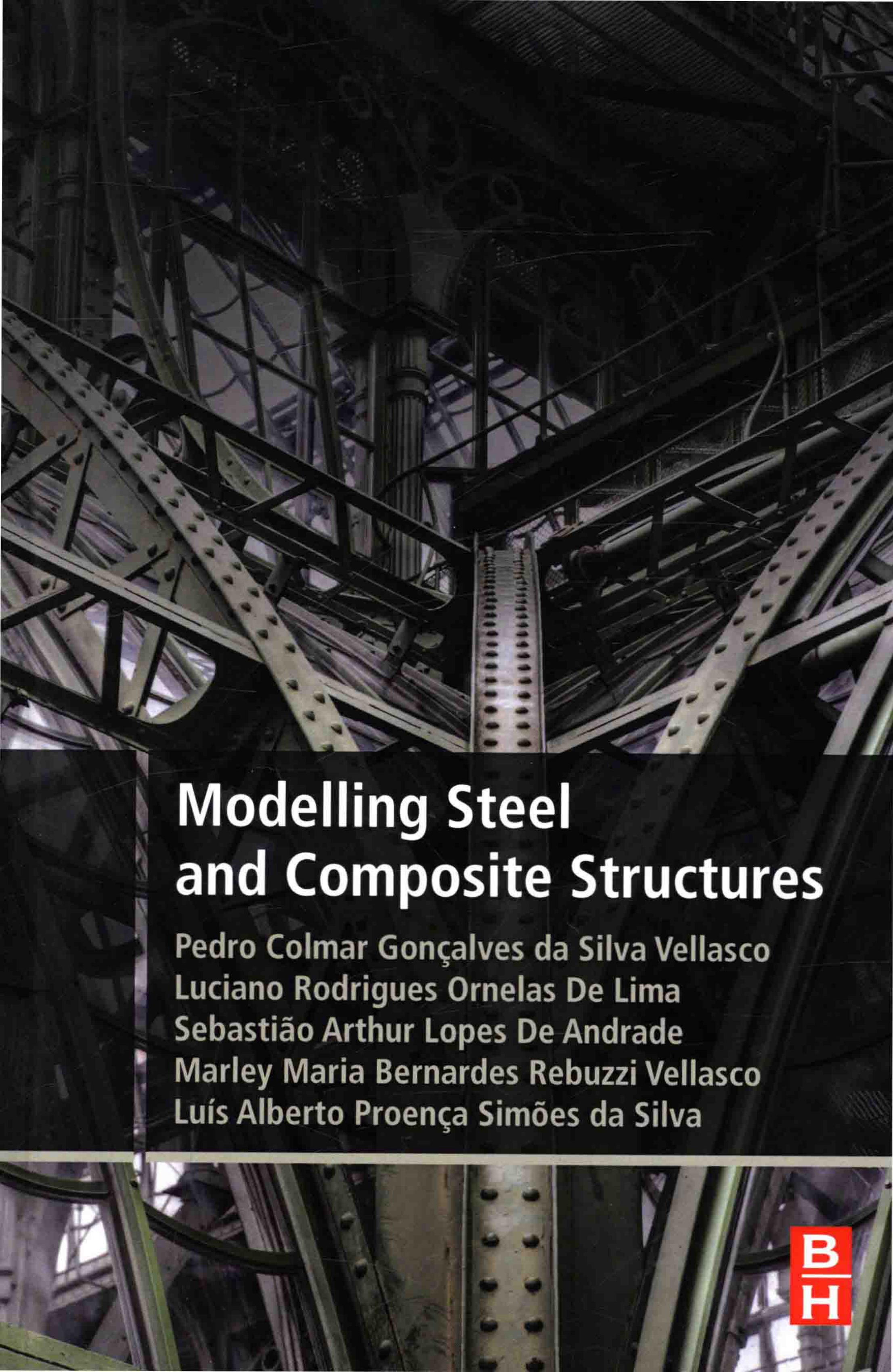

Modelling Steel and Composite Structures

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- Numerical models based on the finite element method
- Numerous simulations presenting a non linear response
- Examples of the use of computational intelligence methods to simulate steel and composite structures

Brief and readable, *Modelling Steel and Composite Structures* expertly explains the computational tools, methods, and procedures used to design steel and composite structures. The reference begins with the main models used to determine the structural behaviour. This is followed by a detailed description of the experimental models, as well as their main requirements and care that have to be taken into account when performing steel and composite structural experiments in the laboratory.

Numerous simulations presenting non linear response are illustrated as well as their restrictions in terms of boundary conditions, main difficulties, solution strategies, and methods adopted to surpass convergence difficulties. Finally, examples of the use of computational intelligence methods to simulate steel and composite structures response are presented.

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MODELLING STEEL AND COMPOSITE STRUCTURES

PREFACE

The main objective of the present investigation is to describe, with the aid of a series of examples, the methods and procedures used for the modelling of steel and composite structures. Initially the main models used to determine the structural behavior of these elements are introduced. This is followed by a detailed description of the experimental models, as well as their main requirements and precautions that have to be taken into account when performing steel and composite structural experiments in the laboratory.

