Theme 4: Education and computer based structural analysis and design

Objekttyp: **Group**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **40 (1982)**

PDF erstellt am: **23.06.2024**

THEME 4

Education and Computer Based Structural Analysis and Design

L'enseignement face à la conception et à l'analyse des structures assistée par ordinateur

Strukturelle Berechnungs- und Entwurfslehre mit dem Computer

Leere Seite
Blank page
Page vide

Education of Structural Engineers in Electronic Data Processing

Formation des ingénieurs civils dans le domaine de l'utilisation de l'ordinateur

Empfehlungen für die EDV-Ausbildung von Bauingenieuren

Heinrich BALDAUF
Dr.-Ing.
Bilfinger + Berger
Mannheim, Fed. Rep. of Germany

Heinrich Baldauf, born 1925 obtained his doctor's degree at the Technische Hochschule Dresden, GDR. After ten years of scientific activity at Dresden and Leipzig, GDR, he started work in 1961 in a construction firm, where he is now head of the technical-scientific computing centre.

SUMMARY
In day-to-day professional work, people are needed who can use electronic data processing in an intelligent and critical way. An engineer must be aware that a computer is a splendid tool to help him to do his job but it must remain only a tool. These recommendations give some guidelines for education of engineers according to this philosophy.

RESUME
Dans le contexte d'un travail quotidien, il est nécessaire de disposer de collaborateurs qui sont à même d'utiliser les procédés de calcul sur ordinateur d'une manière intelligente et critique. L'ingénieur doit se rendre compte que l'ordinateur est une aide précieuse dans la réalisation de ses tâches, sans pour cela dépasser le stade d'un outil. Ces recommandations donnent quelques directives pour une formation allant dans ce sens.

ZUSAMMENFASSUNG
In der täglichen praktischen Arbeit werden Leute gebraucht, die die EDV in intelligenter und kritischer Weise anwenden. Ein Ingenieur soll sich bewusst sein, dass der Computer ein hervorragendes Werkzeug bei der Erfüllung seiner Aufgaben ist, aber er muss ein Werkzeug bleiben. Diese Empfehlungen geben eine Richtschnur für eine Ausbildung in diesem Sinn.

1. INTRODUCTION

When, about twenty years ago, the use of computers began in civil engineering, there were many limitations on their application. The computers were slow, the internal storage was small and the peripheral storage, if any, was limited. By this time, all has changed, today we can make use of very efficient computers in many ways. The size of a program is today of less importance and computer speed has increased so impressively that we can obtain results within seconds for which we needed to wait hours or days twenty years ago. In former times programs were small. Bigger problems could be handled by successive programs, but at each step the data had to be transferred, manually by cards or tapes. But these data could be changed and supplemented very easily. Today we live with complex chains of programs or systems of programs, but an interference during the run is nearly impossible, unless we run an interactive program. This means, that at the beginning of a run we have to know and to define all the data needed throughout the run. This means too, that when designing and developing a program, we must think of all the possibilities the program will have to handle in the future. Subsequent changes and extensions of program systems become more and more expensive, even if the program is divided into small modules with well defined interfaces. Testing of an extended complex program system becomes more expensive as not only the extension itself has to be tested, but we must also prove that the original program remains effective with the extension. If you have a complex program in your computer centre, you need at least one person, who is familiar with the program and who can give advice on how it should be used. He will only keep this capability if he is continually concerned with the program and can make use of it. But in your computer centre you will have not just one, but many complex programs. Today there are many finite element programs, but there is no ideal "super finite element program" which can handle all known or unknown problems. So we have to live with a multitude of programs for use in connection with shells, tunnels, drilled piles etc. In brief: compared with the situation twenty years ago, design and maintenance of software has become very expensive.
We should take into account another fact: in civil engineering we have no mass production. The cost of design and construction must be seen in relation to the cost of the entire building. The cost of construction and computation cannot be spread over hundreds or millions of identical articles. It is not a good use of a computer to carry out excessive calculations of apparently great accuracy if by doing so you can save only a fraction of the computer cost. Certainly it is no accident that the applications of finite elements are mostly reported by designers and manufacturers of machines, cars, trucks, aircraft etc.
It is with this background in mind that we must consider the following recommendations for education in data processing.

2. GENERAL RECOMMENDATIONS

The recommendations presented here are influenced by my own experience and by the experience and requirements of other big construction firms in the Federal Republic of Germany. I must describe them only as wishes, not demands, because the list is very long and I doubt whether all of them can be achieved through study at a technical university or similar institution. Universities are always faced with the conflict between growth of knowledge and the limited time which is available to teach it. Some aspects of education in data processing must undoubtedly be left for the time after studies at the university are completed. But the task of the universities should be seen as giving students the best possible attitude of mind towards the use of computers. In day-to-day professional work, we need people who can use electronic data processing in an intelligent and critical way. An engineer must be aware that a computer is a splendid tool to help him do his job but it must remain only a tool and should not become an end in itself. Anybody who has ever developed programs knows how fascinating this activity is, and that there is the danger of becomming addicted to it and wasting time and effort over making a program "better and better".

3. THE STAGES OF EDUCATION

The education in data processing must be divided into basic and advanced education.

3.1 Basic education

The objective of basic education in data processing must be to make the student conscious of the possibilities and the limitations of computers. He must be put in a position to work with existing programs, to evaluate their results critically, and to write small subsidiary or supplementary programs himself.

3.1.1 Learning a programming language

The student must be trained in a computer language. Since FORTRAN is the main language in technology, instruction in that language is preferable. But programming must not be confined to the beginning of his studies. It is not until his later years, when he has obtained more professional knowledge, that the student can work up to a project of practical use.

3.1.2 The Structure and operation of a computer

For the utilisation of computers it is desirable to have a basic understanding of the structure of a computer, how it operates, and its capabilities. True, today computers are like cars and one can drive a car without knowing how the engine functions. When something goes wrong, however, it is an advantage to know more about a computer. The same, is true for the components of an operating system, as far as is needed for the writing of individual small programs. Examples are:

The big machine in the computer centre
A terminal at the place of work
A small computer
Personal computer
Graphic display unit
Plotter
Digitizer

3.1.3 Types of program operation

According to the type and size of a computer, there are different varieties of program operation. Examples are: batch operation; time-sharing with the possibility of interactive operation; remote data processing.

3.1.4 The application of computers in civil engineering

The application of computers is tending to increase in all areas of a construction company. The number of civil engineers who are concerned with the development of new programs will remain small, but all engineers will come into contact with computers in one way or another. They will have to work with programs which others have developed. This involves the ability to read a program description (in the television age this ability cannot be assumed!). The user must learn to make judgements on:

What can the program accomplish?
What can the program not accomplish?

He must remain critical and ask:

How can I check the working of a program?
(coordinate transformation, rotation, reflection)
How can I check the results in a particular case?
(equilibrium conditions on a single element or global cross-sections, compatability conditions between internal forces and displacements.)

3.1.5 Finite elements

Finite element methods are being employed more and more frequently for computations; these require a specially critical attitude on the part of the user. An engineer should become familiar with the fundamentals and the limitations of certain classes of finite elements but in his basic education he does not need to know how to design new elements. Much more important, for the user, are questions regarding the ways in which accuracy depends on the network structure, the number of elements, and so on. Particularly important is the question of controlling a finite element computation, for the worst control is the attitude "You don't need to control finite element calculations, you can just believe in them".

3.1.6 The economics of computer applications

As was mentioned in the introduction, the economics of computation are highly significant in engineering practice. In universities and similar institutions, one encounters mostly very large, fast computers, and computing costs are relatively unimportant. In practical life, an engineer must be prepared to recognise that unlimited computer capacity may not be available and that a price-tag must be attached to the use of computer time. He must also learn to see the cost of computer use in relation to the overall cost of design, construction and calculation.
The user must evaluate:

Does the aim of the calculation (preliminary calculation, execution, control) justify the application of an expensive program?
Does the accuracy of the initial data justify the use of a "more accurate" calculation procedure?
Will high computation costs be compensated by higher savings?

3.2 More advanced education

The higher stages of education should put the engineer in a position to develop programs independently, from the analysis of the problem to the actual programming. He must be able to make himself familiar with existing programs, to eliminate errors from them, and to carry out modifications and extensions to them. We must strengthen and develop the studies which we have mentioned at the fundamental level. The following areas of knowledge are particularly important:

3.2.1 Mathematical methods

The most important matter here is to recognise the conditions under which existing mathematical methods can be used. A civil engineer does not have to solve mathematical problems, but has to use mathematical techniques correctly in solving his engineering problems:

Matrix caclulus (including the solution of small or large systems of linear equations)
Iterative procedures (criteria for terminating an iteration, from various points of view)
Optimization techniques
Numerical solution of differential equations

3.2.2 More advanced programming

The difficulties in constructing a program increase with the degree of complexity of that program. One has to consider all the aspects of what is now called Software Engineering.

