Structural Concepts and Systems for Architects and Engineers

Second Edition

T. Y. Lin

Sidney D. Stotesbury

Structural Concepts and Systems for Architects and Engineers

Second Edition

T. Y. Lin
T. Y. Lin International
San Francisco, California

Sidney D. Stotesbury
Kansas State University
Manhattan, Kansas

VNR VAN NOSTRAND REINHOLD COMPANY
New York

Library of Congress Catalog Card Number 87-21538

ISBN 0-442-25903-4

Printed in the United States of America

Van Nostrand Reinhold Company Inc.
115 Fifth Avenue
New York, New York 10003

Van Nostrand Reinhold Company Limited
Molly Millars Lane
Wokingham, Berkshire RG11 2PY, England

Van Nostrand Reinhold
480 La Trobe Street
Melbourne, Victoria 3000, Australia

Macmillan of Canada
Division of Canada Publishing Corporation
164 Commander Boulevard
Agincourt, Ontario M1S 3C7, Canada

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Lin, T. Y. (Tung Yen), 1911–
Structural concepts and systems for architects and engineers.

Bibliography: p.
Includes index.
1. Structural design. I. Stotesbury, Sidney D. II. Title.
TA658.L47 1988 721 87-21538
ISBN 0-442-25903-4 (pbk.)

PREFACE

In 1988, the technological and architectural complexity of building design continues to increase. There continues to be a technology transfer gap with respect to the engineering and architectural professions. There continues to exist a corollary education and communication gap that limits the potential for creative interaction between architects and engineers. Such a limitation is especially important at the schematic level of a design project. Here it obscures the overall relationship between space-form and technological thinking; it increases the chance for major conflict at subsequent levels.

This book is intended to bridge the gap at schematic and preliminary levels of design and is dedicated to students of architecture and structural engineering. It focuses on identifying and explaining the more basic, rather than detailed, issues of conceiving and manipulating structural design options. It does so through a unique *overall approach* that emphasizes a total-to-subsystem hierarchy for learning about and projecting structural thinking into architectural design, and vice versa. It is unique because it makes it possible to introduce 1) structural design principles as basic form determinants, and 2) simplified methods for approximate analysis in both conceptual and specific terms.

The second edition represents a clarified, simplified, updated and expanded presentation of the concepts, principles, and techniques introduced in the first edition. Its primary goal is to foster understanding of, as well as the ability to control, the overall relationship between the structural and space-form properties of architectural schemes. The first objective is to enable designers to conceptualize schematic options for providing total-system integrity of buildings. The second objective is to enable quick comparison of alternatives for designing major subsystems.

Throughout, the book will stress the importance of optimizing key force and geometric properties of buildings as total structural systems. This involves quantitative analysis, but the use of formulas and calculations is limited to those needed for *approximate* design of subsystems. Design of elemental components is treated to a level sufficient to establish the feasibility of subsystem layouts and the relative efficiency of main components. Students using this text need to have a basic knowledge of algebra, geometry, trigonometry, simple statics, structural mechanics, and strength of materials.

The book presents a *three-cycle* learning strategy. The cycles are developed to illustrate how a body of overall design principles can be applied to conceptualize total systems as schematic options and to deal with preliminary dimensioning of subsystems and their main elemental components. Material differences are treated, but the emphasis is on the application of basic principles of statical analysis and overall design that are common to all materials.

The first cycle: Chapters 1 to 5 take a total-system look at the relationship between the schematic properties of prototypical building forms and the types of total system behavior that are expected of them. Chapter 1 introduces the idea of an overall approach by exploring the role of engineers and architects in building design and by establishing conceptual linkages between architectural and structural design thinking. Chapters 2 and 3 focus on a schematic exploration of the relationship between types of building form options and the fundamental types of forces and subsystem interactions that are required to achieve total-system integrity. Chapters 4 and 5 provide practical examples and data for estimating overall loads on buildings to illustrate how to apply an overall approach to a schematic-level analysis of several types of building designs.

