

图解

建筑抗震概念设计 基本原则

Hugo Bachmann 编著
高剑平 陈蔚 译



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Seismic Conceptual Design of Buildings—Basic principles for engineers, architects, building owners, and authorities

Hugo Bachmann



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Swiss Confederation

Federal Office

for the Environment FOEN

Swiss Agency

for Development and Cooperation SDC

作者序

长期以来，人们认为地震是一种无法避免的自然灾害。地震通常会对建筑物造成损坏，因此，一直以来，防震措施主要限于防灾管理。尽管在 20 世纪初就已经提出了相关的抗震措施，但直到近几十年，人们经过深入研究，才发现如何有效地降低结构在地震中的易损性。

本书旨在以一种简单明了且清晰易懂的方式来介绍最新的关于建筑物抗震措施方面的知识，在解释基本原则时辅以相应的插图、例子和文字说明。本书所述的原则以及所展示的大量珍贵的图片（由作者本人或其他人提供）及其说明文字均是地震工程领域的研究者长期研究和设计实践的结晶。

作者首先要感谢所有照片的提供者，感谢他们冒着生命危险拍摄的这些宝贵照片。此外，还要感谢瑞士联邦水文和地质办公室以及瑞士发展与合作署对本书的精心编辑，使本书得以顺利出版。

雨果·巴赫曼教授

2002 年 12 月于苏黎世

编者序

在全球范围内，地震经常造成巨大的经济损失，如 1995 年的日本神户地震，造成了 6 000 多人伤亡，累计经济损失约 100 亿美元。地震本身是无法避免的，因此，有效降低灾害风险成为工程师、防灾管理者以及政府规划部门和决策者们首要的工作目标。减灾和降低风险同时也是保证可持续发展的重要先决条件。2000 年 12 月 11 日，瑞士联邦委员会批准了关于建筑地震灾害预防的七点计划，计划从 2001 年至 2004 年，为期四年时间。其中提高新建房屋的抗震性能是其重点计划之一。

本书的作者雨果·巴赫曼教授多年来一直致力于地震风险和建筑物在地震中的抗震性能研究，此次应瑞士联邦水文和地质办公室的请求，撰写了本书，将他在建筑抗震领域的研究成果贡献给读者，在此特表感谢。作者编制这些指导原则的目的在于将研究成果应用到实践中去，这些原则是设计人员在设计中必须要考虑的，以使他们在设计建筑时，用很少的代价，确保其拥有合理的抗震能力。

瑞士发展与合作署希望通过出版该书的英文版，来促进建筑抗震设计知识的传播，使更多的专业人士成为本书的读者。同时，瑞士发展与合作署致力于搜集建设领域、预防自然灾害和技术风险领域的可行经验，以通俗易懂的方式，介绍给发展中国家和转型国家中的专业技术人员。

瑞士联邦水文和地质办公室主任

克里斯汀·富勒尔博士

2002 年 10 月于比尔

瑞士发展与合作署署长沃尔特·富期特特使

2002 年 10 月于伯尔尼

译者序

地震一直是威胁人类生命财产安全的最严重的自然灾害之一。令人记忆犹新的“5·12”汶川大地震，死伤之惨重，举世震惊。

痛定思痛，单纯从技术角度来讲，此次地震，和国内外历次地震一样，暴露出结构设计和施工中犯了许多常识性的概念错误，而这些本应该可以避免。然而遗憾的是，错误总是在不断地被重复着，悲剧也在不断地上演着，土木工程教育在抗震概念设计这一环节的缺失，恐怕难辞其咎。

抗震概念设计从根本上决定了工程的抗震性能和造价，即使是最精细的计算和构造设计都无法弥补在抗震概念设计阶段所犯的错误或失误。可以说，概念设计是土木工程设计之魂。

目前，国内比较系统地论述抗震概念设计的书籍不多。幸运的是，在一次偶然的场合，译者拜读了瑞士联邦理工学院结构工程研究所雨果·巴赫曼教授编著的《图解建筑抗震概念设计基本原则》一书，立即为其丰富的图片实例和言简意赅的解说所吸引，并立即意识到该书在土木工程教育中的价值——很适合帮助专业技术人员建立抗震设计概念。

