Structural Engineering Documents

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Jörg SCHLAICH
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CONCRETE BOX-GIRDER BRIDGES

International Association for Bridge and Structural Engineering IABSE
Association Internationale des Ponts et Charpentes AIPC
Internationale Vereinigung für Brückenbau und Hochbau IVBH

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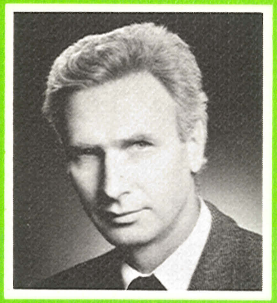

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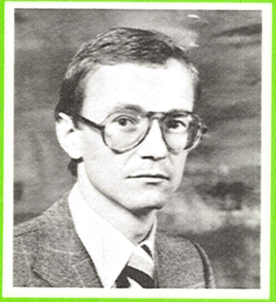

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Born in Stuttgart in 1944. After completing his Civil Engineering studies at the University of Stuttgart with the Diplom-Ingenieur, he joined the bridge design team of the consulting firm Leonhardt and Andrä, Stuttgart. Since 1975 he has been involved in teaching and research at the Institut für Massivbau, University of Stuttgart. His research is devoted mainly to computer-aided nonlinear analysis of statically indeterminate reinforced and prestressed concrete beams.

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FOREWORD

The box girder is today the most widely used superstructure in concrete bridge construction. That fact justifies the suggestion made by the Commission III of the IABSE that a comprehensive survey be written concerning this particular bridge type. The authors proceed from the assumption, however, that its contents will first be drawn upon when all possible design alternatives for the particular bridge project have been thoroughly examined, and the box girder has been proven appropriate. Their aim is less that of encouraging the one-sided propagation of box-girder bridges but rather much more that of contributing to the improvement of the quality of such bridges. They hope to contribute to this by extensively relieving the engineer of the study of today's hardly surveyable mass of literature on the subject so that he can better devote that time to the actual design of the bridge. That explains why this paper is kept short, why in particular cases the reader is referred to the literature, and why subjects not pertaining to the central theme are only touched upon and not handled exhaustively.

For greater clearness, the survey follows the sequence of a practical bridge design process by dividing itself into three main parts, namely, "Design", "Structural Analysis", and "Dimensioning and Structural Detailing"; each section with its individual numbering and literature list.

This survey directs itself especially to the design engineer, which manifests itself, for example, in the fact that the construction methods are handled only briefly and in the section "Design", because they decisively influence the design at the very beginning.

Major contributions to Section II, "Structural Analysis", were made by Prof. Dr.-Ing. Kurt Schäfer, a colleague of the authors in the Institut für Massivbau at the University of Stuttgart. In this section the attempt is made to portray the calculation of the box-girder sectional forces resulting from eccentric vehicle loads with consideration of the folded plate action or profile deformation so comprehensively that it is not only easily understood but also rapidly applicable in the design office. This thereby eliminates the often-discussed, controversial question as to whether the effort involved in the "exact" calculation of this loading case is actually worthwhile or whether an estimation of the transverse load distribution would not suffice.

The authors would like to take this opportunity to thank Professors R. Favre, Lausanne, and C. Menn, Zürich, for their critical examination of the paper. They are indebted to Mrs. I. Paechter and Mrs. E. Schnee for their conscientious preparation of the manuscript; and Mr. E. Kluttz for his empathetical translation of their German original into English.

Stuttgart, January 1982

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Note:

Parts I, II, and III form a whole and are only divided for organisation reasons. Should the reader be referred to a figure, a section, or a reference in one of the other parts, he will find that the Roman numeral of the other part of the text is placed before the Arabic number; for example, Figure II,7 or Section III, 9.1.