Structured programming
Structure of data flow
Breaking down a large program into small modules
Incorporation of modules into other programs

Today, we can only think about the coupling of programming systems after satisfactory specification of interfaces for data.
Consequently, it is desirable to give students also an introduction to data management and data banks. The increasing practical importance of graphical representation of data must be brought home students by means of an introduction to graphical software and CAD systems. Furthermore, increasing use in applications of interactive processing requires that a programmer should be familiar with this technique.
The quality of a program depends, moreover, on its compatibility and portability with respect to interchange of hardware and operating system software. Hence our aim must be to use the language only in a standard form. "Clever" programming may be great fun for programmer but it can have disastrous consequences in routine usage.

3.2.3 Documentation

A piece of software is only as good as its documentation. Since the expense of documentation is often as high as that of developing the program itself, documentation is often neglected. In universities, programs are developed under the time pressure of writing the Diploma thesis, and consequently the process of documentation does not receive proper consideration.

3.2.4 Program development

Misunderstanding and confusion between programmers and their customers is mostly caused by insufficient and imprecise program specification. The student must therefore be made to realize that good programming depends on a continuing dialogue between programmers and customers.

4. INFORMATION PROCESSING AND CIVIL ENGINEERING

The recruitment of mathematicians into the construction industry has often led to disappointment on both sides, caused by differences in professional attitude. The engineer is wanting results, often under pressure of time. If the results are consistent with his previous experience, and can be verified by an independent calculation, then he will accept them. By contrast the mathematician sees his task as that of theoretically guaranteeing the existence of a solution. The result is a communication gap. Some of the mathematician's procedures are familiar to the engineer, but under other names. It often takes a long time to get on the same wavelength.

If a computer scientist is to be successfully active in the construction industry, he has to be very clear that to an engineer it is the end result of the program which matters most. He is not free to regard the program as a work of art, which regrettably must be contaminated by contact with the outside world through input and output. Being introduced to actual engineering work should help to give the programmer an appreciation of the opposite point of view.

5. RESEARCH AND FINITE ELEMENTS

Young engineers often come out of university with the impression that the only point which needs to be justified is the actual use of a finite element program. Then they are very disappointed when they hear that in daily practice finite element applications form only a fraction of all applications. I regard this kind of education as inadequate. A finite element method is still just an approximation procedure, even though it is a very good one. The use of finite elements is necessary where higher accuracy is required and there is no other computational procedure available. But it is wrong to use a finite element program on every conceivable problem, just on principle. This applies particularly in cases where we have no guarantee of the accuracy of the input data to a calculation process. In spite of that, such results are often called "exact". In the situation where initial data may have a probabilistic distribution, we have to make an extensive study of the parameters before we can devise a simple computational procedure, for example, in construction of foundations or of tunnels.

6. CONCLUSION

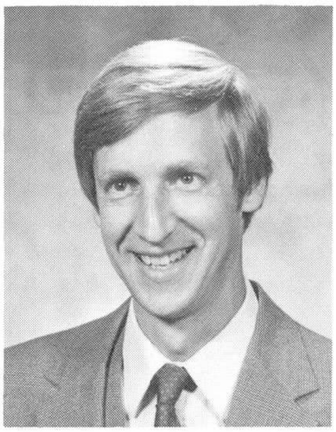
Our list of "wants" is extensive and long. For education, the important thing is to develop a critical attitude towards the use of computers. The computer will in future be employed more and more as an efficient tool in the construction industry. The objective, however, must not be "use the computer whenever you can, no matter how much it costs" but "use the computer whenever it is professionally necessary and justified".

Using the Computer to Teach

Utilisation de l'ordinateur dans l'enseignement

Ausbildung mit dem Computer

Randall W. SCHNEIDER
Ph. D.
McDonnell Automation Co.
St. Louis, MO, USA



Randall W. Schneider, born 1941, earned his graduate degrees from Southern Illinois University and St. Louis University. He taught mathematics at the high school level for seventeen years and has recently joined MCAUTO with responsibilities in computer based training.

SUMMARY

Industrial trainers have only recently discovered a new training medium – the computer. As compared to existing training methods, computer based training has the functional capabilities to fulfill most instructional needs. Engineers and engineering firms can use the computer based training approach in some conventional and some unconventional ways.

RESUME

Les maîtres d'apprentissage de l'industrie ont découvert récemment un nouveau moyen de formation: l'ordinateur. Comparé aux méthodes existantes, l'enseignement assisté par ordinateur remplit la majorité des fonctions nécessaires. Les ingénieurs et les entreprises peuvent faire usage de l'ordinateur comme support d'un enseignement traditionnel ou suivre des voies nouvelles.

ZUSAMMENFASSUNG

Ausbildner in der Industrie haben neuerdings den Computer als Ausbildungsmittel entdeckt. Mit existierenden Ausbildungsmethoden verglichen, hat eine auf Computer gestützte Ausbildung die zweckmässigen Fähigkeiten, die meisten Unterrichtsanforderungen zu erfüllen. Ingenieure und Ingenieurunternehmen können die auf dem Computer basierende Ausbildung auf verschiedene konventionelle und unkonventionelle Arten einsetzen.

1. INTRODUCTION

This is the age of Future Shock! The veritable wealth of new knowledge which inundates the civilized world daily is truly staggering. Even more difficult to comprehend is the technical nature of these new developments. It is said that the early nineteenth century German mathematician, Karl Frederich Gauss, was the last person to understand all mathematics. No mathematician in the last 150 years, no matter how great, can equal this accomplishment. Today, we are in the age of specialization. The true authority is one who thoroughly knows but one small area. With each succeeding year, that small area becomes smaller and smaller.

One of the most exciting aspects of any technical-base industry like structural engineering or computer science is its dynamism. The application of computer assisted design to the structural engineering environment, the added analysis capabilities of the high speed main frame, and the increased availability of terminals brought about by declining hardware costs have but whetted the appetite for what could be. Industrial trainers view these developments with awe. They have increased responsibility for providing training on these new developments.

2. THE INDUSTRIAL TRAINING DILEMMA

2.1 A Perspective

One of the characteristics of research methodology when confronted with a new problem is to step back and look at the problem in perspective. Has anything been done in the past which could help in the solution? Into what larger arena does the new problem fit? With the advent of the wide spread use of computer based training, it is valid to look at training in general and computer based training specifically.

2.2 The Dilemma - Part 1

The duty of the industrial trainer is becoming more and more difficult to fulfill. Management has put both time and monetary constraints on the training process. The research and development community through its work continually adds new material to be taught. Therefore, to answer the questions, "How should this new discipline be taught?" and "What new techniques are available to use to teach?", it is reasonable to do a brief analysis of present instructional methodology.

2.3 The Dilemma - Part 2

The cost of training is becoming expensive. Each hour that an employee is off a job or project costs the company. Therefore, it is most important that the time involved in training be kept to a minimum. Consequently, training time must be used efficiently. No time should be wasted on what is already known or on "nice to know" topics. Training should involve a carefully designed and directed set of learning activities for the express purpose of assisting a specific set of people to learn to do a specific task. The college classroom or the conference paper is the vehicle for educating, but not for training. Training is very task-oriented. Time is money! Trainers should not waste it.

3. TRAINING METHODS

3.1 The Tutorial

A variety of training methods have been used during the past few thousand years. Research has shown, time and time again, that the tutorial method--one teacher and one student--produces subject matter mastery at the highest level. It is a very common method for training entry level personnel. "You sit next to me and watch what I do. If you have any questions, just ask!" Unfortunately, this method is not very cost-effective. The efficiency of the trainer is decreased by this interruption in his daily work and the trainee does not "produce" during this period. The tutorial method is also 'occurrence oriented'. "When the invoice includes these products, do this." "When the word processor acts this way, the **problem is** . . ." Once the training period is concluded, it is hoped that everything has happened that could happen. The flaws in this assumption are apparent. Contrary to these objections the tutorial method has the advantage of one teacher for one student and the valuable teacher-student interaction.

3.2 The Classroom

A very popular approach to training is the traditional classroom. Using this method, a planned presentation by one teacher is given to many students simultaneously. The trainer's time is used more efficiently in that the trainer is reaching many students rather than only one. Rather than the material based on "happenstance", it is normally well-organized. However, the individualized approach benefit of a tutor is greatly diminished. The students are forced into a mold called a class, where the fast learners are held back, and the slow learners learn very little. In addition, the students enter the class with diverse backgrounds. For some, the instruction will be a review and for others it will be too advanced. The trainer can compensate for this by altering the instructional plans. This causes problems with the class schedule as only a given amount of time is usually available for a course. Normally, certain topics are neglected in favor of others. Thus, each class does not receive the same material and the students are not fully prepared to meet all on-the-job problems. One other concern with the traditional classroom approach is the absence of a number of people from their jobs for an extended period. Few jobs enable a worker to be away for such a long time.

3.3 The Multi-media Approach

Another very common training method is called the multi-media approach. The subject matter is relayed to the student through any of a variety of instructional materials--books, audio-tapes, video-tapes. A major advantage is that a subject matter expert, not a trainer, is presenting the material. Often, these materials are written by the pre-eminent authority in the field. (This is much akin to the one-to-one of the tutorial method.) Also, the student can learn at his own pace. Students can reread a book or see a video tape a second or third time. Remember, the term "slow learner" implies that learning occurs at a slower rate, not that it doesn't happen at all. However, this method does have a few drawbacks. Even with the self-paced approach, some of the material could be of the time-wasting review type or some could be too advanced for the learner. In either case, a minimum of learning takes place. A major fault is the lack of student-trainer interaction. Much learning takes place through questions and answers.