The work proceeds focusing on numerical models based on the finite element method. Numerous simulations presenting a nonlinear response are illustrated, together with their main details and restrictions in terms of boundary conditions, main difficulties, solution strategies, and methods adopted to surpass convergence difficulties. Finally, examples of the use of computational intelligence methods to simulate steel and composite structures response are also presented. This is done with the aid of neural and neuro-fuzzy networks and genetic algorithmic focusing on their main advantages, scope, and limitations.

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CONTENTS

CHAPTER ONE

Introduction

1.1 INITIAL CONSIDERATIONS

The current dynamics of scientific progress and technological innovations, in addition to the markets globalisation, imposed changes in the engineers training. On the other hand, an innovation of processes and integrated computer systems was necessary, in order to enable the construction industry to compete at international level. This change of attitude can also be seen in the adoption of more efficient and economical structural systems like the ones that use steel and composite solutions aiming to become cost-effective and viable alternatives.

One of the main objectives of this book is to enable and boost the use of steel and composite structures in buildings. For that, it is intended to improve the training of a new generation of engineers who are familiar with its behaviour to widespread its use in Brazil. The structural design development associated with new constructive techniques turns out to be a direct consequence of such ideas, but this will only be possible with a better understanding of the behaviour of the structural elements that form the global structure.

This understanding is based on the complete development of experimental and numerical models contemplating the behaviour of elements and structural systems. This strategy enables a better understanding of phenomena such as strength, structural stability, and stiffness; fabrication processes effects; erection aspects; and the steel and composite structural systems' dynamic response.

The structural behaviour requires the understanding of a series of physical phenomena related to the occurrence of ultimate limit states like flange local buckling, web local buckling, lateral torsional buckling, plastic hinge formation, or even, the crack distributions shown in Figs 1.1–1.5.

Naturally, over the last few years there has been a considerable evolution of procedures and models used in the steel and composite structures design. This evolution was the result of an increased knowledge level of structural

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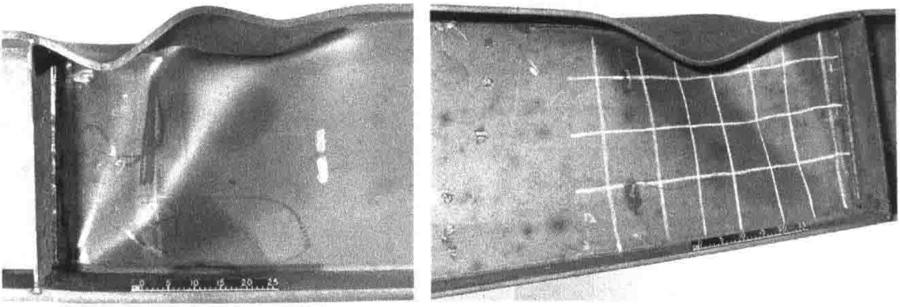
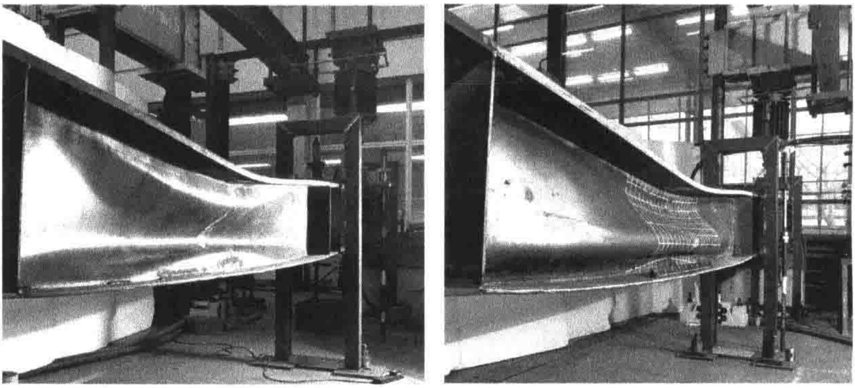


(A) (B)

Fig. 1.1 Flange local buckling.



(A) (B)

Fig. 1.2 Web local buckling.

