# Computers in the education of structural engineers

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# Computers in the Education of Structural Engineers

Rôle de l'ordinateur dans la formation des ingénieurs

Computer in der Ausbildung des Bauingenieurs

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## 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.

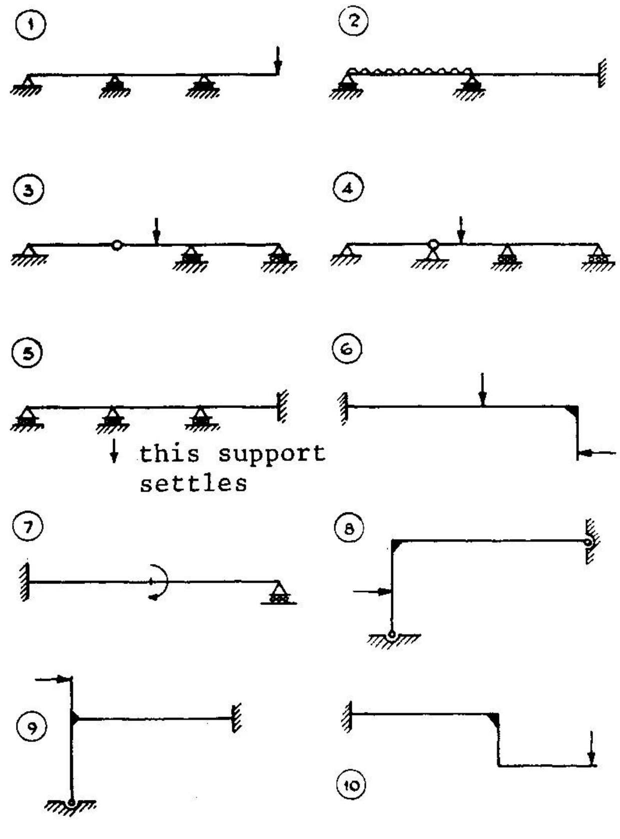


Fig. 1: Part of test paper devised by Brohn and Cowan[7]

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.

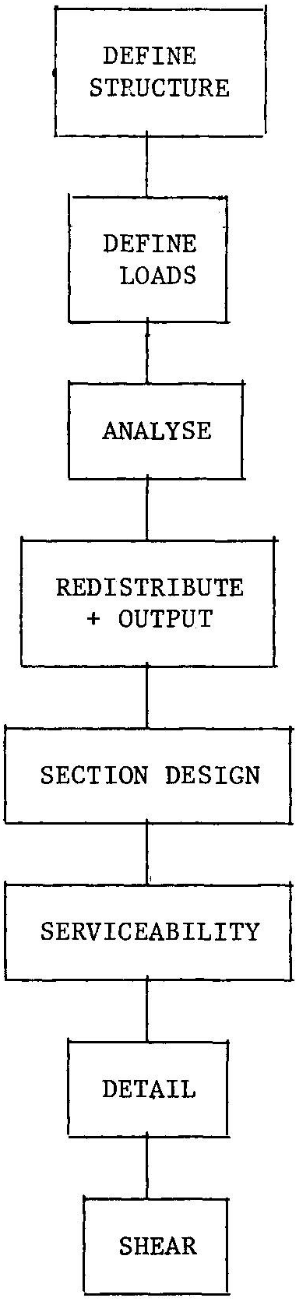


Fig. 2: Flow chart of design of continuous reinforced concrete beam (from the DECIDE system; Beeby[8])

## 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.

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