3.4 Conclusion

In summary, the traditional training methods of the tutor, the classroom, and the book or movie, each have advantages but also glaring disadvantages. What is needed is a training scheme which possesses the one-teacher-one-student technique of the tutorial, the planned organized presentation and student-teacher interaction of the classroom, and the authority-written self-paced mode of the multi-media approach. A classic quote in education and in training is:

> "Those of us in training/education are teaching people who are going to spend most of their working lives in the 21st century. We are training them in the 20th centruy. And most of the time we are using 17th century methods!"

4. COMPUTER BASED TRAINING

4.1 Definitions

A truly 21st century mode of training is Computer Based Training. CBT, CAI, CAL, and CMI are just some of the acronyms used in discussing this training method. CAI (Computer Assisted Instruction) and CAL (Computer Assisted Learning) refer to the actual teaching and learning process. CMI (Computer Managed Instruction) normally pertains to the administrative function. A good CMI system will register students, keep track of student course completions (both passing and failures), store data regarding which students completed which courses, and update student personnel records. CBT (computer Based Training) is an inclusive term which encompasses CAI and CMI. As a point of information, it is possible to have a CAI system without CMI, and likewise a CMI system without CAI.

4.2 A Description of CAI

A typical CAI session would be initiated by the student logging on a terminal. The CMI system would then send the proper course to the terminal; that is, the course for which the student was registered. Most CAI courses are designed to determine, first of all, the baseline knowledge of the student. This is accomplished through a series of questions. The student is then branched to the course material which he needs to learn. Following the instruction, a number of questions will be asked to determine subject mastery. If the student shows mastery, he is then presented with the next segment of material. However, if too many questions are answered incorrectly, the student will be presented with more instruction on the same material. This could be a re-presentation of already seen instruction or it could be the same course material, but presented in a different way. Following this review, questions would again be asked to determine mastery. This sequence of pre-test, course material, post-test, review if needed, post-test, is repeated as the student proceeds through the course.

4.3 The Advantages of CAI

4.3.1 CAI and the Tutorial

CAI has the one-teacher-one-student aspect of the tutorial method. The instruction is individualized, meeting each student's needs. Ten students could go through a course. Each could receive a different order and amount of material. Each would attain subject matter mastery. And each would proceed at his own pace finishing in a different amount of time. For the slower student, it must be remembered that the computer has infinite patience.

4.3.2 CAI and the Classroom

CAI has the student interation found in many classrooms. Students are forced to take an active part in the learning process. They cannot "sit in front of the CRT and sleep." Student responses to questions receive immediate feedback. Correct answers are given positive reinforcement and incorrect answers receive hints which lead to the correct answers.

4.4 A CBT System

4.4.1 CAI Course Authoring

CAI courses can be and should be writeen by subject matter experts just like a book or a video-tape. These courses come from two sources: outside commercial suppliers and in-house written training materials. While many good commercial CAI courses exist, many organizations find they need training materials for their own unique situation. Commercially written materials are probably not available to meet these specific needs. An alternative to having training materials specifically created by a vendor is to create the desired material within the organization.

Such a system should include an authoring approach which is easy to learn. Course writers should be able to write in their native tongue and not some programming language. Engineers, chemists business executives, or scientists should be able to write CAI courses and in the vernacular. The authoring system **should** be easy to use so that modifications can be made without too much difficulty.

Also included should be multi-colored text and graphic capabilities. The use of color can enhance displays and can direct the student's attention to the salient points. Graphics can be very useful in explanations. Remember, "a picture is worth a thousand words."

A necessary feature is text and graphic displays based on student input. A key feature of CAI is individualized learning. CAI is not a programmed text. It is closer to an interactive slide presentation. This feature is vital.

Course evaluation becomes easier with data collection facilities. The author should have at his disposal the ability to collect data such as student responses to questions, the amount of time spent per screen display, and the number of students who decided to take a particular branch. This data will aid the author as he revises his course.

4.4.2 Summary

Thus, CAI possesses the positive attributes of the tutorial, the traditional classroom, and the written presentation. In addition, and of utmost importance, CAI fits the needs of the industrial training environment. A student can take a course at his convenience. He is not tied to a classroom schedule. Courses can be taken during the work day, after work, or on weekends. The computer doesn't mind working overtime. Students may not have to leave their work area to take a course. Many can learn at their own desks. As a course is taken, the CMI system will record student performance. Supervisors can easily learn who took which courses and how long it took (an excellent evaluation tool). Psychologically, CAI is a very personal form of learning. The computer will not laugh at wrong answers or ridicule incorrect responses. CAI will consistently deliver a high quality presentation designed to meet the individual students' learning needs. It has been shown to reduce training time by up to 40 per cent over other methods and with a higher level of subject mastery.

5. CBT AND ENGINEERING

5.1 Engineer Training

Hardware and software developers can train engineers in the latest technological enhancements. Training by developers is normally done in two ways: 1-developers come to engineers, 2-engineers come to developers. In many instances, either involves being away from the job for an extended period of time. CAI can remedy this problem. Developers can produce CAI lessons, put them on magnetic tape or disks, and send them to the engineers. Engineers can then, at their leisure, take the training without the extended absence.

5.2 Employee Training

Within a company, employees can be trained in new developments, techniques, and procedures with CBT. When the new accounting procedure is inaugurated or when that program has been company enhanced and the changes need to be disseminated, CAI will do the job in less time and with greater mastery. Also, employee skills can be upgraded. CAI courses are available in improving writing techniques, spelling, management topics, programming languages, system procedures, and many others.

5.3 Client Training

One of the newest areas in which CBT has been used is in client training. A standardized CAI presentation can serve as an introduction to the products and services of a particular company. A well-written CAI course on each product and

service can be taken by the client at his leisure and at his own pace. If such a **presentation** is well done, it can save many employee hours.

5.4 Problem Simulation

5.4.1 Problem Solving

What do engineers do? The two words that in the most general sense describe the field of engineering are "problem solving". The major tasks of building bridges, sending men into space, of finding a better bonding agent are really problems to be solved. Some tasks involve more problems than others. Some tasks require more problem solvers than others. But, in its most basic unit, engineering is one-man-one-problem.

5.4.2 CBT and Problem Solving

Computer Based Training though still in its infancy has reached such a high level that it can simulate problem solving situations. The problem solver can practice his art in a realistic but non-threatening situation. What can be simulated? It is possible to simulate almost anything that can be described and displayed in words and pictures. The operation of the Inertial Navigation System of a DC-10 from start-up to shut-down and the engine start-up procedures for an F-18 have been simulated. A problem-solving situation can be displayed, the student can be given an option as to how to solve the problem, and the results of that decision can be displayed. All displays are in both text and pictures. This concept of a simulation definition editor is less than six-months old, and thus, its prospects are still in the developmental stage.

6. CONCLUSION

If one were to study the literature or look at conference agendas, one would see that computer based training is the one concept that is disucssed above all others. Then look at the past history of new ideas as written in the literature or discussed at conferences. Within the next ten years, if the usual pattern is followed, CBT will be the preeminent training method. It offers to the industrial training environment the best of all worlds. It has the one-teacher-one-student interaction of the tutorial, the planned presentation advantage of the classroom, and the authority-written self-paced mode of the multi-media approach. Management likes it because it saves them training time and money. Computer Based Training will become the training method of the 1980's.

Post Script:

Your attention is directed to the last sentence of the conclusion and to the second paragraph of the introduction. Those who work on the development side of Computer Based Training and its technology are already looking into the 1990's and beyond. At present, the staggering implications of the interactive video disk with text, video, and audio capabilities are moving from the day-dreaming stage to the drawing board. The imagination is considering the micro-processor and the miniaturization of television receiver. The 1990's will bring an improved cost effective, time efficient, and advanced instructional device for industrial training. The name of this new mode of instruction will be discussed at some conference or in some professional journal in the late 1980's.

Computers in the Education of Structural Engineers

Rôle de l'ordinateur dans la formation des ingénieurs

Computer in der Ausbildung des Bauingenieurs

A. R. CUSENS
Head, Dep. of Civil Eng.
University of Leeds
Leeds, England

Before going to Leeds in 1979, Tony Cusens was Professor at the University of Dundee for 13 years. He is a consultant to Posford Pavry and Partners, Peterborough, U.K. and his main research field is concrete structures, especially bridges. He is Vice-Chairman of the IABSE Working Commission on Informatics in Structural Engineering.

SUMMARY
The paper discusses the nature of the training in structural analysis and design now required for engineering students in the light of the computerised procedures they will meet in professional practice. Greater emphasis on qualitative approaches and approximate techniques is urged with less emphasis on classical mathematics. The value of the micro-computer in design teaching is stressed.

RESUME
Le rapport se penche sur le type de formation portant sur la conception et l'analyse des structures à offrir actuellement aux étudiants en génie civil, compte tenu du degré d'informatisation qu'ils rencontrent dans leur pratique professionnelle. L'accent devrait être mis, sans délai, sur les approches qualitatives et les techniques d'approximation et de contrôle, au détriment des mathématiques classiques. De plus, il est fait mention des avantages qu'il est possible d'obtenir des micro-ordinateurs dans l'enseignement du dessin.

