

# This Week's Citation Classic®

Zienkiewicz O C & Taylor R L. *The finite element method. Vol. 1. Basic formulations and linear problems.* London: McGraw-Hill, 1989. 648 p. *Vol. 2. Solid and fluid mechanics: dynamics and non-linearity.* London: McGraw-Hill, 1991. 807 p.

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At a time when the digital computer was becoming a real tool in mathematical research, this book was an attempt to firmly base the subject of the finite element partitioning on general mathematical principles. [The *SCI*® indicates that the combined editions of this book have been cited in more than 4,100 publications.]

## Defining Finite

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This book, in its four editions, has achieved a considerable "quotability," apparently leading to its selection as a *Citation Classic*. Perhaps the main reason is that the first two editions (those of 1967 and 1971) stood alone as texts for the finite element field in which research had been expanding exponentially and its industrial application growing daily.

The growth of the subject is perhaps best illustrated by the size of the various editions. The first edition included 272 pages, compared to 1,455 pages in the fourth edition. And this was not due only to verbosity!

My first contact with the concept of finite elements was in 1958, through discussions with R.H. Clough of Berkeley. As I was at the time involved in finite differences which presented a clear and general methodology of solving problems of solid or fluid mechanics governed by partial differential equations, I was, at the start, skeptical of such an idea, which appeared to be based on intuitive and physical partitioning of a structure into finite elements of material. Nevertheless, the possibilities it offered seemed to me enormous, at a time when the digital computer was entering the field of serious calculations. However, the subject needed to be firmly based on general mathematical principles, which would also allow its extension beyond the applications to structural mechanics. This was the motivation of my early work in the field, and the first edition was an attempt to find the answers.

In addition to this generalization, the book was an attempt to present the whole fascinating subject in a simple and understandable manner to a wide circle of readers. How wide, I did not realize at the time.

From the beginning, my own interest in the whole field of finite element analysis has continued to grow. Inevitably, the results of continuing research, by my own team at Swansea and at other centers in the US and Europe, required more pages for a comprehensive presentation.

Indeed in 1960 only a handful of papers mentioning the phrase "finite element" were published, but by 1970 the number of articles about the topic approached 1,000. The need for specialist journals was evident. In 1969 the author (representing the Institute for Numerical Methods at Swansea) and R.H. Gallagher of Cornell University launched the first journal dedicated to the subject, the *International Journal of Numerical Methods in Engineering*. This journal was soon followed by others, the second being *Computer Methods in Applied Mechanics and Engineering*.

Today, to deal with the annually increasing literature, some 20 journals devoted to the subject are published. The original journal publishes circa 3,500 pages per annum and any state-of-the-art survey has, per force, to be selective. Nevertheless the fourth edition of *The Finite Element Method* refers to some 1,500 papers, many of these originating at Swansea.

Thus, each edition represented a considerable addition of new matter as well as updating of the original concepts. It pleases me, nevertheless, that some chapters remained virtually unchanged through all editions—presumably containing some permanent perceptions.

Today, despite the passage of some 30 years, research continues and improved answers to some old questions are being obtained.<sup>1-3</sup> However, it is my hope that the book will continue to teach and perhaps give guidelines for development in the future—though at this stage, its size should, perhaps, remain constant, and substitution rather than addition should be the motto of future editions.

The monopoly of my text, which lasted until 1971, has been now extensively broken. Today, at least 50 texts are in circulation, with new titles appearing frequently. Obviously, each text adds some new aspect of interpretation or presentation. However, I am particularly pleased at the popularity of the last edition, which I presume shows that its manner of presentation and increased scope has kept up with the needs of students and researchers.

For this and related work I have been awarded eight medals, 14 honorary doctorates and fellowships in five academies including the Royal Society and the US Academy of Engineering.

1. Zienkiewicz O C. The finite element method—from intuition to generality. *Appl. Mech. Rev.* 23:249-56, 1970.

2. -----, Update to "The finite element method—from intuition to generality." (Steele C R & Springer G S, eds.) *Applied mechanics update* 1986. New York: American Society of Mechanical Engineers, 1986. p. 135-42.

3. -----, Computational mechanics today. *Int. J. Numer. Meth. Eng.* 34(1):9-33, 1992.

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