雨果·巴赫曼教授是国际地震工程协会（IAEE）理事会会员之一，他率领的学术团队在世界结构动力学和地震工程领域十分有名，并且赢得了很高的国际声誉。退休后，巴赫曼教授继续活跃在各种国际专业协会，并以受托专家和咨询工程师的身份解决结构工程和地震工程中出现的特殊问题。作者积累多年的研究成果和工程经验，以图文并茂的形式，深入浅出地阐释了抗震概念设计的基本原则。

因此，我有意将该书译介给国内的读者，包括在校的研究生、高年级本科生、工程师、建筑师等。而且，这也正符合出版商（瑞士发展与合作署）出版该书英文版的初衷，即以通俗易懂的方式，促进建筑抗震设计知识的传播，使更多的专业技术人员成为本书的读者。

译者对雨果·巴赫曼教授和出版商慷慨地免费转让中文译本的版权，深表感谢。

高创平

2010年10月于华东交通大学

Author's Preface

For a long time earthquake risk was considered unavoidable. It was accepted that buildings would be damaged as a result of an earthquake's ground shaking. Preventive measures for earthquakes were therefore mostly limited to disaster management preparedness. Although measures related to construction methods had already been proposed at the beginning of the 20th century, it is only during the last decades that improved and intensified research has revealed how to effectively reduce the vulnerability of structures to earthquakes.

The objective of this document is to present recent knowledge on earthquake protection measures for buildings in a simple and easy to understand manner. The chosen method explains basic principles by matching them with illustrations, examples, and an explanatory text. The principles, photographs (from the author or third parties), and the texts are the result of a long research and design activity in the challenging and strongly evolving field of earthquake engineering. The author would like to thank, above all, the numerous photographs contributors mentioned at the end of the booklet, who have made available the results of extensive and often dangerous efforts. Thanks are also extended to the Federal Office for Water and Geology and the Swiss Agency for Development and Cooperation for editing and carefully printing this document.

Zurich, December 2002

Prof. Hugo Bachmann

Editor's Preface

Worldwide earthquakes cause regularly large economic losses-Kobe in 1995 with more than 6 000 casualties,counted for 100 Billion US\$ of economic loss. Earthquakes are unavoidable. Reducing disaster risk is a top priority not only for engineers and disaster managers, but also for development planners and policy-makers around the world. Disaster and risk reduction are an essential part of sustainable development. On December 11 2000, the Swiss Federal Council approved for federal buildings a seven-point program running from 2001 to 2004 for earthquake damage prevention. The earthquake resistance of new structures is a high priority in the Confederation's seven-point program. The author of this publication, Professor Hugo Bachmann, has devoted many years to the study of seismic risk and behavior of buildings subjected to earthquakes. At the request of the FOWG, which expresses its gratitude to him, he agreed to make available his extensive scientific knowledge on earthquake resistance of buildings. These guidelines are designed to contribute to the transfer of research results into building practice. These results must be taken into account by the design professionals , thus ensuring a reasonable earthquake resistance for new structures at little or no additional cost.

SDC would like to contribute to the dissemination of knowledge on seismic design of buildings by translating this FWOOG publication in English and thus extending its readership among construction professionals.

SDC intends to gather available experience in the domains of construction and prevention of natural hazards and technical risks and to make it accessible to the practitioners in developing and transition countries in an easy to understand form.

Biel, December 2002

Dr Christian Furrer

Director of the Federal Office
for Water and Geology (FOWG)

Bern, December 2002

Ambassador Walter Fuest

Director of the Swiss Agency
for Development and Cooperation (SDC)

Translator's Foreword

Earthquake, as one of the world's worst disasters, is a great threat to human lives and properties. In China, the 2008 Wenchuan earthquake in Sichuan Province has just shocked the world with its heavy casualties.

