goals for load tests can be identified. Prior to the load test, the test engineers should identify the goals for the load test, decide if a load test is the appropriate instrument to meet these goals, and then outline how these goals can be met, and which practical considerations in terms of measurements and load application should be taken into account to meet these goals. The reader will understand through the case studies that each load test is different, and thus requires different particular considerations during the preparation, execution, and post-processing stages.

4 OUTLINE OF BOOK

This book is divided in eight parts. Figure 1 gives the overall structure of the book, which is centered around going from the historical background to load testing, and how past practices led to the current codes and guidelines, to the current practice of load testing, to topics of research that currently are explored in pilot load tests and that will be implemented in the codes and guidelines of the future.

The first part of this book focuses on the historical background of load testing and how past practices resulted in the current codes and guidelines. This part covers the historical perspectives and currently governing codes and guidelines. The background is discussed from an international perspective, outlining the history of load testing in North America and Europe, and summarizing the current codes and guidelines for load testing from Germany, the United States, the United Kingdom, Ireland, Poland, Hungary, Spain, the Czech Republic and Slovakia, Italy, Switzerland, and France.

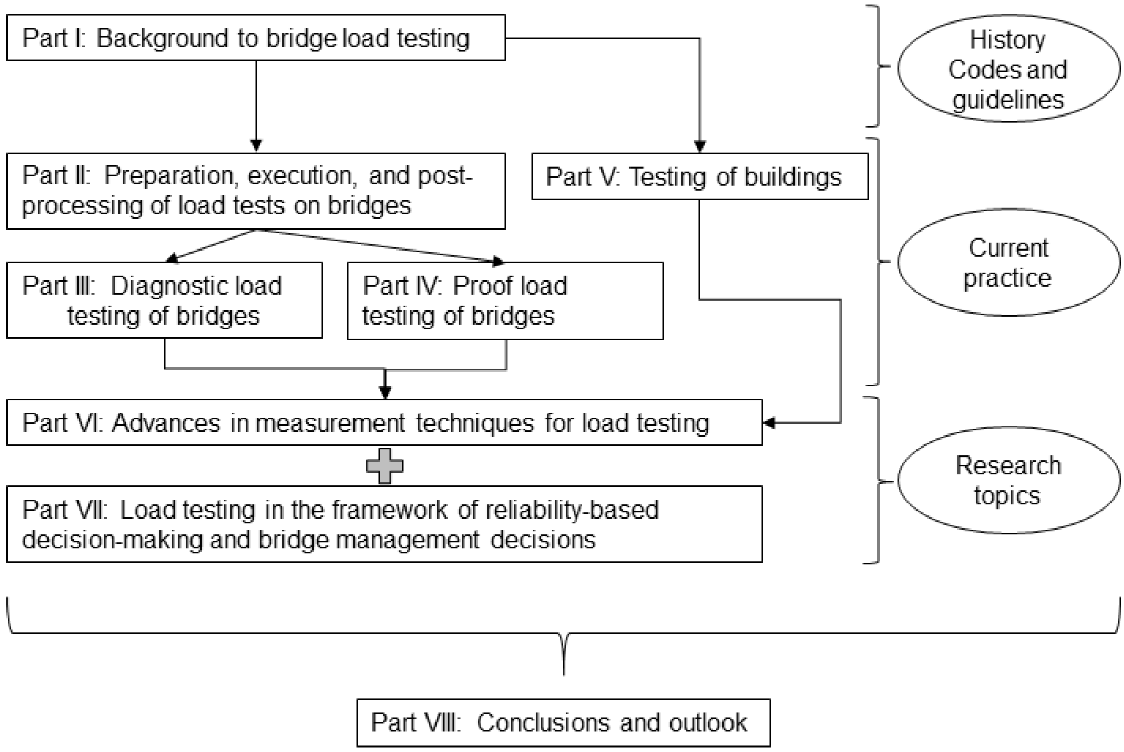

Figure 1. Overall structure of book

The second part of the book is the first part that deals with the current practice of load testing. It gives an overview of the general practical aspects of load testing, which are valid for the different types of load tests (diagnostic and proof load tests) and covers different bridge types in terms of structural systems and in terms of construction material. These practical aspects cover the entire stage of a load testing project: from preparation, to execution, to post-processing and reporting about the load test. The first topic in this part contains general considerations for each load testing project: which type of load test is suitable for the project, and can a load test give answers to the open questions regarding the structure? If the decision is made to load test a bridge, the next step is to prepare this load test. Therefore, the next topic discusses the elements of the preparation of a load test: inspection, preliminary calculations, and planning of the project. Then, general aspects of the execution of the load test, with regard to loading equipment, measurement equipment, and practical aspects of communication and safety are discussed. The last topic of this part deals with post-processing of load testing data, reporting of load tests, and decision-making after a load test.

The third part of the book continues the topic of current practice of load testing, and focuses on the particularities of diagnostic load testing of bridges. It discusses the aspects of the preparation, execution, and post-processing of a diagnostic load test that are different from other load tests, and the general methodology for diagnostic load tests. Chapters describing detailed examples of diagnostic load tests from North America and Europe are included. One chapter discusses diagnostic load testing of pedestrian bridges.

