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The History of the Theory of Structures: from Arch Analysis to Computational Mechanics

Karl-Eugen Kurrer. Ernst & Sohn, Berlin, 2008, ISBN 978-3-433-01838-5, **£105, 848 pp., 667 illustrations.**

German publisher Ernst & Sohn has brought to the English-speaking public this substantial monograph by Karl-Eugen Kurrer, which is a revised and considerably extended version of the highly successful 2002 German edition *Geschichte der Baustatik*. The additional content, especially the inclusion of more international developments, makes this book of truly worldwide significance.

Kurrer presents the history of the theory of structures in a 'historic–logical' approach. For the reader, this appears an attempt to follow the development of theory from its inner logic, trying to discover the nodes of a network that connects theory formation with technological change, biographical data and important historic and even political events. Kurrer links the 'two cultures' of humanities and 'hard' sciences in the field of the theory of structures with the help of a concept of 'genesis of scientific disciplines' that he has borrowed from historians and philosophers of science.

Beside the meta-theoretical discussion of possible approaches, which is of great significance to Kurrer, it is clear that the difficulties of the matter could only have been mastered by an insider of both the history of science and structural theory. And Kurrer indeed has the qualifications for this – rich experience from his work in industry in the field of applied mechanics and a long-term interest in the history of science. For many years Kurrer has been a prolific writer on the history of structural theory and has been chief editor of the journal *Stahlbau* since 1996. An entire monograph on this topic is a *desideratum* and Kurrer has filled the gap admirably.

In the first chapter (Tasks and aims), Kurrer formulates the difficulty of finding 'gates' to access the field. What he presents is a very individual focus in which he tries to link the development of engineering theory with technological development, history and biographical aspects of the subject.

The second chapter uses 'Introductory essays' to formulate the individual themes of study. Moreover, Kurrer defines several distinct periods of development – from a 'preparatory period' (1575–1825) to a 'discipline-formation phase' (1825–1900), a 'consolidation period' (1900–1950) and, finally, to an 'integration period' (1950–present). These time-frames are subdivided further in the following chapters. So, while the reader may or may not agree with his systematic and very sharp definition of periods in the 'genesis of disciplines', the discussion of decisive points and events in history shows many new aspects and is profoundly informative. These essays address the principle of virtual displacements from the Renaissance up to Lagrange, the development of trusses, the history of polytechnic schools and their purpose, the impact of new iron structures on structural theory, the relationship between theory and practice in bridge construction, graphical statics, the emergence of trussed framework theories, the development of the influence line and the secondary stress problems that led to displacement methods and the ultimate load approach.

In chapter 3 Kurrer identifies the theory of structures and applied mechanics as the first 'engineering sciences', based on a 'purpose–means relationship'. In the nineteenth and twentieth centuries, the world of models in the engineering sciences increasingly moved away from design and construction to become more and more dominated by a 'non-interpretive use of symbols'. Nowadays, Kurrer suggests, the engineer is more and more a 'symbol worker'. He discusses the knowledge systems developed by Gerstner, Weisbach, Rankine and Föppl in comparison with new ideas coming from contemporary 'Technikphilosophie' (Ropohl, Krämer). Kurrer's aim is to develop a better understanding of the ongoing transformation of structural theory into modern 'computational mechanics'.

In the following chapters Kurrer unfolds all the *leitmotifs* of his introductory essays a second time, but now in more or less historical order. This includes not only theory formation, biographical notes and some well-known controversies, but also many developments in technology, materials, design and construction. In chapter 4 (From masonry arch to elastic arch) and chapter 5 (Beginnings of a theory of structures), Kurrer mainly discusses the time before 1825, from Galileo and Stevin to Gerstner, Navier and Eytelwein. This section concludes with detailed explanations of Gerstner's derivation of the thrust line and Eytelwein's and Navier's treatment of the continuous beam.

Chapters 6–10 are devoted to the period from the mid-nineteenth to the mid-twentieth century. Chapter 6 (The discipline formation period) elaborates on the topics of graphical statics, the theory of trusses, the beginning of force methods and the emergence of elastic systems including a look at tabular calculation and programmability in the twentieth century. Chapter 7 combines construction with iron to modern structural steelwork with a detailed view on the history of torsion theory from Saint-Venant to Bredt. Chapter 8 deals with member analysis in spatial frameworks and Chapter 9 considers the influence of reinforced concrete on the theory of structures in the twentieth century.

The development of the modern theory of structures is presented in the completely revised and enlarged chapter 10. It ends up in the development of 'computer shaped' structural mechanics and finite-element modelling (FEM) technologies. The development is not only linked with the use of tensor and matrix algebra and trussed framework models for plates and shells; it was also stimulated by developments in structural design in the aircraft industry and the availability of the first computers in the 1950s and 1960s – issues that were both closely linked with contemporary political events. Chapters 11 and 12 on 'Scientific controversies' and 'Perspectives for the theory of structures' form the final part of the book.

A large appendix contains 175 short biographies, a bibliography, and both name and subject indices. Kurrer's approach of varying and elaborating central themes at different places makes it difficult for the reader to keep abreast of the overview of this enormous subject, but the extraordinary appendix helps to provide order and structure to the abundant material. It forms a network of facts, theories and biographies, giving Kurrer's treatise the character of a reference book. The unfolding interdependencies in the history of the theory of structures are perhaps the most important quality of this extraordinary monograph.

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