While investigating the collapses of the inadequately engineered buildings in the earthquake, we have found numerous conceptual seismic design errors due to lack of common sense. All these errors, and those exposed in other earthquakes, could have been avoided if the designers have been trained correctly. These repeated tragedies indicate our current training in the seismic conceptual design of buildings is certainly insufficient, and it should be strengthened.

Conceptual design plays a crucial role in determining the seismic behavior and cost of buildings from the very beginning, even the most careful calculation and detailed design can not compensate for errors and defects in the conceptual design. Conceptual design is the soul of civil engineering design.

Currently, books concerning seismic concept design of buildings are few in China. As I read by chance *Seismic Conceptual Design of Buildings - Basic principle for engineers, architects, building owners, and authorities*, written by Professor Hugo Bachmann of the *Institute of Structural Engineering (IBK)* of the *Swiss Federal Institute of Technology(ETH), Zurich, Switzerland*, I was attracted immediately by its rich examples and concise explanations, and I became aware of its value in the civil engineering education. It would be a suitable guidebook for Chinese professionals to develop seismic design concepts.

Professor Hugo Bachmann was a member of the board of directors of the International Association for Earthquake Engineering (IAEE) in the years 1996 to 2004. At ETH he headed a group of collaborators and doctoral students until he retired in October 2000, which was well known in the structural dynamics and earthquake engineering community world-wide and gained a high international reputation. After his retirement, Prof. Bachmann continued

to be active in various international professional associations and to serve as a fiduciary expert and consulting engineer for special questions and tasks in structural and earthquake engineering. His illustration of the basic principles of seismic conceptual design is based on his research and experience for many years.

The present translators attempt to introduce this book to Chinese readers, which might include graduate students, senior undergraduates, engineers, architects, and so on. This is consistent with the original intention of the publisher (Swiss Agency for Development and Cooperation), as it has produced this publication in English to promote the dissemination of knowledge on seismic design of buildings and thus to extend its readership among construction professionals in an easy-to-understand form.

Lastly, the translators, on behalf of East China Jiaotong University, would like to show their gratitude to Prof. Hugo Bachmann, the Swiss Agency for Development and Cooperation (SDC), and the Swiss Federal Office for the Environment (FOEN), for offering free transfer of the copyright of the Chinese version generously.

East China Jiaotong University, December 2010
Prof. Gao Jianping

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内容简介

本书概述了建筑抗震设计技巧和基本原则。这些原则主要分成：

- 概念设计
- 构造设计
- 结构构件的构造措施
- 非结构构件的构造措施

概念设计，以及结构构件（墙、柱、楼板）和非结构构件（隔墙、围护构件）的构造措施，是决定建筑结构抗震性能和地震易损性（对破坏的敏感性）的关键因素。如果在概念设计阶段就出现了失误或缺陷，在随后的设计计算和构造设计中将无法弥补。因此，为了实现结构良好的抗震性能而又不显著增加成本，正确的抗震概念设计是必要的。

本书涉及的这些原则主要适用于新建建筑。当然，这些原则也同样适用于既有建筑的鉴定和改造，这在应用实例中都特别注明了。

作为入门书，这些基本原则有意介绍得比较简单，计算和构造设计只是一带而过，详细内容可见参考文献（详见 Ba02）。

这些基本原则的思想和概念取材于作者从 1997 年到 2000 年间所作的大量讲演，这些讲演的内容经过不断充实和完善，编撰进入本书。

本书在介绍每个原则时，都辅以示意图和大概的描述。如需进一步说明，通常借助于展示建筑物损毁情况的照片，并配有详细的说明和解释，当然照片中的这些

设计实例既有正确的也有错误的。

这些基本原则（以下简称 BP）围绕以下几个主题进行分组：

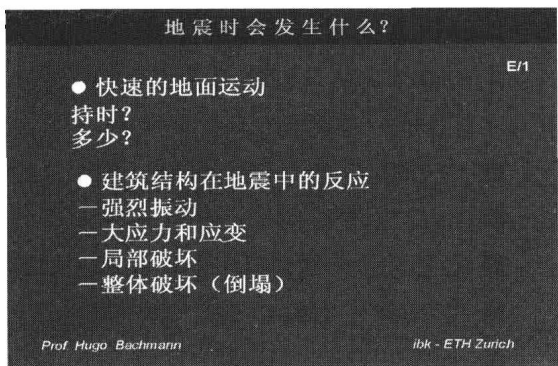
- 合作、建筑规范和造价（BP1~3）
- 侧向支撑和变形（BP4~20）
- 方案设计阶段的概念设计（BP21~22）
- 结构构件的构造设计（BP23~27）
- 地基和基础（BP28~31）
- 非结构构件和设备（BP32~35）