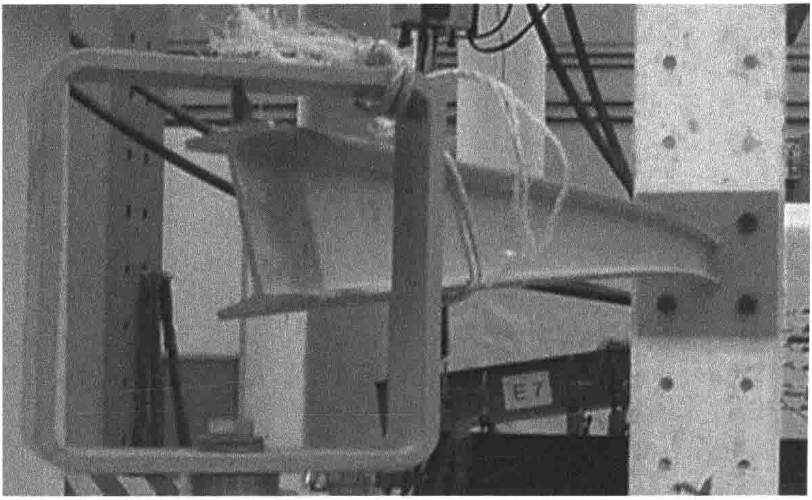
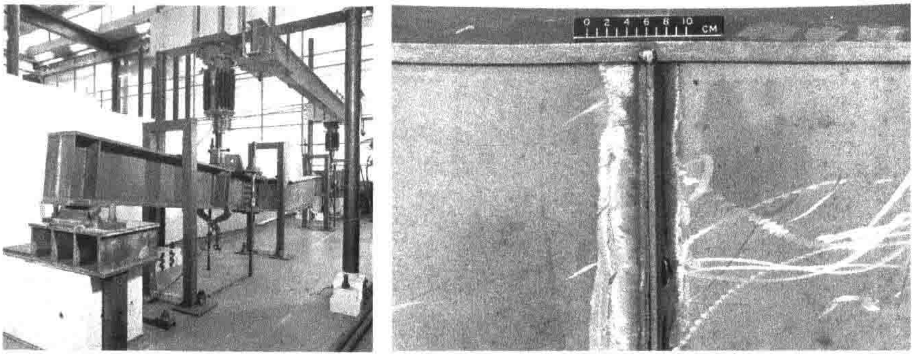
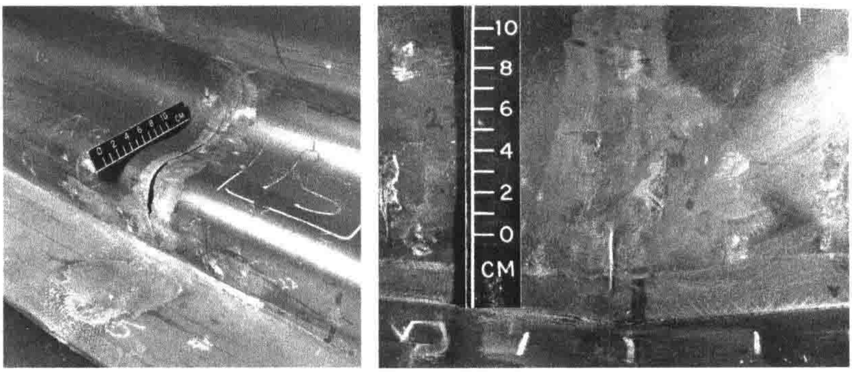


Fig. 1.3 Lateral torsional buckling of a cantilever beam [8].



(A) (B)

Fig. 1.4 Plastic hinge formation.



(A) (B)

Fig. 1.5 Crack formation.

behaviour obtained with the use of new numerical and experimental techniques. The consolidation of such knowledge has been made through structural design scientific publications present in journals and conferences. These publications generated discussions and ideas that were later consolidated by the technical committees of structural design standards, and scientific societies such as ECCS, Eurocodes, and ABNT.

However, the incorporation of the outcomes of experimental and numerical investigations in the design standards is not a simple process, giving rise to numerous discussions and to the development of more accurate models to be inserted in their design recommendations. These structural behaviour models can be associated with various natures, complexities, and formats where the most frequently used will be detailed in the next section of this chapter.

1.2 STRUCTURAL BEHAVIOUR MODELS

1.2.1 Analytical, Mathematical, and Hybrid Models

One of the simplest ways to understand these types of models comes from examples such as the structural joints. The joints classification in terms of moment versus rotation curves can be divided into three types: the analytical, mathematical, and combined models. In the analytical models, the moment versus rotation curve is based on their physical characteristics. In mathematical models, on the other hand, this curve is expressed by a mathematical function in which the parameters are determined by a curve adjusted to experimental results. Finally, the combined models use both analytical and mathematical models.

The analytical models can be used to predict the joint stiffness based on their geometric properties and components arrangement. The joint mechanical behaviour can be predicted by numerical methods such as finite elements based on the connection components deformation mechanism hypothesis. With this in hand, the components deformation and the connection moment capacity can be determined as well as their associated moment versus rotation curve.

Generally, parametric studies are conducted considering the effects of several geometric variables related to joint components. Practical values of these variables are then analysed to produce data for the analysis. However, the cost and time involved are usually unsatisfactory for practical applications, because each type of joint or joint component configuration requires a new formulation for obtaining the moment versus rotation curve, Chan [1]. In addition, the joint uncertainties can significantly affect their model predicted stiffness. There is still the fact that additional data-handling procedures are necessary to incorporate analytical results in the semirigid frame analysis. Another classic model for evaluating joints is characterised by the components method present in the Eurocode 3 pt. 1.8 [19], which is also known as a classical mechanical model. Further details on this model will be made in the examples present in Chapters 2–4.

Another method used to determine the joints moment versus rotation curve consists in approximating a curve to match experimental data by using simple expressions. These expressions are called mathematical models, which directly relate the connections moment and rotation by mathematical functions, using curve-fitting procedures. When these procedures are determined by experimental data adjustment, the moment versus rotation curve can be explicitly expressed and directly used in structural analysis.