第二届传授、运用和推广微型计算机在工程方面的计算方法国际会议

论 文 集

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(EPMESC)

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前　　言

一九八七年十一月在中华人民共和国华南工学院召开了第二届"传授、运用和推广微型计算机在工程方面的计算方法的国际会议"．本集就此会议选辑了一些有代表性的论文。

现在我们日益感到计算机已成为我们生活中的重要组成部分．目前微机计算速度之神速，体型之轻巧及其成本之低廉引起了许多在工业部门工作者的注意．随着微机的飞跃发展，运算过程以及运算方法也不断地出现新的突破．为了使微机能更有效地从事极其精密和复杂的运算，传授、运用和推广微机在工程方面的计算方法已成为当务之急，正因为这样，我们召开有关这方面的国际会议．

第一届会议是于一九八五年八月在澳门召开的．至今已有两年了．在这短短的两年里，微机的功能和计算方法又有了新的、迅速的发展．计算机技术发展如此迅速以致任何时候也不可能有一本书能够及时地充分地反映它的最新成就．由于篇幅所限，本集只能就这次会议选辑部分的论文．我们衷心感谢全体与会的同志，感谢那些鼎力支持会议顺利进行的同志们，而且特别感谢那些为使会议获得完满成功而毫无保留地发表意见、交流经验以及提供宝贵信息的专家学者们。

我们还借此机会，向会议的赞助单位、组织委员会的全体成员致以崇高的敬意和深切的谢意．

第二届传授、运用和推广微型计算机在工程方面的计算方法国际会议组织委员会主席、
华南工学院院长

刘植梓

Preface

In November, 1987, the International Conference on Education, Practice and Promotion of Computational Methods in Engineering Using Small Computers(EPMESC) was held on the campus of the South China Institute of Technology, Guangzhou, the P.R.C.. Included in this volume is a representative collection of research papers recently presented at the Conference.

Now, computers have made their way into all walks of life. Every day more and more of us find that computers have become part of our daily background. The high speed of small computers in performing tasks, their incredibly small size and their low cost of operation have brought them to the notice of workers in many industries. The pace of growth of small computers is matched by the speed at which new processes and computational methods are developed. In order to enable a small computer to perform extremely sophisticated and complex computations, the education, practice and promotion of computational methods can not be neglected. It is for this reason that conference like this are occurring.

Two years have passed since the first international conference of EPMESC was held at Macau in August, 1985. During such a short period of time, many new tasks for small computers have been devised and many new computational methods to perform them have been developed. Computer technology is advancing so rapidly that no book on this subject can ever be fully up to date. Due to limited space, this volume includes only a selection of research papers presented at the Conference. Our hearty thanks go to all those who attended the conference and those who gave their all-out support, and especially to those who have made it a success by supplying valuable information and presenting their ideas and experiences without reservation.

The help received from many individuals and organizations is most gratefully acknowledged. Although it is not possible to acknowledge all of those who assisted in the presentation of this conference, we give special thanks to:

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The Promotion of Computational Methods in Building Engineering using Micro-Computers in People's Republic of China

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SUMMARY

The development and popularization of micro-computers has brought the evolution of computational methods in many problems in solid mechanics and the algorithms of solving large global matrix equations which can used on micro-computers. Lately, computer aided drafting in architectural and structural designs of buildings are being developed and certain realizations on micro-computers are now available in practice. Some future prospects in the use of micro-computers in building engineering are also stated in the paper.

INTRODUCTION

The rapid development of computer hardware and software has brought about profound effect in the evolution of the traditional computational methods of structural and continuum mechanics. In the middle of the fifties, the germination and application of the Finite Element Method has marked a great break-through in computational mechanics. This advancement is due to the development of the generalized variational principle coupled with the come into use of computers in the fifties of the century. The merit of the former enables us to consider the displacements, stresses and strains of a problem as independent functions without the necessity of satisfying a priori the prescribed boundary conditions. From the mathematical point of view, the pioneer work " Difference scheme based on variational principle "[(1)] presented a systematic discretization method for the second order elliptical differential equations with constant or variable coefficients for arbitrary domain configuration with arbitrary boundary conditions. It has thus been proved that the reliability of the theory of finite element method is fully ensured.

The finite element method has proven itself to be excellent in the analysis of bar-system structures and plane stress or plane strain problems of plates whose solutions can be easily worked out on small computers. As to plate bending problems and problems of spatial structures such as shells and suspended cable constructions due to the need of large computer storage, other computational methods should be recoursed to if small computers were to be used.

