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STRUCTURAL MECHANISM AND FINITE FUNDAMANTAL MEMBER METHOD

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责任编辑：吴俊燕

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内容提要

本书介绍著者30多年来对“结构机理”研究的部分成果和著者提出的“有限基本构件法”。所谓“基本构件”，在本书中用到的是浅梁、悬臂梁、板带、圆环、折环和折拱等，它们的应力状态和变形为大家熟知或者是很易确定的。所谓结构机理或称结构作用，根据计算要求不同，可以是研究弹性阶段或弹塑性阶段的，也可以是破坏阶段的。

本书可作为结构工程专业的大学生、研究生及有关教师的参考用书，也可供结构设计人员参考。

Ding Diajun (April 28, 1923—), Bachelor of Eng. (1948) from Anhui Uni. Assistant, Lecturer & Professor of Nanjing Institute of Technology, Honorary Professor of 9 institutions of high learning; one of the advisors of doctorial students, approved by the State Council of PRC for the 1st time (more than 70 students got master and 20 doctor degree); Director of China Civil Engineering Society, member of IABSE and Chairman of Limit States Design Committee (26) of Concretc & Masonry Buildings Group of Council on Tall Buildings & Urban Habitat (USA), Honorary Director of International Federation of Highrise Structures (India). Committee Member of the Editorial Board of Journal of Building Structures. Prof. Ding has published more than 160 Chinese papers in 30 Chinese periodicals and more than 80 English papers, besides 20 papers published in other foreign languages (Polish, Russian, Hungarian, Romanian, Japanese, German, French, Italian & Danish), more than 100 in total included in 25 Journals in 17 foreign countries, among which more than 40 papers in 16 international authoritative periodicals in 12 countries; also published 34 text, reference & monograph books on concrete, masonry & mechanics, among which the text of Masonry Structures had an impression of 290, 000 copies, and won the Excellent Text Prize. Prof. Ding has conducted a series of tests on concrete & masonry members, only the specimens for stiffness & crack exceeded 700, 10 series of long-term tests succeeded 23 years and the longest lasted for more than 6 years. Prof. Ding has founded a complete calculation system of stiffness &

crack of concrete members (including: RC, PC, light RC, FRC; members under uniaxial & biaxial bending and eccentric tension & compression, with 5 shapes of section), the most part of which has been listed in relevant Chinese Codes & Standards; erected new theories on local compression & transversely reinforced masonry, respectively improving and replacing the old, and suggested a series of important problems in concrete & masonry structures; created finite fundamental member method (FFMM) for calculating plates, shells, etc. on the basis of fully studying the mechanism of structures, and also many simplified calculation methods, such as those for frames, beams on elastic foundation, shallow shells, applications of analogy, etc. Studying RC deep well pipes to replace cast iron pipes has practical use almost over China and saves more than 200 million yuan. He suggested to consider the influence of compression, tension & prestressing on shear (1967) firstly in China and gave a continuous formula to calculate ultimate displacements of eccentric compression members (1967) and the calculation for crack width along cover thickness (1983), both firstly in the world. Advised his post-graduates to finish a series of experimental studies on new self-control of concrete tall building components or structures (" modified structures") under cyclic loading & tests on shaking table, some proposals have practical use. He won National Scientific Congress Prize (1978) & National Prize of Natural Science for the research of stiffness & crack (1982) and the provincial prizes, etc. more than 10 times in total. Prof. Ding has chaired 4 international conferences and been

invited to be international advisor & member of scientific committee of international conferences more than 20 times. He visited 25 countries & an area and lectured at 31 foreign universities (besides, at 22 Chinese universities), 4 academies, 8 societies & two big construction corporations in foreign countries and makes wide exchange with foreign colleagues in 6 continents. Composing ancient Chinese poetry and ci, painting Chinese traditional pictures and learning Chinese calligraphy are also his hobbies.

序　言

著者认为在进行结构分析时，首先要研究结构的受力行为，也就是结构在承受荷载后将会产生什么样的内力和变形，以及通过什么样的机制或机构将荷载传至支座，也就是要研究结构受力的作用或机理。在此基础上才能作出正确判断和分析，进行合理的设计。例如有人将双曲扁壳比拟于四边支承的双向板，双向板由两个方向的板带传递荷载至四边支座，而认为双曲扁壳也是由两向拱结构来传递荷载的，因而可以厚度很薄而跨越很大空间。双向板虽是由两向许多受弯板带组成，但它们所受的荷载不仅是横向的（板上垂直荷载和板带间剪力增量），而且还因变形的差异而在板带间作用有扭矩增量，这些扭矩增量将大大降低弯矩值。至于双曲扁壳虽可视为由两向许多形似拱结构的曲线构件组成，但它们不同于一般只承受垂直荷载的拱结构；而是除承受壳面上向下作用的垂直荷载外，还在曲线构件间的截面内作用有剪力（在平面剪力 S），由壳的中部向边缘增大，是主要通过这项剪力的垂直分量将荷载传至支座（侧边构件）的，而不是象一般拱那样通过由支座垂直和水平反力组成的斜向推力来传递拱面垂直荷载的，因此拱的支座设计时必须能承受上述推力，而双曲扁壳却并不如此，如果双曲扁壳也象拱结构那样作用，则推力必将侧边构件推倒，同时薄的拱带也将很容易失稳和在半边荷载作用下产生薄壳截面远不能承受的弯矩。由此可见，对结构机理的研究，能较深入地了解事物的本质，对学习和研究大有裨益。著者曾对横向配筋砌体受力机理进行理论和

