BOOK REVIEW / CRITIQUE DE LIVRE

The history of the theory of structures: from arch analysis to computational mechanics. By Karl-Eugen Kurrer. 2nd ed. Ernst & Sohn Verlag für Architektur und Technische, Wissenschaften GmbH & Co. KG, Rotherstraße 21, D-10245 Berlin, Germany. 2008. Hardcover; 848 pp. CAN$159.99. ISBN-13: 978-3433-18385. ISBN-10: 3433018383.

The impetus for a book on structural analysis was based on the author's personal interest and from the first conference on "The History of the Theory of Structures" held in Madrid in 2005. This book is the second updated and expanded edition that has been translated into English from the original German. As with any encyclopedia, the author enlisted other contributors and friends who provided some texts and illustrations. Additionally, there are 175 mini-biographies of prominent figures in structural mechanics as well as an extensive 52 page bibliography containing significant research references. Two detailed indices containing names and subject matter are very helpful. Almost every page contains a diagram, a table, a photograph or an equation that illustrates an event in the development of the subject at a point in time.

This is an encyclopedia of a somewhat esoteric subject to some, but of interest and importance to those concerned with the origins of the design of structures: bridges, cranes, buildings, soil mechanics, ships or airplanes. Teachers of structural mechanics will find the book invaluable, as there is, in addition to the usual equations found today in textbooks, much more detailed information about the evolution of ideas and theories over time. Professor Kurrer has organized the history into four time periods: preparatory period (1575–1825); discipline formation period (1825–1900); consolidation period (1900–1950); integration period (1950 to date). Within each time period, a further division is made into phases covering significant ideas that have added to the basic ideas of the past or have provided a step forward with new ideas in analysis or construction. Of the 12 chapters in the book, eight are devoted to the history and mathematical concepts underlying structural analysis and design. The remaining four chapters provide comments on the perspectives of a coherent history of thought on the subject.

The subtitle of the book, *from arch to computational mechanics*, concerns the development of analysis theories of masonry arch and dome structures from the distant empirical past to the present. Elastic behaviour of arches based on mathematical theories still intrigues investigators today who use photoelastic analysis, finite element models or ultimate strength methods.

Opinions vary about the beginnings of the application of mathematics to structural design. The ancient Greek thinkers produced theories that can be interpreted as mathematical tools, e.g., Archimedes and the lever properties. Galilleo's *Two new sciences* (1638) and Leonardo da Vinci's *Notebooks* (circa. 1500) have been given as examples of early thinking about the relationship of material strength to structural behavior. With the development of mathematical tools over the centuries — calculus, graphical methods, and extensive material testing — mathematicians and natural scientists provided many theories, and controversies, of member behavior. This led to the development by the 19th century of the basic equations still in use in design today. The extensions of structural theories and mathematical tools in the 20th century were the foundations of spatial structures and orthotropic bridge design (based on earlier shipbuilding design). The development of reinforced concrete had been made before a coherent theory was formulated — a case of the material behaviour driving the structural analysis theory of slabs, space structures, and reinforced concrete frames with multiple redundancies.

The development of higher engineering education is documented in Section 2.3f. The transition from military engineering to civil engineering in France (École des Ponts et Chaussées, 1775), was followed by the evolution to technical universities from polytechnic schools in Austria and Germany in the 19th century, and establishment of polytechnic schools in Prague, Vienna, and St. Petersburg (p. 55). The nature of the subject is that most of the development of principles and references before the 19th century took place in Europe, Russia or England. University training based on the European model began in the USA at West point in 1802 to provide graduates for the Army who also served as a Corps of Engineers. In 1862, the U.S. government established technical universities throughout the country, with the majority located in the Northeastern states (p. 61). A significant detail in the U.S. university programmes was the inclusion of practical laboratory work in addition to lectures. The value of this was recognized by visiting Europeans and was copied at many German universities. In time, through a lack of strict university entrance criteria, U.S universities lagged, in scientific terms, behind the European ones until about the 1930s. Today (2008), through the Bologna Accord, European universities are adopting the North American three-degree programmes. This will encourage the globalization of engineering with transfer of credentials.

Descriptions of major bridge construction in England, the USA, and Europe in the 19th century are given with significant details and drawings. A point of interest is the erection scheme for Robert Stevenson's railway Britannia Bridge in Wales (1846–1850). Continuity of the centre spans was achieved in the field by lifting the outer ends of the adjacent span to match the end angle rotations of the centre span un-

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der girder weight. This matching of the field joint over a pier allowed the riveted field connection to be made. Calculations were made, by Edwin Clark, in advance of the erection. Clapyron's three-moment equation was not published until 1857.

From the 1950s onward, with the development of digital computers and applications of matrix algebra, the earlier stiffness method was re-formulated. The development of finite elements based on the stiffness method is dealt with in detail, originating from work in the field of aircraft structures. A welcome inclusion is a description of the early (1940) pioneering work by Professor Alexander Hrenikoff of The University of British Columbia, whose contribution of a framed grid to represent plate and shell elements was a precursor to the finite element method.

The phase from the latter half of the 20th century emphasizes the role that the computer played as it began to transcend the usual longhand calculations of the past. The computer is now a link between calculations in design, detailing, fabrication, construction, planning, estimating, and accounting. The development by the German automobile industry of finite element analysis from 1963 onwards for shaping design is well explained. Structural design and analysis software for almost all structural design problems is widely available today, which creates the problem of how to teach structural engineering without losing the grasp of the underlying theory.

The author had twin goals in writing this book. One was the history of the development of structural engineering in detail, the second was to provide a didactic scientific theory, construction history, and biographical and bibliographic perspective, providing a union between science and the humanities. This goal has succeeded in large measure due to Professor Kurrer's knowledge of the subject and his ability in organizing the material. The English translation from the original German is very good, with only a few typographical errors and solecisms.

One egregious omission is the lack of the probabilistic aspects of structural design, perhaps because it is too new or because it is outside of the main thrust of the book. A separate volume on this aspect of structural theory would be very interesting and useful.

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