STRUCTURAL ANALYSIS IN BUILDING ENGINEERING

By the generalized variational principle, the potential functional of the problem can, in general, be represented by:

$$\Pi = \frac{1}{2}\iint_{\Omega}(\varepsilon^T D_n \varepsilon + \chi^T D_m \chi)dxdy - \iint_{\Omega} P^T U dxdy - \int_{\partial\Omega} \bar{q}^T U ds - \int_{C_u} (U - \bar{U})^T F ds \qquad \ldots\ldots (1)$$

In general, the following interpolation formulae may be adopted:

$$u(x,y) = \sum\sum a_{ij}\varphi_i(x)\psi_j(y) \qquad \ldots\ldots (2)$$

$$v(x,y) = \sum\sum b_{ij}\varphi_i(x)\psi_j(y) \qquad \ldots\ldots (3)$$

$$w(x,y) = \sum\sum c_{ij}\varphi_i(x)\psi_j(y) \qquad \ldots\ldots (4)$$

There are many ways of choosing the interpolation formulae, each having its own features and merits in application. The finite element method, presented as a convenient method of analysis of continuum media by analog with discrete problems for which the computers have provided as powerful tools, is now recognized as a versatile process of computation applicable to a larger variety of building engineering problems. However, due to the need of large computer storages for most types of computational problems, the alternate track of solution is to turn to the semi-analytical approach of analysis. This will not only reduce greatly the need of computer storage and the computer time as a result of the much lower order of the global matrix equation of the undetermined coefficients, but also it can offer a good insight of the structural behaviour of the structure under analysis and the relationship between the variations of internal stresses and external deformations or displacements with the various parameters of the structure. This makes the solution quite adaptable and feasible on micro-computers. Furthermore, using the generalized variational principle in the analysis, we can take the displacements, stresses or strains as independent variables save the necessity of satisfying a priori the prescribed boundary conditions of the problem.

The various ways of choosing the interpolation formulae give rise to different computational methods, all of which can be solved on micro-computers. They can be enumerated as follows:

Semi-analytical Methods

(a) Single Series Solution[2]

If a series representation is chosen either for $\varphi_i(x)$ or for $\psi_j(y)$ and the resulting ordinary differential equation is discretized by any of the discretized methods, the solution can be easily realized on micro-computers.

(b) Finite Strip Method [3]

If a polynominal function or certain interpolation function is chosen for $\varphi_i(x)$ and the beam function chosen for $\psi_j(y)$, then we have the finite strip method . It is applicable for the static and dynamic analysis of tubular structures in tall buildings, plates and shells on micro-computers. Researches have been made to improve the convergence of the method and some useful suggestions have been obtained.

(c) Spline Finite Point Method[4]

If a B spline function is chosen for $\varphi_i(x)$ and a beam function is chosen for $\psi_j(y)$, then the method is called the spline point method. This method has been used in cases where the boundary conditions can be easily approximated by such functions.

(d) **Boundary Element Method**[5]

The boundary element method has long been recognized as a rather important alternative to the finite element method in the solution of many specific problems as it shows to be more economical , more feasible for solutions on micro-computers with certain merits absent in the finite element method. However, we should have, at our disposal, the fundamental solutions of the problem. For plates and three dimensional elasticity, they are already available in many literatures[6][7]. For shell problems, the fundamental solutions of double curvature translational shells can be found by the plane wave decomposition method[8]. If the direct method is used, some mathematical artifices are needed to bypass singular integrals of higher order but for the indirect method, such singular integrals do not even exist in the computation. Great attention has been paid to this method and reseach on its theory and application are being carried on at present.

(e) Boundary Collocation Method [9][10]

If the complete solutions of the governing differential equations of the problem are found, the boundary conditions can be approximated by the collocation method through the variational principle of minimum energy. There are many ways of finding the complete solutions such as by the plane wave decomposition method. But the method of generalized Fourier Transforms based on the theory of generalized functions offers a very methodic way of obtaining such solutions[11].

Other Discretization Methods

(a) Variational Finite Difference Method[12]

The finite difference method used to be a rather popular method prior to the finite element method but for the case of higher order of the governing differential equations and complicated boundary conditions, the method has lost its attraction for practical purposes. The merit of the finite difference method based on the variational principle lie in the fact that it has greatly reduced the order of the differential equations by half and that the boundary conditions can be incorporated in the variational equations.

(b) Spline Function Method[13][14]

The generally adopted cubic B splines are piecewise polynominals of the third order. It is continuous to the second derivative belonging to C^2. As a interpolation formula, it is better than the third order Langrange formula which belongs to C^0 only and also better than the Hermite formula which belongs to C^1. By this method, the order of the global matrix equation is greatly reduced as compared with that by the finite element method. With the aid of Langrangian multipliers the method can as well be used for problems with arbitrary boundary conditions.

(c) Spline Finite Strip Method[15]

If in the finite strip method stated previously the beam function for $\psi_j(y)$ is replaced by the cubic B spline function, then the method is changed into the present one with much better convergence in the calculation. This is due to the fact that the beam functions which contain hyperbolic functions are undergoing big variations in numerical values as the independent variable of the beam function increases.