ZUSAMMENFASSUNG
Dieser Bericht behandelt die Art der Ausbildung in Festigkeitsberechnungen und Entwurf auf dem Computer, die bei den Ingenieurstudenten jetzt erforderlich ist, so wie sie es später in der Praxis antreffen werden. Grösseres Gewicht wird auf qualitative Methoden und Näherungsverfahren gelegt, mit dafür schwächerer Betonung der klassischen Mathematik. Der Wert des Micro-Computers in der Entwurfsausbildung wird verstärkt.

INTRODUCTION

The advent of the computer age has led to the virtual elimination of much of the tedium and burden of detailed calculations for complex structures. Shute[1] records that the stress analysis for the airship R100 required a period of intense work lasting 2 years. The calculations for the Sydney Harbour Bridge occupied a similar period of time. Today a few days of work would encompass the same volume of calculation.

In the preparation of drawings for structural projects the cost of the human effort needed to produce a high quality of detailing has led to a simplification and a deterioration in standard during this century. The development of hardware and software for Computer-Aided Drawing is now leading to a dramatic revolution in this field. New computer graphics systems are capable of producing accurate design drawings with the involvement of the structural engineer in an interactive role.

The problem that arises for the structural engineer who is responsible for the teaching in universities and polytechnics of the engineers of tomorrow is how to prepare these young men and women for the working situation they will encounter. Every structural design office, however small, will have its own micro-computer with a capacity superior to that available on most mainframe computers of a decade ago. There is some debate over the nature of the software to be developed for the micro-computer: Bell[2] maintains that most small design offices will merely computerise long-hand calculations but others, e.g. Collington and Adey[3] are proposing more sophisticated interactive systems. The author predicts a mixture of both approaches, but irrespective of approach several questions can be posed:

1. Is the rigorous and classical mathematical training given to engineering students now an anachronism?
2. Are the current courses in structural analysis appropriate? What new aspects of structural teaching should be incorporated?
3. What approach should be made to structural design?

This paper attempts a brief discussion of these questions and thus provides a commentary on the future teaching of structural engineers in the universities and polytechnics.

MATHEMATICAL TRAINING

In 1965, the Organisation for Economic Co-operation and Development held a Seminar on the Mathematical Education of Engineers and the resulting report[4] provided a core curriculum for all engineers together with specific advice about specialist areas such as civil and structural engineering. It is interesting to note reference on the first page of the report to the need for further discussion on consideration to be "given to the ways of introducing computer science into the education of engineers" and to an American project on the effect of computer science on engineering education.

With the increasing use of numerical techniques in the computer-based solutions of engineering problems it is obviously open to question whether the concentration and depth of effort spent, for example, on the direct solution of differential equations is now necessary for the majority of engineering students. On the other hand subjects such as matrix analysis and numerical analysis have taken on an increased significance. There is a case for a new look at the mathematical content of engineering courses in all countries of the world and this would be welcomed not only by engineering teachers but also by engineering students who are increasingly challenging the relevance of their mathematical curriculum.

STRUCTURAL ANALYSIS

In most countries there has been a substantial change of approach in the teaching of structural analysis with a greater emphasis on the application of matrix techniques to flexibility and stiffness methods. The classical structural equations are still covered together with topics such as moment distribution and influence lines which are essentially long-hand approaches.

It is more than ever vitally important that students develop an instinctive understanding of structural behaviour and an ability to make simple checks of the complex structural calculations carried out by the computer. Long before the computer age, Nervi[5] regretted that "some of the highest qualities of the human mind, such as intuition and understanding, have been overwhelmed by abstract and impersonal mathematical formulae". In a recent paper, Brohn[6] suggests the introduction of a new philosophy to shift the emphasis from a predominantly quantitative approach to a predominantly qualitative approach and to reduce the time spent on numerical methods. An earlier paper by Brohn and Cowan[7] provides some illustrations of this form of qualitative approach. Figure 1 shows part of a test paper designed to examine the understanding by engineering graduates of structural behaviour. For each of the structures the candidate is asked to sketch the shape of the bending moment diagram. On the basis of the results of this type of test set for various groups of senior students and young engineers it was concluded that, in general, they lacked qualitative skill and did not have a sound understanding of structural behaviour.

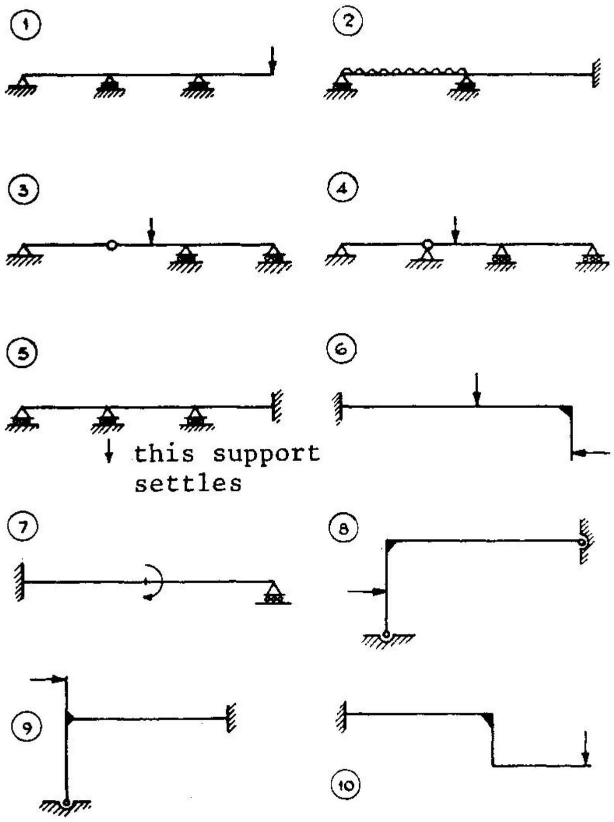


Fig. 1: Part of test paper devised by Brohn and Cowan[7]

In the author's view the current need in the teaching of structural analysis is to lay stress on the qualitative approach as an essential preliminary to quantitative processes. It is of comparatively little use in design if an engineer can picture the shapes of deflection, shearing force or bending moment diagrams but is unable to find the actual values of these parameters. Thus Brohn's recommended "new philosophy" may evoke expressions of sympathy, but eventually an understanding of numerical methods and an ability to obtain numerical answers must predominate. However it is clear that the teachers of structural engineering must *ab initio* spend time on the qualitative aspects to instil an understanding of structural behaviour, before plunging their students into the mathematical techniques of analysis.

STRUCTURAL DESIGN

For many years it has been difficult to teach structural design either from the exposition of principles or as a creative process. The elaborate and detailed clauses in national and international codes of practice may be helpful to experienced designers (although that statement is open to doubt), but they greatly obscure the procedures of design for the engineering student. Moreover, the students' limited capability in analysis often inhibits a proper choice of structural form.

Here the micro-computer can be used as a valuable teaching aid - to eliminate much of the tedious detail of both the analysis and the codes of practice. This leaves the student free to make design decisions and to appreciate the effects of such decisions upon structural forms. However successful application of this technique calls for the availability of interactive programs for the micro-computer. Such programs permit rapid generation and modification of data for elastic or elastic-plastic analysis and the incorporation of relevant sections from the code of practice. Students interact with the computer at appropriate stages where decisions are required and they are expected to verify analyses by applying approximate numerical checks. In their design submissions they must also justify decisions made in the use of the program.

To take a single example, the design of a single continuous (multi-span) reinforced concrete beam may be a small element of a design project but it is a time-consuming task for an engineering student. Use of a simple program which will tackle the routine calculations, such as that illustrated in the flow chart in Fig. 2, enables the student to see the effects of different loading cases and, in seconds rather than hours, to see the envelopes of maximum bending moment and shear force, redistribute peak values as appropriate and then to position reinforcing steel.

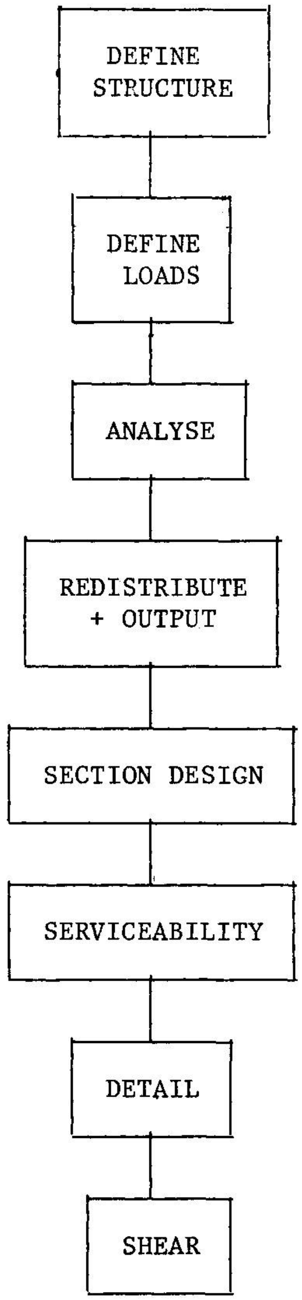


Fig. 2: Flow chart of design of continuous reinforced concrete beam (from the DECIDE system; Beeby[8])

CONCLUSIONS

The now almost universal availability of the computer in structural design offices must be reflected in the direction of education of students of civil and structural engineering. The following are suggested as essential components of structural courses in universities and polytechnics.

