

# **CHAPTER 1: ABOUT THIS STUDY**

This first chapter shall provide information necessary for the reader to put the topics of the study into the right context and shall describe the research approach that was undertaken in writing this study. Afterwards, a brief overview of the contents of each chapter of this thesis is given as a quick reference for the reader.

## **1.1 THESIS STATEMENT**

The construction of bridge superstructures is a highly complex process due to the interrelationships between the erection method used and the manifold internal and external effects related to loads and material behavior, and to environmental influences.

Analyzing these concepts on a particular example helps to develop better understanding of the construction engineering practice and contributes to the safety and economy of future bridge structures.

## **1.2 INTRODUCTION**

Why are bridges important, why are they of interest and oftentimes attract special attention? The answer to these questions lies both in form and function of bridges. Some key issues that show the outstanding nature of bridges are addressed in the following paragraphs.

*Bridges connect.* The structures that are the topic of this study and of many other studies not only fulfill their function in a purely physical way. Apart from simply providing means of crossing natural and artificial obstacles in the environment, bridges also connect. They connect parts of a city across the river that is dividing them, they connect regions, and they even, in some cases, connect and symbolically link countries. But first and foremost, they connect people. It is this

why they are so important to us; bridges connect the people with families and friends, with places of living, work, and enjoyment.

*Bridges fascinate.* In our built environment, some bridges are amongst the largest structures built. But apart from sheer size of some of the most famous bridges, e.g. the Golden Gate Bridge, there is more to these structures. Regardless of scale, they may incorporate aesthetically pleasing shapes and colors; thus becoming places of sightseeing and landmarks that enhance the natural beauty of their settings. Bridges are objects of art as well as they are technical structures. Their unique appearance influences the look of the site. In many places bridges have a symbolic value as they are shaping the skyline of cities and sometimes representing the city itself, as e.g. the Tower Bridge in London.

How many novels, poems and movies tell stories that are related to bridges in certain periods of time? Personal memories might be tied to special bridges and their surroundings, and the stories of building great bridges are full of novel and adventure. They could only be built with an exceptional amount of engineering knowledge, management skills, and courage.

It is this fascination that makes it worth studying them, being big or small, their history as well as their future.

*Bridges challenge.* In many cases, bridges have brought innovation into Civil Engineering. Bridges clearly represent the exceptional effort that engineers take to build structures that accommodate the society's needs within the restrictions set by laws of nature. The difficulties that lie in the construction of larger and larger spans with less and more sophisticated material under economical constraints of time and cost have given inspiration to the engineers in charge. Important advancements, as e.g. the introduction of prestressed concrete, have been developed especially for bridge construction, but also had revolutionary influence on many other branches within Civil Engineering.

As the next millennium approaches, a vast array of projections and predictions for the future faces us. Engineering will contribute its share to the anticipated technological progress. Advancements in material sciences, computing, management, and other areas will open new paths to the future achievements of the Civil Engineering profession. The next decades will put forth a variety of engineering problems, such as upgrading and retrofitting of existing structures as well as construction of new innovative bridge structures with advanced materials and methods – a challenging era is awaiting the bridge engineers.

### 1.3 RESEARCH OBJECTIVES

This study deals with the constructability of bridges. The Construction Industry Institute, an organization composed of many key players of the U.S. construction industry, founded to foster economy of construction projects through research, defines constructability as follows (CII 1982, p2):

*“Constructability is the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Maximum benefits occur when people with construction knowledge and experience become involved at the very beginning of a project.”*

When planning to build a bridge, engineers need to come up with a feasible way of erecting the structure in a safe and economic manner. Finding an optimum solution is based on comparing alternative techniques of erecting the bridge, along with the different means and methods employed and their implications on schedule and budget. Analysis of these methods always has to consider the bridge itself, as well as the characteristics of the site at which it is to be erected.

Currently, the traditional university education in Civil Engineering – especially in undergraduate studies – deals with actual construction procedures only to a limited extent. Much weight is put on conveying the basic body of knowledge with respect to construction materials and their properties as well as practicing structural analysis of the systems that they form, based on the current professional codes and standards. The highly dynamic and complex construction procedures sometimes seem to be lost from recognition. It is one of this study’s objectives to serve for a change of this state by raising awareness to this issue.

In actual field operations, a major issue is consideration of the interrelationships between the growing, yet unfinished structure and the various kinds of loads that affect it. Several failures of structures under construction in the past, both bridges and buildings, caused by underestimating the construction loads and their effects, underline the importance of research on this issue.