(d) Generalized Continuum-Discretization Method[16]

For some complicated structures such as tall building shear wall construction with many openings along the height of the building, the generalized continuum-discretization method may sometimes be used to advantage on micro-computers. The real structure is replaced by an equivalent continuum structure which is then discretized for numerical analysis. It is generally found to be simpler in manipulation and smaller in the order of its final global matrix.

(e) Method of Weighted Residuals[17]

Crandall first classified those methods of approximate analysis such as the Galerkin, the least squares, the sub-domain, the collocation and the method of moments etc. as the method of weighted residuals.Lately, the latter has been extended to include the finite difference and the boundary element methods. All these methods can be worked on micro-computers with basic theory studied.

NUMERICAL IMPLEMENTATION AND SOFTWARE TECHNIQUE

For the numerical implementation of engineering problems using micro-computers, besides the proper choice of the method of computational analysis, the software technique for solving the simultaneous equations of the global coefficient matrix plays an important rôle. For symmetrical and sparse matrix of high order, one can adopt the method of storage of variable band width and solution by blocks. In order to speed up the numerical computations, it is important to reduce the number of exchanges of numerical datas between the incore and low-speed storages. For this purpose, the method generally chosen is to store all the diagonal elements in the incore storage and none in the low-speed storage. Although this method cannot reduce the order of the matrix, but it will greatly raise the speed of computation of the analysis. In such a way, we can solve a matrix equation of the order of 2000 (double precision) on a micro-computer like the IBM PC/XT with a storage of 512 K. and this covers all ordinary problems of continuum mechanics

For the solution of problems using the boundary integral equation method or the boundary element method, one has to deal with matrices which are often fully populated and non-symmetrical. However, they can be made symmetrical if a spline boundary element method is recoursed to but for the solution of such matrices, we can either use the method of orthogonal transformation or the method of generalized inverse. If one adopts the method of storage of the elements of the matrix of high order by rows or by columns and appropriate exchanges between the incore and low-speed storages are duly conducted, then one can still solve a matrix equation of the order of 1000 on a micro-computer such as the IBM PC/XT with an incore storage of 512 K.

For linear dynamic problems, the Rize-Lancoz method can greatly speed up the solution of the eigen pairs with a speed faster than that by the subspace iteration method by one order of magnitude[18]. For vibrational problems of tall buildings, the solution of the eigen pairs by the perturbational method can be adopted to advantage on micro-computers.

For non-linear problems, one can use the preconditioned conjugate gradient method of solution on micro-computers. This is quite effective due to the fact that a transformation matrix has been introduced to reduce the number of conditions in the original coefficient matrix and to reduce the total amount of work in iteration and storage.(21)

New software programs are incessantly emerging to replace the old ones as a result of the development of the software techniques. The latest finite element method software[19] in China is one that has been proved to carry out the static, dynamic, linear as well as the non-linear analyses on IBM PC/XT computers. Besides, it possesses many new features and specialities such as the possibility of inserting desired short programs into it by users themselves, advanced dynamic solvers with very reasonable data documentations etc. Other softwares such as the SAP84 CH, JIGFEX, HAJIF, Building Design Software Package can all be used on small computers with the aid of the technique of coverage and mass treatment. It is expected that we can arrive at using still larger software programs on small computers in the near future.

COMPUTER AIDED DRAFTING ON MICRO-COMPUTERS

Since 1985, much work has been done aimed at the development of computer aided drafting on micro-computers such as IBM PC/XT. The general policy is to push forward AUTO CAD with domain of application directed at:

(1) Architectural Drafting
 - mainly on drafting of architectural plans, elevations, sections and perspectives. At present, we have already the CAD softwares HOKCE of Huayuan, Beijing, the BEIJING CAD of the Architectural and Civil Engineering Society of Beijing and the CAD of Liaoning and of Mianshan Institutes of Architectural Design.

(2) Electrical Design Drafting of Buildings
 - under development by Huayuan of Beijing.

(3) Structural Design and Drafting of Buildings
 - at present, we have the FBCAD for reinforced concrete frame for analysis and drafting with reinforcements. Similar programs also from the Liaoning and Tienjin Institutes of Design and Dalian Institute of Technology are available.

(4) Urban Habitat Planning
 - computer aided planning of urban habitat and drafting under cooperation by Shanghai Planning and Designing Institute with Fudan University.

In order that computer aided design or drafting be really helpful to the designers, they should be such that the users have to give only the parameters of design or of drafting and not the orders or the menu to obtain the necessary design and drawings by the computer. This substantially means that AUTO CAD should be linked to certain higher computer language through stipulated links so that the parameters can be processed through the higher computer language to the AUTO CAD software to make the computer to work automatically.

PASCAL has been successfully used in this respect through the link between the program of structural drafting and the program for AUTO CAD by the document of DXF automatically generated by the computer[20]. The Shen-Yang Institute of Building Engineering has successfully established the link named SCR between AUTO CAD and the