- greater emphasis on qualitative approaches to structural analysis to increase understanding of the behaviour of structures
- development of skills in approximate techniques of structural analysis to allow rapid checks of equilibrium
- less emphasis on classical mathematics
- use of interactive design programs in micro-computers in teaching, to eliminate tedious code details and complex analyses and to enable students to concentrate upon design decisions.

REFERENCES

[1] Shute, N.: Slide Rule, Heinemann, 1951.

[2] Bell, W.J.: The role of micro-computers in civil and structural engineering. Proc. 2nd Intl. Conf. on Engineering Software, London, March 1981, pp. 852-861, CML Publications.

[3] Collington, D.J. and Adey, R.A.: Integrated engineering system for small computers. Ibid., pp. 806-818.

[4] OECD: Mathematical education of engineers. Report of Seminar, Paris, 1965, Organisation for Economic Co-operation and Development, 1965.

[5] Nervi, P.L.: Structures. Dodge Corporation, 1956.

[6] Brohn, D.M.: Structural engineering - a change in philosophy. Structural Engineer, 60A, 4, April 1982, pp. 117-120.

[7] Brohn, D.M. and Cowan, J.: Teaching towards an improved understanding of structural behaviour. Structural Engineer, 55, 1, January 1977, pp. 9-17.

[8] Beeby, A.W.: Reinforced concrete design calculations using small computers - DECIDE. Structural Engineer, 56A, 10, October 1978, pp. 287-289.

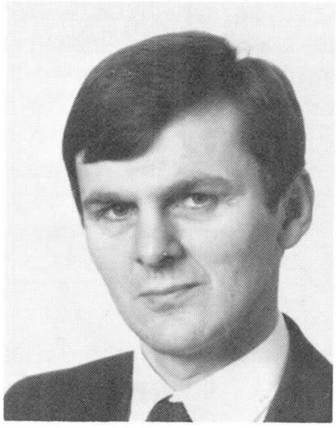
Leere Seite
Blank page
Page vide

On Structural Computing in Education

Le calcul des structures par ordinateur dans l'enseignement

Festigkeitsberechnungen in der Ausbildung

Johan BLAAUWENDRAAD
Prof. of structural mechanics
Rijkswaterstaat-Bouwresearch
Utrecht, the Netherlands



Born in 1940. Degree of civil engineer at Delft University of Technology in 1962. In research until 1970. Moved to Structural data processing at Rijkswaterstaat (State Public Works). Since 1981 head of Bouwresearch, division of Rijkswaterstaat for structural research. Part-time appointed at Delft University since 1979. Joint interest in FEM and CAD.

SUMMARY
Developments in the hardware and software industry are reviewed briefly, and some limitations in education are discussed. Essentials in present-day structural computation are listed and then expanded. A number of aspects are dealt with in more depth. The usefulness of engineering differential equations is stated, and misunderstandings in FEM in education are exposed. This design tool can already be introduced in lower training levels, and major emphasis must be put on the managing and validation of results.

RESUME
L'article donne un bref résumé des développements réalisés par les industries du matériel informatique et dus logiciel. Les aspects principaux de l'analyse des structures par ordinateur sont recensés et certains d'entre eux traités avec plus de détails. L'utilité, pour l'ingénieur, du recours aux équations différentielles est relevée ainsi que divers malentendus relatifs au rôle des éléments finis dans l'enseignement. Cette méthode peut être introduite dès le début du cycle de formation mais un accent tout particulier doit être mis sur les procédures de contrôle et de validation des résultats.

ZUSAMMENFASSUNG
Entwicklungen in der Hardware- und Software-Industrie werden kurz zusammengefasst und Beschränkungen im Unterricht werden erörtert. Wichtige Aspekte der heutigen elektronischen Strukturanalyse werden genannt und erläutert. Einige Gesichtspunkte werden ausführlicher behandelt. Der Nutzen von Differentialgleichungen für den Ingenieur wird dargelegt und Missverständnisse in der Ausbildung über die finite Element-Methode werden aufgedeckt. Dieses Entwurfswerkzeug kann schon bei einem niedrigen Ausbildungsstand eingesetzt werden; die Kontrolle der Ergebnisse soll aber sehr betont werden.

1. PROBLEM STATEMENT

The training of a structural engineer consists of many subjects. Roughly speaking, we distinguish courses which are directed to construction and courses which are connected with design. In this paper we stick to the latter. But even this clear-cut part of the engineer's education is too divers to discuss it in general terms. Therefore we introduce the distinction between two types of structural engineers in the design profession. On the one hand we have design where the (all-round) designer executes all necessary analysis himself, and on the other hand a situation of specialization in which a designer is closely cooperating with a structural analyst who specialized himself in structural computation. The all-round designer will normally be found in smaller design offices and may execute rather common design tasks, whereas the specialized team of a designer and a structural analyst will rather be seen in bigger companies, executing more advanced and less routineous jobs. Taking it roughly, the education in structural computation can be the same for the allround designer and the specialized designer. We will call this allround computing. On the contrary the training of a structural analyst is a chapter by itself. This we will call specialized computing.

The paper tries to trace which parallel developments occur in respect of the use of computers. Noticing several changes we have occasion to question whether or not nowadays ways of computerized computing may be commuted for new ways of computing in the near future. Or we may conclude that trends who are already going, may be strengthened in the future.

2. PARALLEL DEVELOPMENTS

As for the hardware we have seen a development which started with a series of generations of main frames, roughly 25 years ago. At first these computers only have been used in a batch mode, but later on also conversational modes became possible. The introduction of minicomputers has been a big step forward. The nowadays (super)minis are even more powerful than earlier mainframes. And in combination with array processing facilities minis even exceed the facilities of nowadays main-frames. Meanwhile also graphics hardware developed rapidly. Black and white screens are since long time common practise and color screens fastly invade the design profession. Finally the large scale integration (LSI) chips resulted in micro computers which yield a new almost revolutionary situation. Together with new disc facilities (winchester drives) such micro's appear to become design and analysis tools which are easily within reach of small design units, and which introduce advanced programs in user environments which untill now could not think of intensive computerized analysis. And very large integration scale (VLSI) chips are coming right now!

As for the software development a simultaneous evolution has been noticed. In old times all types of separate monolytical non-structured programs came into being. At a later stage chains of programs were introduced as well as the concept of integrated program(ming) systems. User oriented languages and problem oriented languages have been proposed to match the typical hardware shortcomings at the time. Recently all accent is put to what is called engineering working stations. The rigidity which still has been annex to the integrated systems is rapidly releasing by these new design and analysis facilities, offering the combined comfort of computing, storage and retrieval, and graphics presentation techniques.

Parallelly to the already mentioned developments in hardware and software an evolution in applications was seen. Everybody started in early times with programs for trusses and frames, and moved in time to finite element programs. Later on the handling of input and output could get more attention, such that now a total new industry in pre- and postprocessing has appeared to come in being. In fact an integration of hardware and software is becoming possible which connects the fields of computer aided design (CAD) and computer aided manufacturing (CAM), which makes us to use a new slogan, computer aided engineering (CAE). Also CAD and FEM relate to each other progressively more.

Lastly, the author believes that a fourth parallel line will come through more and more. The trend is showing that emphasis is shifting from writing one's own programs to the use of already available programs.

3. BOUNDARY CONDITIONS

Education on the use of computers in structural engineering in the eighties is subject to some serious constraints. First of all the recession in western society puts limits on budgets which have not been known to this extent since long times. Reduced finances result in decreased possibilities to purchase present-days hardware. For the same reason there is high pressure to change the student teacher ratio such that a higher number of students has to be served by one teacher.
Furtheron we must bear in mind that analysis is not the only subject which has to be teached. In fact we want to introduce in a very general way the concept of computer aided engineering. That is to say, the students have to train the use of a working station environment, including new ways of drafting, presenting results and storing or retrieving data. This will put many more calls on the available time, and above that so many other important subject matters ask for their part in the curriculum. This is especially a big problem in universities where no special structural engineering department exists, but in stead of that structural engineering is a specific choice within a civil engineering department. And civil engineering is by nature of much broader spectrum, which almost necessarily reduces depth in structural engineering skill.

4. ESSENTIALS OF COMPUTING EDUCATION

How should a course in allround computing be composed? In universities which distinguish between undergraduates and graduates, this training is a matter for undergraduates. Essentials of this education are:
- To impart to the student basic understanding of structural behaviour.
- Fair knowledge of matrix methods for trusses and framed structures (stiffness method and flexibility method).
- A primer to the finite element method (only stiffness method).
- Emphasis to handle existing programs, and skill to integrate them in the design proces.
- A wide training in the skill to interpret results and to check their validity.

Specialized computing in structural engineering education adds to the above already mentioned essentials a couple of other ones:
- Advanced knowledge of matrix methods in general, and finite element methods in particular.
- The ability to adapt, extend or develop algorithms in structural computation.

These characteristics are typical for graduates. Author believes that still a third category of students is needed, be it only a rather small number. They must combine the above mentioned essentials with the skill of software engineering. It is this group of engineers who extends the library of programs and/or adapts the existing programs.

