Computer Aided Design & Erection of Long Suspension Bridges

Dorian JANJIC
Managing Director
TDV GmbH,
Graz, Austria
office@tdv.at

Dorian Janjic, born 1960, civil engineering degree from the Faculty of Civil Engineering, Sarajevo. 15 years of experience in technical research, software development.

Heinz Bokan
Manager Project Centre
TDV GmbH,
Graz, Austria
office@tdv.at

Heinz Bokan, born 1947 civil engineering degree from the Technical University of Civil Engineering, Graz.
Over 30 years of experience in structural analysis in a wide range of applications.

Johann STAMPLER
Senior Project Engineer
TDV GmbH,
Graz, Austria
office@tdv.at

Johann Stampler, born 1951, civil engineering degree from the Technical University of Civil Engineering, Graz. Over 30 years of experience in structural analysis in a wide range of applications.

Abstract

Wherever built, suspension bridges attract public attention due to their size and conspicuousness. However, the long spans combined with extraordinary slenderness yield outstanding challenges.

First of all, in any case the slenderness and kinematical conditions of these structures bring about large displacements due to the permanent loads. Therefore, the shape of the bridge is a non-linear function of the loading, deviating to a great extent from the hypothetical "stress-less" shape. The *form finding process* is a complicated iterative process if done in the conventional way. As an alternative, the *Additional Constraint Method* has been provided in the program RM2006 in order to find and optimize the shape of the suspension cables and the hangers.

A further great challenge is the simulation of the *erection process*. Further on, un-symmetric loading due to traffic causes large displacements and requires non-linear traffic analyses. Last but not least, a major engineering challenge of long suspension bridges is their *susceptibility to wind induced vibrations*.

The *Hardanger Bridge* project is used as a descriptive example for an integrative procedure including form finding, simulation of the erection process, and detailed analysis with considering geometric non-linearity and dynamic impacts like wind induced vibrations.

Keywords: Suspension bridge, form finding process, fabrication shape, erection procedure, wind impact, buffeting analysis, Hardanger Bridge

1. Introduction

Although the construction of modern type suspension bridges dates back more than 120 years, bridges of this type have still a special fascination due to their architectonical elegance combined with a touch of lightness predestining them to become landmarks wherever built. For bridge engineers this fascination is also based on the size of these structures, with allowable spans being longer than for any other bridge type. The long spans combined with extraordinary slenderness yield outstanding challenges for any bridge designer.

Non-linear behaviour: First of all, the slenderness and kinematical conditions of these structures yield in any case large displacements due to the permanent loads. Therefore, the shape of the bridge is a non-linear function of the loading, deviating to a great extent from the hypothetical "stress-less" shape. Due to the high non-linearity of the problem, the usual straight-forward design approach for conventional structures – i.e. using the desired design shape in the analysis and compensating the deformations in the erection process by applying appropriate pre-camber values – is not suitable anymore. Therefore, a complicated form-finding process with taking into account geometrical nonlinearities is required. This process is described in detail in the next section.

In addition to the geometric non-linearity, various other non-linear mechanisms generally occur. They require on the one hand the use of special element type, and on the other hand a global

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