The second cycle: Chapters 6 to 9 elaborate on the first cycle by introducing the requirements for design of specific subsystems. Here, a greater depth of comparative analysis is presented to reveal the issues of component efficiency and to enable approximate calculation to arrive at specific layouts and preliminary dimensioning of key members.

The third cycle: Chapters 10 to 14 treat some of the more special types of problems that must be considered in the design of buildings. Chapters 10 and 11 focus on high-rise and long-span designs while Chapter 12 concentrates on foundation subsystems. Chapter 13 focuses on construction issues and Chapter 14 treats construction economics.

The scope of the book is broad. It is not intended to enable final design of structural components and their connections. Rather, it is intended to provide a working introduction to the basic concepts and issues of total-system building design. A serious study of this text can enable one to understand and communicate clearly about basic types of structural forces, subsystems, and their interaction options as architectural form determinants. In addition, one can learn to quickly analyze and compare various total and subsystem layouts in approximate terms that are adequate for schematic and preliminary design purposes.

In short, individuals who learn the principles presented can be able to apply an overall approach to structural design at the important schematic stage of a design project. Thus, one can assure that there is a basis for fundamental compatibility between architectural and engineering design thinking. Those students who move on to more specialized studies (or have already done so) will find that this text provides a broad and insightful background that promotes consolidation and creative application of more specialized learning.

The authors believe that this book will promote technological transfer by providing a common foundation of knowledge for students of architecture and engineering. It will also promote mutual respect for natural differences in design responsibilities and improve the potential for creative collaboration of future professionals. The book will be useful to contemporary professionals and their staff employees as a refresher on how overall thinking can be applied to building design.

T. Y. Lin
Sidney D. Stotesbury

CONTENTS

5 Structural Loads and Responses

6 Overall Design of Horizontal Subsystems

7 Vertical Subsystems

8 Horizontal Linear Components

9 Vertical Linear Components

10 High-Rise Buildings

14 The Cost of Building Structures

Structural Concepts and Systems for Architects and Engineers

Second Edition

T. Y. Lin
T. Y. Lin International
San Francisco, California

Sidney D. Stotesbury
Kansas State University
Manhattan, Kansas

VNR VAN NOSTRAND REINHOLD COMPANY
New York

1

Introduction: Structure in Design of Architecture

SECTION 1: Overall Thinking

Because of modern technology, the capabilities of architectural and engineering designers are linked. As a result, architecture should be the product of a creative collaboration of architects and engineers. But such collaboration is often difficult. In contrast to most physical products, architecture is intended to perform in spatial terms and to be experienced as a total environment. This complicates matters by making the design responsibility at the same time comprehensive and specific, tangible and intangible.

To generate effective architecture, a designer must deal with the space-form implications of three types of interacting performance needs: activity-associated, physical, and symbolic (Figure 1-1). The designer's challenge is to organize the many properties of a building in such a way that they fill these needs in a collectively optimum manner.

Activity-associated needs are operational and derive from the human desire to conduct activities in a controlled environment. For a given project and site, the interaction of a variety of activity spaces must be organized in terms of unique requirements for physical definition, enclosure, association, climatological control, and services. Of course, this implies that there are physical needs that can be viewed as primarily constructive in nature if they are considered alone. That is, a designer must examine the issues of

FIGURE 1-1
ARCHITECTURAL DESIGN IS A COMPREHENSIVE SPATIAL ORGANIZATION PROBLEM.

THE DESIGNER MUST
ORGANIZE THE PERFORMANCE
PROPERTIES OF BUILDINGS IN SPATIAL TERMS
TO FILL THREE TYPES OF USER NEEDS:

1. ACTIVITY-ASSOCIATED (OPERATIONAL)
2. PHYSICAL (CONSTRUCTIVE)
3. SYMBOLIC (EXPERIENTIAL)

providing for energy, mechanical equipment, structure, and construction. But, to become architecturally relevant, these physical needs must be considered in the context of a total scheme for organizing the interaction of a ity spaces.