5. ILLUMINATION OF SOME ESSENTIALS

One can ascertain wide agreement on the necessity first to impart to the student fundamental knowledge about structural behaviour before he should start computerized analysis. This holds both for statics, dynamics and buckling problems. However, what is basic understanding? A lot of misunderstanding still leads an obstinate existence in this respect.
Older colleagues who lecture the design of concrete structures or steel structures may use one or two small typical hand calculation techniques of structural mechanics, sometimes hardly distinguishable from tricks, and are inclined to judge this as basic knowledge of structures. However they can reach a same result when they use a more present-day approach which is better in line with systematics of the stiffness method or the flexibility method. Basic knowledge rather is an aspect regarding the structure and has nothing to do with the method of analysis. Of course, to keep well balanced, we must say alike that lectures on structural mechanics can help a great part to bridge the supposed gap. They must always feel challenged not only to teach the formalisms of the matrix methods, but at the same time to demonstrate how it can be applied by hand for simple calculations in specific practical design circumstances. The one thing needs not exclude the other!

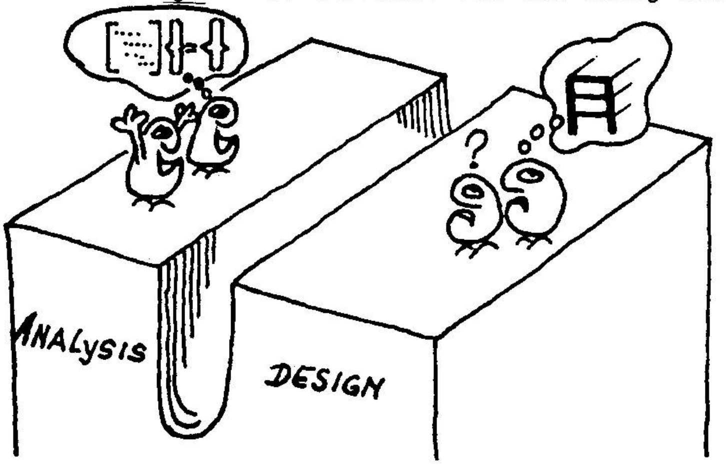


Figure 1.

Lots of possibilities exist for misunderstandings and gaps between classic lecturers in design and present-day teachers of structural analysis.

Basic knowledge is an aspect of the structure, we already said. Therefore the students must get thorough experience in distinguishing and identifying the behaviour of a structure. How is its main way to transfer loads to the supports, and why does it do it this way? Ample training in the use and meaning of moment diagrams and related diagrams is very much needed, and is far more profitable than extensive exercises in the computation itself of such lines. And present-day computer aids progressively more to support this statement.

The more the computer becomes an integrated companion at the engineer's design spot, the more occasion a designer gets to rely on this help.
The fast evolution of the last two years, particularly in the micro market, makes us expect that after a couple of years the computer becomes the personal assistant of the designer. A couple of years implicates that the inflow of students at colleges and universities now, will use this aid as a self-evident mate when they are in the design office later on. Thus, we preferably should get him trained in this way. We are in the advantageous situation that we can instruct a student to execute a considerable number of calculations. The results can be submitted to him immediately in a graphical way, ready for interpretation.
So we have the occasion to confront him with the implications of modifications in his design, and to have him accustom to important types of output. Merely the above mentioned budgetary boundary conditions may be a kill-joy.

Clearly the emphasis should be on interpretation of the output and on validation of the results, casu quo the programs. Still to often one is inclined to believe that results are valid merely because they were achieved by computerized analysis. The enlarged facilities to make many calculations during the education period, offer possibilities to show the student the limits of a program. We can order him to make runs which produce nonsens, and stimulate a critical attitude in this way.

6. ARE DIFFERENTIAL EQUATIONS SUPERFLUOUS?

When we discuss numerical methods in engineering, the question rises whether or not to train a student in differential equations. It is rather clear that the treatment of differential equations in the past (many of which had no clear physical or engineering back ground) is of doubtable importance in a decade in which numerical techniques are widely available. However, we should beware for the extreme to remove from the curriculum all matter of differential equations. In stead we right now get more time to derive and present typical engineering differential equations which apply for specific types of structures. It is a rich experience to know (and thus be able to recognize.) the solution of such engineering differential equations. Typical examples are linear structural systems with a distributed spring component, be it of second order (extension, shear, cables) or of fourth order (bending). Above that, such solutions are welcome references to check the validity (rather: the degree of approximation) of numerical calculations! In practise, this part of education may be reserved to students of graduate levels. At least futural structural analysts will attend such courses.

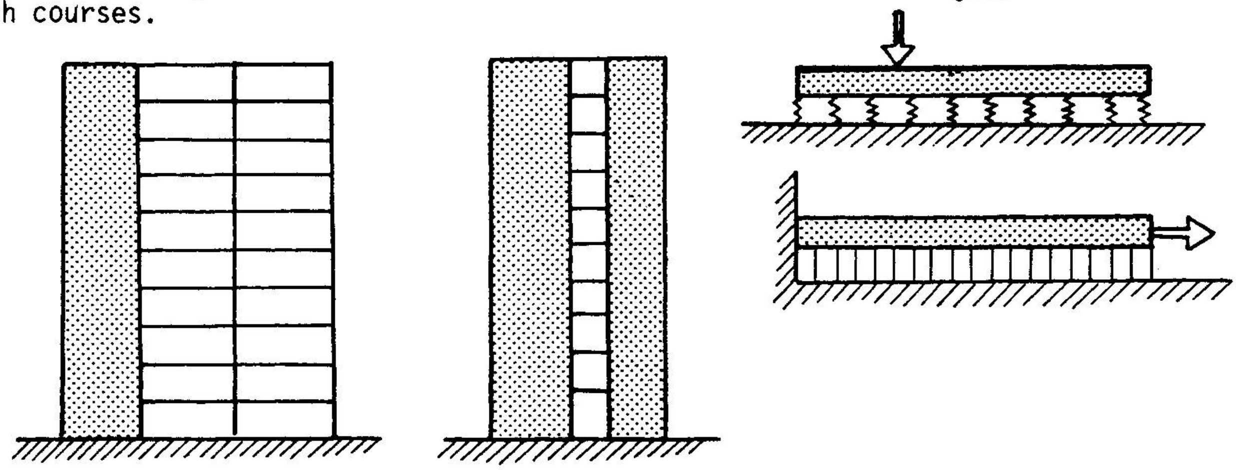


Figure 2. Examples of wall-systems and of structures with spring systems, which are governed by typical engineering differential equations, which also yield useful validation material for numerical tools.

7. FEM IN EDUCATION. WHAT AND WHEN?

In section 4 a primer to the finite element method has been proposed for undergraduate level, and advanced knowledge for graduates. The latter part of the proposal does not meet serious objections. It is widely agreed that a small number of specialized structural engineers must have in depth knowledge on the variational methods which lie behind, and on the applicability for all problems, including dynamics, buckling, and nonlinear analysis, both materially and geometrically. However, unfortunately still a lot of resistance is offered to an introductory course on FEM (a primer) at lower levels of training.

This opposition is allied to the misunderstanding on the basic understanding of structural behaviour, which we already touched in section 5. Many structural teachers seem still to be loaded with a tremendous prejudice against this analysis tool. Sometimes it appeares impossible to convince colleagues that the finite element concept really true can be explained in a simple way, and that it even helps to understand structural behaviour better. Instead they keep nursing initial deeply rooted ideas, which meanwhile rendered out of date completely.

For, present-day reality confronts designers with a complete FEM-industry, which provides analysis tools of ever growing usefulness and elegance. Especially the pre- and postprocessing facilities will become powerful aids. This also holds for education. Here again it applies that students need not be loaded anymore by nonrelevant details, but that they can stick to their very engineering design and analysis task. So, we can afford to ask them to examine a number of structural congifurations, right now yielding the basic understanding, of which others right here fear that it will not be gained!

8. HOW TO MANAGE FEM-RESULTS.

A broad training in the skill to interpret results has been proposed in section 4, and we illuminated this somewhat in the following sections. A most important aspect regarding this training is the check of equilibrium both globally and for parts of the structure.

An example of a global equilibrium check is shown in fig. 3. A concentrated load F is subjected to a simply supported orthotropic bridge slab, and causes a distribution of longitudinal moments m. The slab can be seen as a beam of length l and width b. The mid-span moment in this beam is $\frac{1}{4}Fl$, and this value must be equal to the integral of the moments m across the width of the slab. Trivial you say? Yes, but your attention must be drawn to it when you start doing such jobs! We must cultivate a student's attitude that he does not concentrate on the numerical tool (which FEM really is), but on the information which it yields about the structural behaviour (which is the main responsibility).