Part I DESIGN

1. TERMS, SYMBOLS

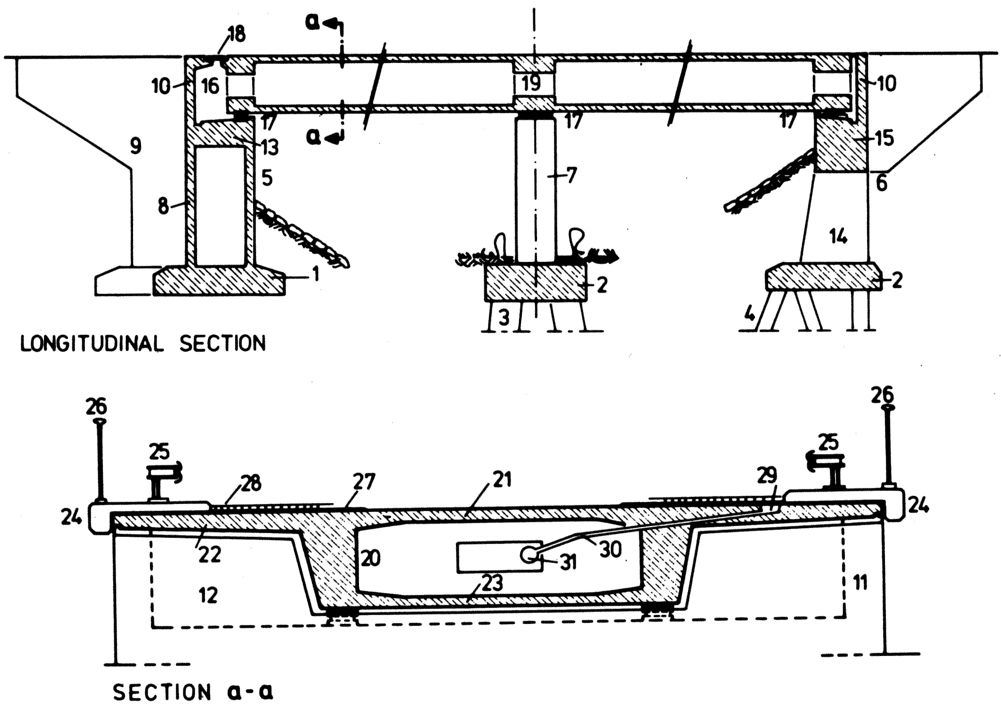


Fig. 1 Sections through a typical simple box-girder bridge

The Elements of a simple Box-Girder Bridge

Foundation

1 plate
2 pile plate
3 bored piles
4 driven piles

Substructure

5 box abutment
6 spill-through abutment
7 columns, piers (with 2 or more bearings)
8 breast wall
9 wing wall
10 back wall
11 edge beam
12 end diaphragm
13 bridge seat
14 support walls
15 bridge seat beam
16 access chamber
17 bearing (can be fixed or allow movement)
18 expansion joint

Superstructure

19 transverse diaphragm (at abutments, within the span and over the piers) with opening
20 box-girder web
21 top slab (area between the webs)
22 top slab (cantilever section)
23 bottom slab
24 fascia beam
25 guard rail
26 railing
27 sealing membrane
28 wearing surface
29 drain inlet
30 cross drain
31 longitudinal drain

By and large the text and formulas use CEB or ISO symbols.

Part II STRUCTURAL ANALYSIS

(Co-author: Kurt Schäfer)

1. INTRODUCTION

This part deals with the structural analysis i.e. the computation of the sectional forces or stress resultants of box-girder bridges. It is based upon the elastic theory. For statically indeterminate reinforced and prestressed concrete structures, however, the underlying assumptions of the elastic theory only agree with the real conditions for a low range of stresses. Therefore one may be of the opinion that a separation of the analysis from the dimensioning does not make much sense. Nevertheless, as explained more fully in Section III 2, this manner of structural analysis is the only method which can simultaneously consider all of the effects to be found in connection with box-girder bridges and their interactions with each other. Other more realistic and consistent methods of analysis and determination of the dimensions and properties of the structure have not yet reached a satisfactory stage of development. Moreover, the method of calculating the sectional forces according to the elastic theory and thereafter of dimensioning of the critical sections for the limit state of failure satisfies the lower bound criteria of the theory of plasticity, thereby always supplying an ultimate load value that lies on the safe side. In the case of complicated statically indeterminate systems acted upon by high restraint stresses one should in addition to the elastic approach, always determine the real ultimate load capacity of the entire structure by means of the theory of plasticity (Fig. III, 2).

With these facts stated, a few critical preparatory remarks should be made concerning the structural analysis, especially the computer-aided analysis, as follows:

- Garbage in---garbage out. A structural analysis is only as good as the structure's idealized model, the properties assumed, and the input data.
- The results should always be drawn up so as to be able to visually check the variation of the sectional forces throughout the structure.
- Computer results are not automatically correct results. One should therefore always check them by means of a simpler analysis. Still better is to plump for a computer analysis only after having first conducted a rough analysis by hand so as to know approximately what result to expect.
- The amount of computer print-out is not proportional to the accuracy of the analysis.
- Because of the ratio of labour costs to material costs, a straight-forward, clear-cut structural detailing and method of erection produce a greater effect on the total costs of the bridge than any amount of refinement in the analysis and dimensioning.