The main objective of this study is therefore to compile and review constructability-related concepts that are used in current bridge engineering. This overview of construction procedures is not carried out to do research on already existing methods, which actually have proven to work very well in the past. In fact, it will be performed to use these pieces of information – linked with a profound analysis of a case study – to serve as an understandable introduction into the more broad topic of how to deal with the complex construction process in bridge building. Teaching these concepts may be beneficial for future construction engineers' education.

## **1.4 RESEARCH METHODOLOGY**

Two major sources of information are used for the two main parts of this study. Literature on the history of bridge construction is used to outline the development of different types of bridges and their means and methods of construction. Following sections on design and construction of segmental bridges are based on information from the professional literature on the state-of-the-art in segmental bridges. Special attention is given to the Balanced Cantilever Construction and related issues. Furthermore, a brief overview of future research areas and developments in bridge design and construction is provided.

Secondly, information specific to the case study bridge structure is used to illustrate how a real-life bridge is built. The bridge project that is used for the case study, the Wilson Creek Bridge, is located in Ellett Valley in Montgomery County in Virginia. Overall project data is obtained from reviews of the plan drawings and shop drawings for the bridge and its specialized construction equipment. The so-called Geometry Control Manual that has been developed for construction of the Wilson Creek Bridge is used as an additional source of information to give a detailed account of the planned construction sequence and its anticipated effects on the structure. A number of site

visits, including interviews with the Project Engineer were performed to document the actual construction process and to keep the information presented close to engineering practice.

## **1.5 RESEARCH SCOPE AND LIMITATIONS**

As mentioned before, this study consists of two main parts. First of all, a comprehensive literature review reports on historical developments that led to the current state-of-the-art in bridge engineering and assembles information on future possible developments. It is examined how bridge engineers deal with design and construction of bridges, from the very first sketch to the final complete structure. Moreover, technical background information on the different important erection methods for bridge superstructures is provided and it is analyzed to what extent the different erection methods are influenced by their respective construction loads. The focus of attention lies on Balanced Cantilever Construction, which is the method actually chosen for erection of the Wilson Creek Bridge. However, many of the concepts outlined in this study can be applied to other erection methods as well.

While Balanced Cantilevering Construction is certainly an important erection method in bridge construction, other methods exist as well and may in some cases, depending on the characteristics of an actual bridge project, be even more feasible. This study concentrates on Balanced Cantilevering while mentioning certain constructability aspects of other erection methods.

Providing the case study of the Wilson Creek Bridge that is located in Montgomery County in Virginia as a real-life construction example complements the theoretical parts of this study and helps gaining better understanding of construction engineering practice. It documents how the Wilson Creek Bridge was built and gives a detailed insight into how Balanced Cantilever Construction is implemented in practice. Graphical representations of the erection process such as schematics and photographs are used to illustrate the case study. Conclusions are drawn in the final part of this study.

## 1.6 THESIS ORGANIZATION

Chapter 1 of this thesis contains introductory information on bridge engineering, it covers the research objectives, scope, and limitations and the methodology used in developing this study. A brief description of each chapter is given in the following paragraphs.

Chapter 2 covers the historical background of bridge construction, outlining the development of bridge types and their construction throughout main phases in history and giving some examples. The most important future challenges in bridge engineering – areas of improvement throughout the life-cycle of a bridge, high-performance materials, and innovative structural concepts – are the topic of the second half of this chapter.

Chapter 3 covers the process for design of segmental bridges that engineers undertake. Thoughts on the general nature of design will be given and the importance of aesthetics in Civil Engineering with its various aspects will be discussed. Furthermore, characteristic factors influencing both design and construction will be mentioned. The modeling approach taken in structural analysis of bridge structures will be described to contribute to the reader's overall understanding. Finally, constructability considerations of segmental bridges will be given in preparation for the following sections on actual project execution.

Chapter 4 deals with the construction process of segmental bridges. The important erection techniques and equipment necessary for construction of segmental bridges are presented in more detail, including the Balanced Cantilevering Method that is used for the case study bridge. With this knowledge assembled, a discussion of the consideration of construction loads and stresses is given.

Chapter 5 introduces the project chosen for the case study, the Wilson Creek Bridge in Virginia, U.S. It gives a chronological description and discussion of the conceptualization, design, construction, and anticipated utilization. Particular emphasis is put on the means and methods in actual construction operations, in this case the Balanced Cantilevering Method. The casting cycle for the bridge and the equipment used are presented in detail.

Chapter 6 sums up the contributions made in this thesis and points out further related areas of research that may be worth being explored.