The fourth part of the book stands next to the third part, see Figure 1, and focuses on proof load testing of bridges. It discusses the specific aspects of proof load testing during the preparation, execution, and post-processing of a proof load test. Important topics in this part are the interpretation of the measurements in real-time during the experiment and thresholds to the structural response, and the determination of the target proof load. Since in proof load tests, high loads are applied, the risk of collapse or permanent damage to the structure exists. For this reason, careful instrumentation and monitoring of the bridge during the proof load test is of the utmost importance. Criteria based on the structural response that can be used to evaluate when further loading may not be permitted are discussed. Chapters describing examples of proof load test from North America and Europe are included.

The fifth part fits in the current practice of load testing, and describes how the practice of load testing can also be applied to buildings. Whereas the main focus of this book is on bridges, the same principles can be used for load testing of buildings. Buildings can require a load test prior to opening when there are doubts about the adequate performance of the building, or during the service life of the building when there are doubts regarding the capacity as a result of material degradation or deterioration, or when the use and associated live load of the building is to be changed. This part also discusses current research topics related to the practice of load testing that will be included in future issues of the German guideline for load testing.

The sixth part of this book is the first part that focuses on research topics and the future of load testing. This part discusses novel measurement techniques used for load testing that are not yet part of the standard practice for load testing. Methods using non-contact sensors, such as photography- and video-based measurement techniques are discussed. With acoustic emission measurements, signals of microcracking and distress can be observed before cracks are visible. Fiber optics are explored and applied as a new measurement technique. The topic of measurements through radar interferometry is also discussed. These chapters contain the background of these measurement techniques, recommendations for practice, and identify topics for further research and improvement for these measurement techniques.

The seventh part of the book also deals with research topics and the future of load testing. This part discusses load testing in the framework of reliability-based decision-making and in the framework of a bridge management program. The first topic of this part is the research-related theme of applying concepts of structural reliability to the practice of load testing, in order to quantify "safety" of a structure after a load test. In particular, the first topic includes updating the reliability index of a bridge after load testing, and discusses the required proof load magnitude for this purpose, as well as systems reliability considerations. The second topic deals with the effects of degradation, and in particular corrosion, and how results of load tests van be used to update the reliability index which diminishes over time when degradation is considered. The final topic of this part deals with the future of load testing, when load testing will be an integral part of a bridge management program instead of an isolated object-specific practice. In this chapter, the bridge owner discusses how load testing fits in the overall framework of a bridge management program.

The final part of this book brings all information from the previous parts together and summarizes the current state-of-the-art on load testing. An overview of the open questions for research is given, along with practical recommendations for load testing.