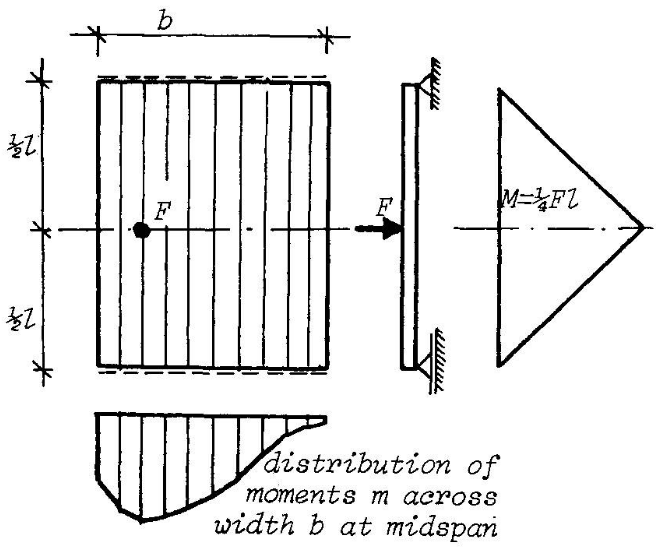


Figure 3.
An example for checking global equilibrium.

A typical example of a local equilibrium check is found in the corner of a slab with free edges, which corner is supported by a single point support, see fig. 4.

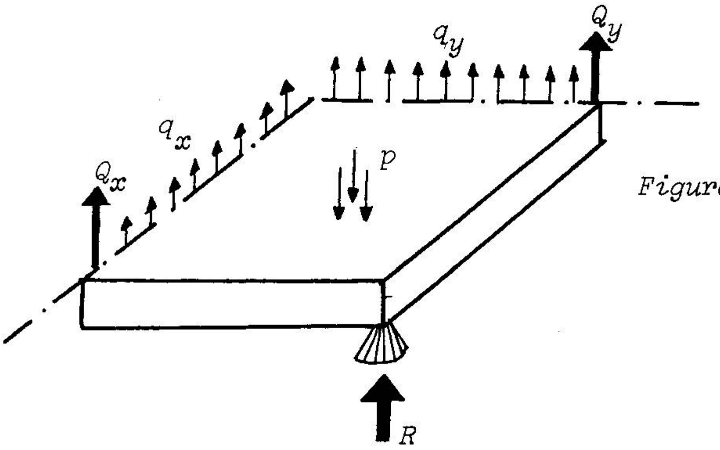


Figure 4. An example for checking local equilibrium.

An educative question is to verify the printed value of the support reaction R, considering a square part of the slab near the support. Everybody will take account of the distributed shear forces q_x and q_y in the slab and of (eventually applied) load p on this part of the slab. But does everybody realize himself that concentrated shear forces Q_x and Q_y occur in the edge zones of free edges? They even will strongly dominate the distributed shear forces q_x and q_y. Basic knowledge of slab behaviour is a prerequisite here to execute a proper equilibrium check. Therefore, a plea for finite element education always presupposes that adequate understanding of structural behaviour is teached simultaneously.

The slab examples shown above make clear that the application of FEM provides much detailed information which improves our design skill. However, honestly speaking, the FEM sometimes introduces new problems which we had not before. Important examples are stress concentrations in singular points, which occur in plate and shell structures. A continuously refined mesh would in the limit result in infinite values of the stresses. It is not possible yet to present a general solution how to handle such situations. In practise one may decide to investigate such important details and connections experimentally, or (if possible) the structure is modified such that infinite stresses do not occur anymore. And in how many cases "local limit analysis" will be called in to face this problem? The question rises whether or not we ask the right questions to the computer. Is it information on stresses that we need? Or is it an energy quantity which maybe better describes the initiation of plasticity, or cracks, or crack propagation? And how to define such new criteria such that no mesh dependency occurs? Plenty of reasons to pay attention to this interpretation problem in the future.

Introducing CAD to an Undergraduate Engineering Curriculum: Advantages and Difficulties

Donald P. Greenberg
Prof.
Cornell University
Ithaca, NY, USA

I. INTRODUCTION

Obviously, the uses of computer graphics and computer-aided design and manufacturing techniques are growing rapidly in modern engineering and systems design. Most organizations engaged in industrial production, both large and small, now recognize that computer graphic techniques have proven to be very effective for improving the man - machine communication interface. Such techniques range from interactive design at the onset of an engineering project through the final production of the manufactured part. In many industries, this has become, or will become, a totally integrated process.

It is necessary that universities be fully responsive to the future directions of engineering practice. Specifically, we must provide education in the development and application of computer-aided design systems. These systems must be "active," and allow the student to participate in the iterative design loop, without losing sight of the conceptual aspects of the problem. Furthermore, we must train the next generation of students to not only use and be familiar with computer-aided design methods, but to harness the awesome computational power that will be commonly available in the future.

Consistent with this philosophy, Cornell University has established an Engineering College Computer-Aided Design Instructional Facility. Its primary objective is to introduce new techniques to enhance instruction, comprehension, and design insights in all areas of the undergraduate engineering curriculum. With this new facility, we are bringing sophisticated computer graphic and computer-aided design tools into the classroom. We hope that this will have a significant effect on the curriculum of each specific discipline in engineering, and may well introduce substantial changes in the modes of instruction.

II. VISUAL PRESENTATION

Slides of the Computer-Aided Design Instructional Facility and classroom instructional modules.

III. PROBLEMS AND DIFFICULTIES

Despite the inevitable advantages and potential, there are many problems in establishing the capabilities for teaching computer-aided design, computer-aided manufacturing, or computer graphics at an institution of higher education in the United States. The following are some personal observations or comments related to commonly existing obstacles.

1) Many universities are suffering from the financial constraints which prohibit them from keeping pace with current computer technology. Most major university computer systems were in existence prior to the economic and technological breakthroughs of computer graphics. Universities are frequently burdened with the continuation of these older systems, partly because of the necessity for administrative continuity. Thus, research and instructional facilities may be encumbered by an outdated technology. I believe that it is necessary to accept this situation, and to eliminate the dependence on the older systems. It is necessary to enter this field with new computer systems. It is clear that the technology will continue to improve in both cost and performance, and education in this field must recognize this trend.

2) Because "A picture is worth 1024 words," it is easy to understand. People do not realize the immense amount of software which is necessary to drive the system. Computer graphics itself is quite seductive, and has enormous implications, but the task of creating powerful, interactive software is tremendous.

3) Another difficult situation is caused by the common misconception that software which can be demonstrated can also be used for commercial purposes. However, in most cases, the software was written on an experimental basis, possibly by a graduate student who has already graduated, and documentation is generally poor. Furthermore, universities are not in a position, nor should they be, to provide software maintenance. Industry should provide financial support to universities for the development of ideas, but industry must assume responsibility for the actual production of the computer code.

4) The proper reward structure for software development, particularly in computer science or computer-aided design, does not exist. Appropriate credit is not given for a well-developed, operable piece of software, particularly software which is used for teaching. It is much easier to obtain publications which are theoretical, or even ones which are design-oriented, rather than write a fairly extensive computer program. Since one's ascent up the ladder of tenure is partially judged by one's external publication record, this severely hampers cultivating the software development interest of younger faculty.

5) In a general sense, computer-aided design spans many subject areas. Creation of a usable system can require knowledge in programming, operating systems, graphics software and hardware, numerical methods, human factors, and color science, as well as an intimate knowledge of the application field itself. Obviously, these projects cut across the traditional, discipline-specific, departmental boundaries. Thus, it is not infrequent that the development and education of computer-aided design is retarded by existing university organizational structures.

6) Perhaps the most difficult of all the problems, is the training of faculty to use these new techniques. Tools can be provided which will enable ideas of broader concepts and new dimensions to be explored, and still create a communication language which both the student and the professor can understand. To use this tool properly, one must rethink the entire approach to teaching certain subjects and redevelop a curriculum to use these technologies.

I do not know any specific solutions to these problems, but it is clear that we can not continue to base our goals or solutions on what were accepted practices in the past. We must recognize the new technologies, and step back far enough from the problems to ask ourselves the correct questions. Only with this approach can we attain proper solutions to the computer-aided design education of future engineers. Thank you for your attention.

Leere Seite
Blank page
Page vide

SESSION V

DISCUSSION

October 8, 1982 - Afternoon

Chairman: B.A. SZABO (U.S.A.)

H. BALDAUF - Mr. Schneider, what kind of answers does the program accept? Are they prepared answers from which the correct one has to be chosen? If four answers are available and one guesses, there is a 25% probability of getting the right answer! Furthermore, you stated in your paper that the computer has "infinite patience" and one can go back as often as one wishes and there is always adequate time for one's work. On the other hand, you said: "what might happen, will happen". The computer can monitor progress and keep track of the time consumed. So the training manager may finally say: "Get out, you are too slow". I believe these methods are an addition to our traditional methods, but not that they will completely replace existing techniques.

R.W. SCHNEIDER - When we write a course, we basically start with a blank piece of paper and the system; and the author of the course builds all of that into the course. The author can say that the student will only have three chances to answer this question correctly and, if he doesn't answer the question correctly, then we are automatically going to send him to some intermediate work. So it is all based on the experties of the author.

B.A. SZABO - Can you give me an order of magnitude, say in manhours, or manyears of the effort required for writing such a course?

R.W. SCHNEIDER - Actually anybody who knows what they are talking about won't quote any hours, because there are too many variables. If you have a course with a lot of graphics, a lot of branching, it takes longer. Our courses have very simple "course", from the time the boss comes in and says "write a course on this" to the time that is operational (it is about an hundred hours for every one hour of student's work, so an hundred hours to one). If it is more complicate and has more graphics, it can go up to six hundred hours to one. It takes a long time.