The engineer with experience in the analysis of box-girder bridges will perhaps see an inconsistency in this report between the extent devoted to the calculation of sectional forces due to eccentric live loading and the effect that these have upon the total stresses. On the other hand, precisely and only this part of the analysis is particularly difficult for the less experienced. The literature dealing with this topic is also extensive and often not very easy to

Part III DIMENSIONING AND DETAILING

1. INTRODUCTION

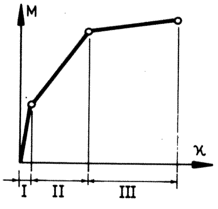
In this part the dimensioning and detailing of box-girder bridges is handled. This includes also those areas whose stresses cannot adequately be described with the normal bending theory as assumed in part II. Further appropriate prestressing tendon profiles and reinforcement arrangements are suggested, and elements of detailing and bridge finishing are illuminated.

2. GENERAL DETAILING PRINCIPLES

The general design principles of reinforced and prestressed concrete structures apply of course as well to box-girder bridges but with the more stringent requirements necessary to ensure their serviceability and durability. In this publication intended for the international forum of IABSE, only the CEB/FIP Model Code in its latest edition [1] can be recommended as a safe and practical basis for ensuring the structure's ultimate strength and serviceability. Meeting the safety requirements of the national codes of practice must be left up to the individual reader.

With today's level of knowledge and state of the art, the structural analysis and dimensioning of box-girder bridges cannot dispense with any of the three methods named below or achieve a satisfactory result with the exclusive use of only one. The following methods are also allowed equal status in the CEB/FIP Model Code:

- the determination of the sectional forces as according to elastic theory; i.e. the assumption of the uncracked State I independent of the magnitude of the stresses (see Part II of this paper) and the dimensioning of the critical sections so that the behaviour of the member with regard to cracking, deformation, and vibration is satisfactory under working load or service load conditions and so that the ultimate resistance of the member at failure or collapse (Fig. 2 a) should provide for sufficient safety.
- the determination of the sectional forces when the nonlinear stress resultant - deformation relationships of the cracked State II are considered, in particular the nonlinear moment - curvature relationships (Fig. 1) which are a function of the loading and the restraint deformations (e. g. due to temperature or settlement). Step-by-step iterative integration or approximate methods are used [2, 3]. The dimensioning of the sections is carried out as described above.



$$\frac{1}{R} = \varkappa = \frac{|\varepsilon_c| + |\varepsilon_{sm}|}{d} = \frac{M}{B_{II}}$$

Fig. 1 Moment - curvature relationship

Structural Engineering Documents

Objective

Information for the practising engineer through documents of high scientific and technical level, of international character, on structural engineering themes.

Fields covered

- construction materials
- structural analysis
- dynamic analysis
- civil engineering structures
- construction methods
- research
- design
- execution
- maintenance
- history of construction science and technology
- interaction between structural engineering and other fields (e.g. architecture)

Readership

Engineers throughout the world interested in civil engineering structures: researchers, professors, designers, entrepreneurs, administration and owner's representatives.

Publication frequency

Normally 2-3 volumes per year.

About the Publisher

The IABSE — created in 1929 — is the International Association for Bridge and Structural Engineering, comprising more than 3000 members in 75 countries. As a scientific, international, non governmental and non profit organisation, the IABSE conducts conferences and issues publications.
Other series published by the IABSE are:

IABSE PERIODICA
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Concrete Box-Girder Bridges

The box girder is today the most widely used superstructure in concrete bridge construction. The aim of this document is to relieve the engineer of the study of today's hardly surveyable mass of literature on the subject so that he can better devote that time to the actual design of the bridge. This document directs itself especially to the design engineer and therefore follows the sequence of a practical bridge design process:

Part 1, Design, presents the most important factors influencing the architectural and structural design of box-girder bridges,

Part 2, Structural analysis, follows the structural analysis in longitudinal and transverse direction, and deals, with the interaction between both, namely the folded plate action,

Part 3, Dimensioning and Structural Detailing, mainly treats the analysis and dimensioning of those regions of the bridge whose stresses cannot adequately be described with the Technical Bending Theory. Structural details are presented.