MECHANICAL ENGINEERING AND SOLID MECHANICS SERIES

Materials and Structures under Shock and Impact

Patrice Bailly

ISTE WILEY

Materials and Structures under Shock and Impact

ISTE WILEY

First published 2014 in Great Britain and the United States by ISTE Ltd and John Wiley & Sons, Inc.

ISTE Ltd
27-37 St George's Road
London SW19 4EU
UK

www.iste.co.uk

John Wiley & Sons, Inc.
111 River Street
Hoboken, NJ 07030
USA

www.wiley.com

Library of Congress Control Number: 2013951423

British Library Cataloguing-in-Publication Data
A CIP record for this book is available from the British Library
ISBN: 978-1-84821-651-8

Printed and bound in Great Britain by CPI Group (UK) Ltd., Croydon, Surrey CR0 4YY

Materials and Structures under Shock and Impact

Introduction

In risk studies, engineers may be required to consider the consequences of an accident resulting in a shock on a building. This may be, for example, the impact of a vehicle or aircraft, or the effects of an explosion on an industrial site.

This book combines elements of applied mechanics from which practical and sometimes simplified methods used in such studies arise. It is aimed at Master's students or students of engineering schools with a fairly general mechanical training. It can also be used by practicing engineers who wish to enter the field of structural resistance to accidental mechanical actions. This book is an intermediary between two types of scientific literature: on the one hand, bibliographic resources on the areas of mechanics involved in studies of shocks on structures, i.e. the waves in continuous systems, behavior of materials, resistance calculations of structures, vibrations, structural dynamics, etc., and on the other hand, technical manuals devoted to practical calculation methods and design of structures to withstand shocks or explosions. These manuals may be technically very accurate, especially regarding the constructive arrangements. Just like regulations related to the calculation of reinforced concrete or metal structures, their effective use requires knowledge of the theoretical mechanical elements that led to the methods they advocate. It is also important to have a basic understanding of the physical

phenomena involved in the predicted accidental events. For example, concerning the effects of explosions on a building, the engineer responsible for the structural design must understand the physical parameters involved in the explosion process, their relationship with the extreme effect of the explosion, that is the blast wave, and the manner in which the interaction with a building leads to a dynamic load on the latter. In this book, the proposed approach is to provide the elements of fairly general and theoretical mechanics in order to develop their applications to cases of shocks and impacts. Throughout the developments, hypotheses and limitations of the models used will appear. The engineering methods discussed in this book are not based on the use of important digital codes for structure calculations.

Impact on a building is primarily a local phenomenon that causes stress and strain in the form of propagating waves in the material. The movement then extends to the entire structure. Both local and global phases of the mechanical response have different time characteristics. This book follows this chronology: Part 1 is devoted to the study of the dynamics of solids that come into play during the local phenomena. Part 2 deals with the dynamics of structures in response to a global impact on a building.

In Part 1, the propagation of movements in a continuous system is first presented in the context of linear behavior such as elasticity and viscoelasticity. Shocks on solids induce stress waves, the amplitude of which is related to impact velocity. These waves propagate and diffract and are reflected within the solids. The impact velocities during accidental events are sufficient for the level of stress to exceed the yield strength of the construction materials. It is then necessary to understand how the nonlinear aspects of behavior influence the propagation of stress and strain. A feature of shocks is to provoke pressure levels much higher than those commonly found in materials under static loads. The study of behavior, in this case, is quite specific to the field of shock.

In Part 2, the case of a simple structure (modeled by a mechanical system with one degree of freedom) is used to introduce the engineering tools of the shock response spectrum and iso-damage curves. Two types of short-term dynamic loading are then introduced:

collisions and explosions. Collisions of structures, or crashes, are discussed with the aim of clarifying the load imposed on the structure that is affected. The case of explosions is approached by defining some basic knowledge of dynamics, which is necessary to understand the phenomenon. The goal is to achieve the characteristic elements of dynamic loading that can be imposed on a structure. The basic construction element is usually a beam. A study on the evolution of stress and movements in beams during impacts is considered in order to identify the various possible levels of modeling and their areas of relevance. To study the overall response, structures of buildings or industrial buildings can be modeled by mechanical systems with several degrees of freedom, as it is customary to do in earthquake studies. The nonlinear behavior phase of structures can be achieved. In metal or reinforced concrete structures, it is most often through the formation of plastic hinges that these nonlinearities occur. The response to the shock of a structure with plastic hinges is considered.

Despite its compact size, this book covers various significant and representative aspects of problems related to studies on shocks on buildings. Not all types of materials and structures are covered in this book, for example composite materials, plates and shells are not included. Finally, it should be noted that an educational approach guided the organization of this book.

Table of Contents

PART 1

Dynamics of Solids