试验研究，发现原强度提高的理论是错误的，因而破除了传统的三向应力状态理论而建立了新概念，提出了新型横配筋。因此可以认为研究结构受力机理是十分重要的，为此建议建立“结构机理学”这一新的学科分支。

著者在30多年来对结构机理的研究和在前人工作的基础上，发展和提出一些结构的简化计算方法，特别是“有限基本构件法”（原称“杆件力学法”），即将复杂的结构，划分为若干杆件体系，这些基本构件的内力和变形规律已为我们熟知或很容易求得。目前著者已完成深梁、圆形贮液池、圆形和环形板、有直线边的板、薄壁管道和筒壳屋盖等的有限基本构件法，初步完成了一个计算体系。

著者认为一个复杂结构可以细分为有限单元，也可较粗地分为有限条或有限段，乃至粗分为有限基本构件来进行计算。因为如上所述基本构件的内力和变形为已知或很容易求出，因此计算较为直接和简单，概念也较清楚，而不至将整体结构的受力机理为繁冗的数学运算所掩盖。已故前苏联符拉索夫教授用折壳屋盖代替圆筒壳屋盖的计算，虽然也属有限基本构件法，但方程式系数的数学推导过于冗长，不仅不便记忆，而且也将它们的力学概念掩盖住，因而不利于对事物本质的认识。著者所提的方法，计算公式都是基本的，为一般工程技术人员所熟悉，因此避免了上述缺点而同时也有利于对方法的掌握。

著者认为，在简单的前提下，计算应尽可能地直接些，如果有现成简单而较准确的简支受弯和偏心受力构件的弯矩曲率 $M-\frac{1}{r}$ 全过程曲线，则用以计算连续梁和刚架的受力全过程将是最直接和简单的，也应是较准确的。

事物总有其特定的适用场合的。因此著者还认为可不拘一格地进行结构分析，而不必局限于一种方法，为此本书也介绍了著者提出的某些简化计算。

本书共分四章。第一章简单论述结构在弹性阶段、弹塑性阶段和破坏阶段的机理以及研究结构机理的重要性。第二、三和第四章分别介绍著者对深梁、圆池、圆形板、环形板和有直线边的板、薄壁管道以及筒壳屋盖（长壳和中长壳）的受力机理和相应的按弹性理论有限基本构件法。最后在附录中简单介绍了著者提出的一些结构简化计算，供读者参考。

由于本书主要介绍某些特定结构的有限基本构件法和相应结构的结构机理，但为了举例，也涉及到其它一些结构的结构机理，但未能进行系统的阐述。著者还拟编写一本专门论述建筑工程中常用结构的《结构机理学》。

为了方便计算，李爱群博士和陆勤博士分别为本书编制了薄壁管道有限基本构件法和双曲扁壳内力直接差分法的计算机程序。刘伟庆博士在深梁和圆池的分析中，进行了很多电算工作。郜扣霞同志抄写了全部书稿。著者在此一并表示感谢。

丁大钧

一九九五年三月

SYNOPSIS

This book presents a partial result of studying the structural mechanism by the author and the " Finite Fundamental Member Method (FFMM)" erected by him. So—called" fundamental members" adopted in this book are shallow beam, cantilever beam, strip, circular ring, folded ring and folded arch, the stress states and the deformations of which are known or easy to be determined. The author considers that a complicated structure can be divided finely into finite elements, also roughly into finite fundamental members in some cases, thus the calculation will be more direct and simple, the physical conception will be more clear and the calculation exactness is also better.

According to different calculation requirements the structural mechanism or structural action may be in elastic or elasto—plastic stage, may also be at ultimate stage, and will be presented generally and briefly in the Chapter " Introduction".

Basing on the full understanding of structural mechanism in all stages, the author has suggested a series of simplified calculations, including the calculation system of FFMM mentioned above and the others. Just because of understanding the mechanism at ultimate strength stage the author has put forward the improved local compression theory of masonry and criticized the international traditional strength theory of reinforced masonry with meshed steel and founded new one. He has supervised the doctorial students to conduct the experimental re-

search on new" modified structures" (aseismic self-control), i. e., to change the brittle failure to ductile failure so as to increase the aseismic capacity of structures. This research is also based on the studying of structural mechanism. Some new construction proposals have been used in practical engineering.

This book emphasizes to introduce in 3 chapters the FFMM calculations of deep beams and circular tanks, circular and annular plates, and rectangular plates (triangular plate can also be calculated) subjected to different loads and with different supports, thin-webbed pipe and long and intermediate cylindrical shells, where the corresponding structural mechanism is expounded before the concrete calculation so as to deepen the physical conceptions of calculation. Following FFMM, not only the calculation is simplified, can also calculate some structures which can not be calculated by the conventional simplified methods, such as intermediate cylindrical shell, but the formulas used are also fundamental without need of forcing to be remembered, and the physical conceptions in every calculation step are also very clear.

The author has such an opinion, namely, for making structural analysis, it should not be stuck to one pattern of methods, i. e., should not be limited to one method and should select which is the most suitable in concrete case. Therefore some other simplified methods proposed by the author are briefed in the Appendix to provide the reference for the readers.

This book consists of 4 chapters and an appendix, with more than one hundred thousand Chinese words.

It can be referred by university students and post-graduates of the specilities of structures and relevant teachers, can also be used as reference by the technicians engaging in structural design work.

丁大钧

Ding Da Jun

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