J. BLAAUWENDRAAD - If you allow - Mr. Chairman - once more the same question. It's indeed individualized, but - on the other hand - it is unpersonalized or depersonalized in some way. I think this way of learning is too mechanical. You are right that it will be part of the market, but it is not all, for it never can be a substitute of that social aspect which is in learning and in instructing. Also a teacher (which has experience in design) can, in some way or another, carry over to the student his engineering judgement. It may be a boundary about which this type of instruction and learning will never can and should go.

B.A. SZABO - Can you give an indication of how many people are taking this kind of instruction and how do they feel about it?

R.W. SCHNEIDER - You are correct. What we try to do, when we write a course, is that we try to make it personal. You may have taken or seen CAI courses and the computer would say "What is your name?" and you type your name and he says "Well this is what we are going to do". One of the things we have asked our software people for - and we have gotten - is that we can automatically pull off some of the variables, some of the primaters in a file, so we don't have to ask you what your name is, we know what your name is and we can pull your name out of a file automatically. That depersonalizes it a little bit. Also, when I try to write a course, I always try to write one with a dialog. It is not a book. It should not be read like a book. It should be a dialog, just like we are talking now. An other thing: CAI is not going to take the place of the college classroom, is not going to take the place of other areas, where other methods of instruction are used. But it is good for one thing: if you have ever done any teaching, you know that for certain courses there is a lot of dull and boring aspects to a course; it is good for those. Wouldn't it be nice to take those first two weeks a class when all the students take the dull and boring stuff and when they come in they are all ready to go. It also is good to bring all the students up to a certain level, so when they do come in your classroom they are all to a closer level to each other. We have, as far as number of people is concerned, approximately 40 students per week who are taking any of 35 different courses. A course lasts from half hour to two or three hours on a wide range of topics and they seem like they like it; if they wouldn't like they wouldn't sign up for it. In training sometimes that's what you want. If you are training somebody to do a dump of a system, all you want to go through is pushing a button, that's all. You don't want them to make any decision, just go through this procedure, and that's where training is good. It is not education, it is training.

B.A. SZABO - I have a similar question for Prof. Greenberg. You mentioned in your presentation that something like two thousand undergraduates are taking the course that you offer. Is this course compulsory and if so, how do these people relate to it?

D.P. GREENBERG - Let me try to clarify one misunderstanding. We have approximately two thousand undergraduate engineers at Cornell University and they are in approximately ten different departments. The objective is to make sure that each one of those students gets exposed to one course using computer aided design systems before they graduate. There are approximately, 15 may be even 20, courses now tought on the system. I don't think that any course has more then 150 or 200 students. If you consider the fact that some students may take 2, 3 or even 4 courses on the system, we are probably teaching in the neighborhood of 600 to 850 students per semester now, although they are not in a single course.

S. ELKMESHI - Although I am impressed with Prof. Greenberg's presentation,my question goes to Dr. Schneider. Concerning the general attitude that computer is a black magic thing, you are teaching other things out of computer: how that affects your students when you are teaching them about those things you mentioned? Mixing up these things together, if you teach them whatever works or these different courses you mentioned, how are they affected? I mean they can be easily trained without computer, but with computer are they more affected?

R.W. SCHNEIDER - There have been a number of studies in the United States and a rule of thumb is that you can, through computer aided instruction, cut the instructional time down by about 40% with the same level of mastery and, in the industrial training enviroment that's very important. In addition any student, any trainee can take a course whenever he wants to take a course, he doesn't have to wait for the scheduled classes. We have in our company a great extension of training programs, probably ten classes going on at anyone time, just within the company for the company people.

Leere Seite
Blank page
Page vide

Closing Address

Prof. Michele A. FANELLI

The activity of the structural engineer, or indeed of the civil engineer in general,can be summarized as the art of reconciling enviromental constraints, limited material and financial means and functional goals. This art is exercized as a dynamic process in which a certain body of knowledge must be brought to bear (either through a set of formalized rules,or by use of existing experience, i.e. analogy with past projects), certain data have to be obtained and processed, certain responsibilities fulfilled. Moreover, the flow and processing of data can be characterized - in successive steps - as the synthesis of a conceptual reality (design), the keeping track of a growing reality (construction), the monitoring of behaviour of an existing reality (follow-up of the completed structure during its service life). During each of these phases a running comparison must be effected between actual and expected properties, and corrective actions must be taken whenever the discrepancy exceeds certain thresholds.

And still,in each phase of this process the data will usually be neither complete nor acccurate enough to reach conclusions endowed with "absolute" certainties, so that at every step there will be - whether we are ready to recognize it or not - a risk of error in judgement and hazards to property or lives, as well as legal and financial responsibilities toward third parties.

Thus,the art of civil engineering - far from being the mechanical application of a body of rules, such as the layman is so often bound to envision it - is a largely personal gift born of and grown by experience,intuition and scientific knowledge, all of them applied in a flexible way so as to cope with ever-changing, fuzzy contexts.

How can the computer assist the human designer in this complex endeavour?

The most evident feature of the computer is its capacity to handle, recall and process large amounts of data in a very fast and efficient way,provided these data are stored according to certain rules and provided the processing can be defined in a formally nonambiguous way. This explains in retrospect why the first applications of computers to structural engineering were in the field of structural analysis, where formalized set of rules can often be defined, at least as "first approximations".

Now the focus of interest is shifting to more ambitious goals. In the field of CAD and CAM it is now sought to secure the assistance of the computer system also in the more creative, ill-defined phases of design layout, construction drawings, planning, etc.

In a like manner the focus of the "Terms of Reference" of our W.C. is changing: besides cautioning the practicing engineer against improper use of the computer for structural analysis, we should endeavour to grasp comprehensively the full potential of computer application to the integrated process of civil engineering activities. In order to do this, we have to overview the mighty stream of information around and inside civil engineering activities.

I would like to mention that also in Italy, and in particular within my organization, ENEL (The National Power Agency), efforts are under way to set up a system of computer aided design for new power plants.

Also looking at the contents of the papers that have been presented and discussed, the novelty of this Colloquium as compared with the first edition

(1978), or even with the more recent Specialized Session of the Vienna Congress (1980), lies in a shift in emphasis from "structural analysis" to hardware and software systems for CAD and CAM on one hand, microcomputers and computer graphics on the other hand.

Many contrasting views have been expressed, ranging from deep skepticism to sanguine optimism.

Some people seem to think that a nearly complete automation of design activity is in sight (at least within the horizon of the next 10 years) if not just around the corner; they would like to include everything into "computer aided management": layout, preliminary design, structural analysis, quantity evaluation, costing, planning, construction management and accounting.

It is natural to be tempted along this way: the logic of the computer system is powerful and, once you have adopted it for one step of the process, there are very strong reasons for doing the same thing on the other steps as well. But to draw up a rational, feasible plan leading in a carefully thought-over way to complete (or nearly complete) design automation is indeed a formidable task, and we cannot even be sure that it is feasible with present-day means and techniques.

I think it more reasonable to envisage successive attacks on small, relatively well-defined "segments", or phases, of the design activity. In this way, successive advances can be incorporated, experience gained can be brought to bear, errors corrected and the transition from a completely "hand-made" design activity to a "completely automated" one will be made less painful and difficult. More flexibility can be maintained at every moment.

We should also keep in mind that analytical tools of different degrees of complexity are needed in the different phases of the design activity. Normally, just to make an example, a full 3-D F.E. analysis is neither warranted for nor economically justified at a preliminary design stage: simpler methods should be used at that moment, allowing the designer to modify and try again for optimization and making easier an "interactive" working mode.

To conclude, I would like to remark that what we are dealing with is a huge problem in communication between man and machine, and even between different kinds of machines. This reminds me that the dawn of the "Cybernetic era", in which we are now living, was marked by the appearance of a classical booklet by Norbert Wiener, titled "Cybernetics, or Control and Communication in the Animal and the Machine". In this booklet, the process by which either an animal or a cybernetic machine pursues its "goals" is described as a continuous comparison between aims and realization. This same comparison - as I said at the beginning - is central at every step of the design process: the designer is comparing its objectives (in terms of functions, aesthetics, strength, costs, behaviour, time schedule, structural damage or whatever else) with what is achievable or has already been achieved, and takes corrective actions whenever he detects a difference between aims and realizations. The concept is, of course, that of <u>feedback</u>, which is also at the core of "interactivity" and "adaptivity".

Now I try to jump on an other plane of reasoning, a "meta-level" so to speak, and to look - in the spirit of our W.C. - to the process of development of a CAD system. We should adopt the essential process of feedback even on this plane: to begin with the first step of an action, to watch its results and to correct our line of work accordingly. The so called "direct control" approach, in this case starts from complete specifications and runs straight for the complete objective, could well lead to an unstable process, as in a biological and cybernetic system without feedback. The step-by-step approach is not only easier: it is intrinsically safer.

This, I think, both the structural engineer and the "informatician" will have to keep well in mind while developing CAD and CAM.

Thank you for your kind attention.

Leere Seite
Blank page
Page vide