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David Blockley

# STRUCTURAL ENGINEERING

A Very Short Introduction

OXFORD

## Structural Engineering: A Very Short Introduction

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David Blockley

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# Preface

If you have ever wondered how a skyscraper, like the Shard in London, a big bridge, like the Golden Gate in San Francisco, a jumbo jet like the A380, or a cruise liner, like the *Queen Elizabeth*, stand tall: if you have ever wondered where the architecture stops and the engineering begins—then this is a book for you. We will explore in non-technical language how large man-made structures are created.

The purpose of the book is three-fold. First, I aim to help the general reader appreciate the nature of structure, the role of the structural engineer in man-made structures, and understand better the relationship between architecture and engineering. Second, I provide an overview of how structures work: how they stand up to the various demands made of them. Third, I give students and prospective students in engineering, architecture, and science access to perspectives and qualitative understanding of advanced modern structures—going well beyond the simple statics of most introductory texts.

Inevitably in such a short volume choices have to be made about what not to include. There will be gaps—in particular I have made no attempt to describe the everyday life and work of a structural engineer, the science of materials is limited, and I make only brief

references as to how structures are actually put together. I have included some recommendations for further reading.

Everything has structure. The function of structure is to provide the form and shape on which other functions can operate. Natural structures vary from the very smallest part of an atom to the entire cosmology of the universe. Man-made structures include buildings, bridges, dams, ships, aeroplanes, rockets, trains, cars, and fairground rides, and all forms of artefacts—even large sculptures like the Angel of the North in the UK.

Structure is the difference between a random pile of components and a fully functional object. Through structure the parts connect to make the whole.

Engineering is the ‘turning of ideas into reality’. Structural engineering is a critical part of the fulfilling of some of our most basic human needs—particularly for shelter, protection, and travel. It has evolved from the common-sense building of primitive huts, bridges, and weapons of ancient history, through the craft skills of medieval master masons who built castles, cathedrals, and country houses, to the latest and most sophisticated use of the science of structures and materials.

The wide range of different industries in which structural engineers work includes construction, transport, manufacturing, and aerospace. Each industry has its own particular ways of doing things. The book attempts to get behind those differences to the essential common core.

The work in a typical structural engineering design consultancy might be 30 per cent on design discussions; 30 per cent on structural analysis; 30 per cent on determining construction details; and 10 per cent on specifying, supervising, and checking the work. The structure of the book does not follow that pattern—instead we begin in Chapter 1 to trace the close and

often controversial relationship between architectural and structural form and function. This clarification is important because so many people, including much of the media, see structure as architecture. We will see that architects rely on engineers to make their ideas work, in other words, to stand up safely and operate successfully. However, just as an architectural form may not function well structurally so an efficient structural form may not be good architecturally. The best structures are a harmony of architecture and engineering—where form and function are one and the flow of forces is logical. We also learn in Chapter 1 how you can develop your own understanding of structural form with some very simple experiments you can do at home. In Chapter 2 we examine the three requirements for good structure set by the Roman Vitruvius long ago: resilience, purpose, and delight. We see that force pathways are degrees of freedom and that so-called form-finding structures are exciting and innovative examples of the fusion of engineering and architecture. We find that structures are naturally lazy because they contain minimum potential energy. Chapter 3 gives us the historical perspective necessary to understand the modern controversies as we trace the story of the emergence of the master mason and the increasingly separate roles of the architect and the engineer. We see how, from the Renaissance onwards, specialisms grew through new scientific knowledge, new materials, and new demands for structures. We begin to understand how the engineering profession developed into a science based capability to create some very large and breathtaking structures. Chapter 4 then builds on that background to help us understand better the science of how structures work. By that I mean how they resist all of the demands made on them by forces of self-weight, people moving about, wind that may blow a hurricane and ground that may vibrate in an earthquake. These forces have to ‘flow through’ the components of the structure rather as water flows through a set of pipes. We introduce some of the major theoretical principles that are the basis for modern computer analysis methods. In Chapter 5 we examine the commonalities and differences between