In addition, if the designer is to generate the operational and constructive properties of a space-form scheme as a total environmental system, he or she will have to consider the symbolic needs of its future users. This is of basic importance because users will experience, as well as operate in, a built environment. For users, a building is viewed as a symbol of their life context, society's attitude toward them, and the owner's respect for their social and aesthetic values. The designer of architecture must respond by insuring that an expression of these experiential values is made an integral part of all design proposals. In fact, one can say that the fundamental challenge of all architectural design projects is to provide a humanistic setting for the pursuit of activities, one that is inherently inspiring instead of indifferent or, even, degrading to the user.

For architects, the above-mentioned needs represent an interactive set of design proble that must be dealt with in a comprehensive manner. As a result, architects usually stress an overall, rather than an elemental, approach to design thinking. This is especially true early in the design process, when they must conceptualize a space-form scheme as a total system. The objective is to assure overall compatibility in activity, physical, and symbolic performance. en they use this holistic picture to guide their subsequent efforts, and those of collaborating designers, to elaborate and refine the scheme in terms of specific parts and details.

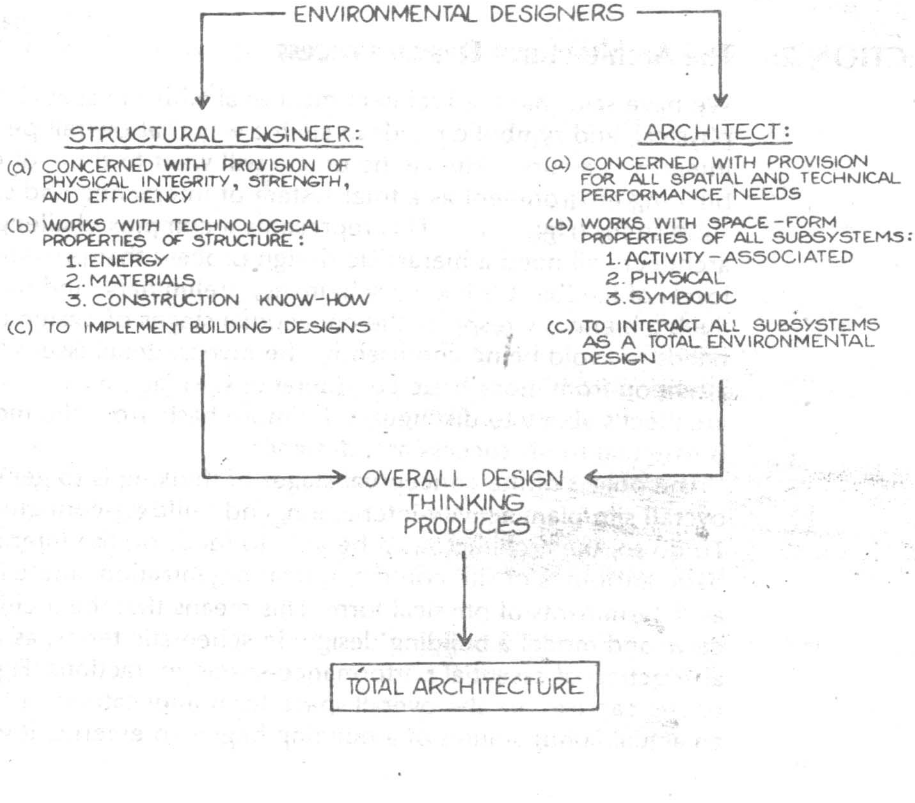
The interactive nature of architectural projects makes a comprehensive approach necessary. At the schematic stage, creative collaboration of architects and engineers must be possible. Both participants must be capable of overall thinking about technological issues. Unfortunately, the specialized mode of engineers' education often leads them to think in the reverse, starting with details, and without sufficient regard for the overall picture. This causes a conceptual gap to exist that acts, in general, to limit creative interaction between architects and engineers at all levels of design. Moreover, a gap of this kind is especially limiting as it affects schematic and preliminary stages of a design process. Architects are often in no position to help bridge the gap because their education in structures is often a condensed version of engineering courses. As a result, engineers tend to wait for an architect to initiate a (nonstructural) space-form scheme, and then to try to find a way of implementing it. This is not only an inefficient use of knowledge, energy, and time; it also produces conflicts.