无论是泛泛而谈还是针对某一个特殊方案，这些基本原则的重要程度显然并不相同。基于工程实践经验的折中方案是允许的，这取决于灾害的严重程度（区域灾害或场地效应）和结构特性。最重要的是要严格遵守涉及生命安全的那些原则，特别是那些与侧向支撑有关的原则，只有那些意在减少建筑材料本身损伤的原则才可以考虑作出让步。

本书主要面向专业技术人员，如结构工程师和建筑师，还有业主和行政主管部门。不仅适合自学，也可作为大学课程和继续教育的专业基础教程。

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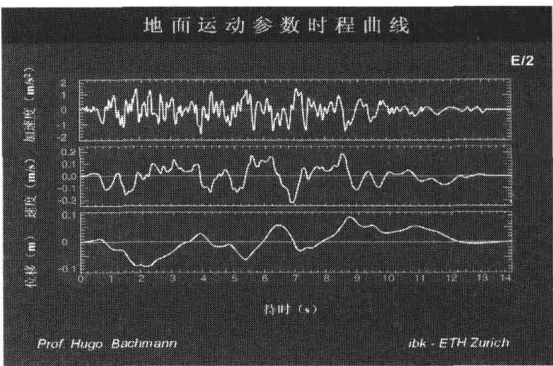
地震时会发生什么？



发生地震时，由于地壳中某个活性断层突然错动而产生地震波。由于不同类型和速度的地震波在到达建筑场地之前的传播路径不同，结果导致不同的局部地面运动。

地面在各个方向作快速的往复运动，通常以水平方向运动为主，也有垂直方向的。地面运动的持续时间有多长呢？举个例子，一次中等强度的地震大约持续 10~20 s，这是比较短的。那么，运动中的最大振幅是多少呢？典型的如瑞士瓦莱（Valais）地震，大约 6 级，和 1855 年的瑞士菲斯普（Visp）地震差不多，水平各个方向的振幅大约可达 8 cm、10 cm，甚至 12 cm。在一场 6.5 级或 6.5 级以上的地震中，像 1356 年的瑞士巴塞尔（Basel）地震，造成大部分城区及周边环境破坏，地面位移可达 15~20 cm 或者更大。

建筑物会产生怎样的反应呢？如果地面快速地往复运动，那么建筑物的基础也会被迫随之作同样的运动，但是建筑物本身由于惯性而保持不动，而这将会引起上部结构产生强烈的振动，结构



和地面之间产生共振现象，也因此导致结构产生很大的内力，而过大的内力往往导致结构产生塑性变形和大量的局部破坏，严重时甚至会引起结构倒塌。

地震对建筑物的影响主要取决于表征地面运动三个参数的时程特性，即地面运动的加速度 a_g ，速度 v_g 和位移 d_g ，以及它们特定的频谱组成。举例来说，上图所示为人工合成的瓦莱地震波的线性水平运动时程曲线。显然，加速度的主频远远高于速度的主频，而比位移的主频就更高了。

即使地震强度相同，但某一场地的地震动参数和其他特征参数变化也非常悬殊。这取决于很多因素，如震源的距离、方向、深度和震中的发震机理，尤其是局部土壤特性，如土层厚度和剪切波速等。与岩石相比，软土特别容易将地震波的作用局部显著放大。至于建筑物在地震中的反应，主要取决于结构的自身特性，如自振频率、结构类型、延性等。

因此，建筑物的设计必须考虑相当多的变数和不确定因素。

图解建筑抗震概念设计基本原则