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FATIGUE DESIGN OF STEEL AND COMPOSITE STRUCTURES

Eurocode 3: Design of Steel Structures
Part 1-9 – Fatigue
Eurocode 4: Design of Composite Steel and Concrete Structures

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FOREWORD

Steel structures have been built worldwide for more than 120 years. For the majority of this time, fatigue and fracture used to be unknown or neglected limit states, with the exception in some particular and "obvious" cases. Nevertheless, originally unexpected but still encountered fatigue and fracture problems and resulting growing awareness about such have that attitude reappraised. The consequent appearance of the first ECCS recommendations on fatigue design in 1985 changed radically the spirit. The document served as a basis for the fatigue parts in the first edition of Eurocodes 3 and 4. Subsequent use of the latter and new findings led to improvements resulting in the actual edition of the standards, the first to be part of a true all-European set of construction design standards.

As with any other prescriptive use of technical knowledge, the preparation of the fatigue parts of Eurocodes 3 and 4 was long and based on the then available information. Naturally, since the publication of the standards, have evolved not only structural materials but also joint techniques, structural analysis procedures and their precision, measurement techniques, etc., each of these revealing new, previsouly unknown hazardous situation that might lead to fatigue failure. The result is that even the most actual standards remain somewhat unclear (but not necessarily unsafe!) in certain areas and cover some others not sufficiently well or not at all. Similar reasoning can be applied for the fracture parts of Eurocode 3, too.

Having all the above-mentioned in mind, the preparation of this manual was intended with the aim of filling in some of the previously revealed gaps by clarifying certain topics and extending or adding some others. For the accomplishment of that task, the manual benefited from a years-long experience of its authors and its proofreaders in the fields treated in it; it is a complete document with detailed explanations about how to deal with fatigue and fracture when using Eurocodes… but also offering much, much more. This is probably the most exhaustive present-day fatigue manual on the use of Eurocodes 3 and 4, checked and approved by members of ECCS TC6 “Fatigue and Fracture”.

This document outlines all the secrets of fatigue and fracture verifications in a logical, readable and extended (in comparison to the standards) way, backed by three thoroughly analysed worked examples. I am convinced that a manual as such cannot only help an inexperienced user in the need of some clarifications but can also be hailed even by the most demanding fatigue experts.

Mladen Lukić
CTICM, Research Manager
ECCS TC6 Chairman

PREFACE

This book addresses the specific subject of fatigue, a subject not familiar to many engineers, but relevant for achieving a satisfactory design of numerous steel and composite steel-concrete structures. Since fatigue and fracture cannot be separated, they are indeed two aspects of the same behaviour, this book also addresses the problem of brittle fracture and its avoidance following the rules in EN 1993-1-10.

According to the objectives of the ECCS Eurocode Design Manuals, this book aims at providing design guidance on the use of the Eurocodes for practicing engineers. It provides a mix of "light" theoretical background, explanation of the code prescriptions and detailed design examples. It contains all the necessary information for the fatigue design of steel structures according to the general rules given in Eurocode 3, part 1-9 and the parts on fatigue linked with specific structure types.

Fatigue design is a relatively recent code requirement. The effects of repetitive loading on steel structures such as bridges or towers have been extensively studied since the 1960s. This work, as well as lessons learned from the poor performance of some structures, has led to a better understanding of fatigue behaviour. This knowledge has been implemented in international recommendations, national and international specifications and codes since the 1970s. At European level, the ECCS recommendations (ECCS publication N° 43 from 1985) contained the first unified fatigue rules, followed then by the development of the structural Eurocodes. Today, fatigue design rules are present in many different Eurocode parts : EN 1991-2, EN 1993-1-9, EN 1993-1-11, EN 1993-2, EN 1993-3, etc. as will be seen throughout this book.

Chapter 1 introduces general aspects of fatigue, the main parameters influencing fatigue life, damage and the structures used in the worked examples. The design examples are chosen from typical structures that need to be designed against fatigue: i) a steel and concrete composite bridge which is also used in the ECCS design manual on EN 1993-1-5 (plate buckling), ii) a steel chimney and iii) a crane supporting structure. Chapter 2 summarizes the application range of the Eurocode and its limitations in fatigue design. Chapters 3 to 5 are the core of this book, explaining the determination of the parts involved in a fatigue verification namely: applied stress range, fatigue strength of details, fatigue design strategies and partial factors, damage equivalent factors. For each of the parts a theoretical background is given, followed by explanation of the code prescriptions and then by application to the different design examples. Finally, chapter 6 deals with steel selection, which in fact is the first step in the design process but is separated from fatigue design in the Eurocodes. In this chapter, the theory and application of EN 1993-1-10 regarding the selection of steel for fracture toughness are discussed. Note that the selection of material regarding through-thickness properties is not within the scope of this book. The books also includes annexes containing the fatigue tables from EN 1993-1-9, as well as detail categories given in other Eurocode parts (cables). The tables include the corrections and modifications from the corrigendum issued by CEN on April 1st, 2009 (changes are highlighted with a grey background). These tables also contain an additional column with supplementary explanations and help for the engineer to classify properly fatigue details and compute correctly the stress range needed for the verification. The last annex contains the tables from EN 1993-1-10 and EN 1993-12 giving the maximum permissible values of elements thickness to avoid brittle fracture.

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