The existence of the gap and its limiting effect on designers has been recognized by many creative engineers and architects for some time. They acknowledge the importance of learning how to conceptualize the constructive implications of a space-form scheme along with, instead of after, the generation of its basic operational and experiential characteristics.

Many educators in both fields also agree. Despite the fact that the content of an engineer's education will, of necessity, be more specialized and in depth than the architect's, there are many educators in architecture and in engineering who agree that any field of technological knowledge, such as structure, must be understood in overall terms before it can be applied with creativity at the formative stages of environmental design thinking. They do not deny that specialized learning can be useful, but they recognize a central challenge for educators: A means must be found for teaching students of both architecture and engineering how to conceptualize technological knowledge in a total-system context. It is becoming clear that the potential for creative collaboration of future environmental designers can be improved to the degree that total-system thinking can be developed.

The general argument may be easy to agree with: Overemphasis on educational specialization can produce creativity problems for most environmental designers. But the essential reason why a capacity for overall thinking will support creativity is that it can provide a natural bridge for

FIGURE 1-2
OVERALL THINKING ENABLES INTEGRATION OF ENGINEERING WITH ARCHITECTURAL SKILLS.



linking the more comprehensive, space-form aspects of architectural design with the more specialized and physical concerns of the engineer (Figure 1-2). It can enable the two professionals to work at the same level to recognize, and to resolve, structural-spatial design conflicts in broad schematic terms *before* they attempt to tackle the problems associated with the more detailed levels of final design. Overall thinking makes designers confident that they will always be able to communicate easily about the more basic structural implications of architectural concepts and vice versa. This makes creative collaboration not only possible, but also welcomed, at early design stages, because it can support rather than interfere with the generation of total architecture.

Accordingly, this book advocates that overall thinking should form a basis of one's introduction to structural knowledge so that one is able to view future specialized studies in a total-system context. Hence, the first four chapters will emphasize an overall approach to structural learning by introducing the structural problems of building design from a total-system, rather than elemental, point of view. As the total-system picture becomes clear, subsequent chapters will turn to the specifics of preliminary design of basic subsystems and their key components.

SECTION 2: The Architectural Design Process

We have said that the architect must deal with the spatial aspects of activity, physical, and symbolic needs in such a way that overall performance integrity is assured. Hence, he or she will want to think of evolving a building environment as a total system of interacting and space-forming subsystems (Figure 1-3). This represents a complex challenge. To meet it the architect will need a hierarchic design process that provides at least three levels of feedback thinking: schematic, preliminary, and final (Figure 1-4). Such a hierarchy respects the conceptual stages of design thinking when one needs to avoid being confused by the myriad detail issues that can distract attention from more basic considerations. In fact, we can say that an architect's ability to distinguish the more basic from the more detailed issues is essential to his success as a designer.

The object of the conceptual stages of thinking is to generate and evaluate overall site-plan, activity-interaction, and building-configuration options. To do so, the architect must be able to focus on the interaction of the basic attributes of site context, spatial organization, and use of symbolism as determinants of physical form. This means that the architect can first conceive and model a building design, in schematic terms, as an organizational abstraction of essential performance-space interactions (Figure 1-5a). Then he or she can explore the overall space-form implications of the abstraction. As an actual configuration of a building begins to emerge, it will be modified to