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Construction Industry and the Future of Informatics

Industrie de la construction et futur de l'informatique

Die zukünftige Rolle der Informatik in der Bauindustrie

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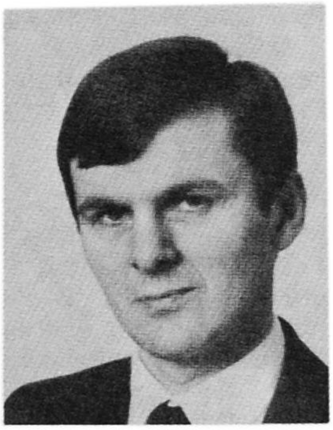

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SUMMARY

A brief discussion of the expected future scale of construction is followed by a description of developments in informatics. The computers of the future will be cheaper and more intelligent and image and graphics will play an ever increasing role. Computers are having a major impact on the construction industry in both design and construction, and the role of the drawing in the construction process is changing radically. The survey closes with some comments on the training of engineers and some thoughts about the future of the profession and the role of governments.

RÉSUMÉ

Après une brève estimation des activités futures dans la construction, quelques commentaires sont consacrés à l'évolution de l'informatique. Les ordinateurs de demain seront moins chers et plus intelligents, et la représentation visuelle jouera un rôle de plus en plus grand. L'influence de l'informatique va croissant dans le processus de la construction, tant au niveau de la conception qu'à celui de l'exécution, en même temps que le rôle du dessin se modifie profondément. Quelques remarques sur la formation des ingénieurs et quelques réflexions sur l'avenir de la profession et le rôle des pouvoirs publics sont présentées en conclusion.

ZUSAMMENFASSUNG

Es wird kurz auf die voraussichtliche Entwicklung der Bautätigkeit eingegangen, dann werden die Entwicklungen im Bereich der Informatik behandelt. Die Computer der Zukunft werden billiger und leistungsfähiger sein; die graphische Wiedergabe spielt eine immer grössere Rolle. Dies wird erhebliche Auswirkungen auf die Bauindustrie haben, und zwar sowohl auf den Entwurf als auch auf die Ausführung selbst. Die Aufgabe der Zeichnung im Bauprozess ändert sich grundlegend. Der Überblick schliesst mit einigen Bemerkungen zur Ingenieurausbildung und mit Überlegungen zur Zukunft sowie zur Rolle des Staates.

0. ENTRY

A scene taken at random from the mid-sixties. A computer hall has two doors to the corridor. A long paper tape is carried to the computer's optical reader via a type of moving track. The tape forms a closed circuit which leaves by one door, runs along the corridor, comes in again at the other door, passes through the reader and disappears into the corridor again. In the earliest computers this was the way in which a certain part of the program was frequently repeated - a "do loop" as it is termed.

The above describes one of the earliest calculations for cracked reinforced concrete girders. But everyone was acting in similar vain and thought they were being progressive (who dares to laugh?). Compared with this, there have been a large number of changes in a remarkably short time and there is still no end in sight to the developments.

1. FROM BABBAGE TO CONSTRUCTION

Christopher Evans talks about the impact of the computer revolution on society in his book "The Mighty Micro". Even with a scenario shorn of anything unexpected, developments will still be overwhelming. We are all experiencing the fact that the pace of change is constantly accelerating.

Fig. 1 *IBM opens a "Calculating and Computing" exhibition in the Chicago Science Museum with a stand devoted to Charles Babbage and his Analytical Machine.*

Much has happened since Charles Babbage built his 'Analytical Machine' with cog wheels and rods about 150 years ago (Fig. 1) and the revolution has been greater in the last 20 years of this period than in the first 130. This is characteristic of processes with exponential growth, and as yet there is little of no sign of stabilisation. The opposite in fact; for the time being we would do well to prepare ourselves for yet more products of the future which will certainly draw our attention.

What will happen to construction in this period? Construction is a creative production process which underwent substantial expansion in the industrial revolution. But our era is characterised as post-industrial, with more focus on conservation than construction. It is a fact that the conventional construction task of building a good infrastructure is on the decline in the western countries - at least for the present.

For the purposes of our survey the future scale of construction is not the sole important factor. One point that is clear is that it will be different. It seems to me that we must guard against two extremes in our assessment. At one end, the volume of work is expected to be so small that there are already heavy cut-backs on funds for research and automation. This destruction of knowledge prompted by pessimism (and politics?) seems fatal to me in the medium term. But the other extreme is also misleading. Those who wave aside today's circumstances as a trough which occurs once every 40 to 50 years in accordance with Kondratieff's economic cycle are certainly failing to realise the full impact of the situation. We expect a permanently lower level of construction in the future but the main point is that it will be different in nature. Maintenance, replacement and renovation will be at least as important as totally new construction and, internationally, competition will be even fiercer. Only those consultants who are enterprising and (almost) aggresive are likely to maintain their position in such a market.

In construction we will use a wide variety of computer aids to assist in our work. There follows an outline of what is available or coming down the track and an indication of their many applications. It will be an extremely incomplete overview, or to put it a better way, an overview which will soon be outdated as the pace of development is so fast.

2. INFORMATICS PUSH

The word informatics does not trip so readily off the tongue in the construction world. It seems vague and abstract and appears closely linked to mathematics. Computer use and computer aids are preferred. Then people understand each other at least. The fact that informatics has not become a familiar concept, however, has to do with the way in which the concept was introduced and with the group of scientists who immediately appropriated the word. We are prone to associate it, therefore, with builders of compilers and other people who tinker around with bits and bytes, but that is a shame. Consistent usage of the term informatics immediately expands our framework beyond the limited sphere of calculating and drawing with a computer. And that is to our advantage.

Microelectronics

Electronic engineers are also employed in the world of informatics. One of their products, the chip, has led to a completely separate branch of technology: microelectronics. Here the emphasis is somewhat more on the tools that are available: microcomputers with numerous possible uses. Of course, large central computers, the mainframes, which many people can use at the same time have been with us for a long time. Such installations cost many millions of dollars.

These were followed by the minicomputers which are of varying power, sometimes having the features of a mainframe, but considerably cheaper, up to half a million dollars say. And recently we have witnessed the rise of the microcomputer. For about a thousand dollars, you can buy your own personal computer.

And if you spend a little more, about five thousand dollars for example, you can have a configuration which is suitable for a large category of medium and small business.

If you want to, you can already run the largest program packages on a powerful micro. The cost is no more than fifty thousand dollars while the capacity matches that of the minicomputer. The product range now runs from the simplest pocket calculators to mainframes. And that does not include the even more powerful supercomputers and parallel processors which will not be discussed in this article.

Nor has the development been so one-sided as to produce only highly enhanced calculating speeds. In parallel, there has also been much progress in the area of man-machine communication and visual display capabilities. We now have input menus, tablets, light pens, flat screens and much more besides. The graphics available on screens and the print-out options have improved markedly.

Moreover, colours can now be used although the printing and duplication of colour images is not yet commonplace. As graphics applications become more important, there will be increasing awareness of the need for a software standard. The Graphical Kernel System (GKS) has now been widely accepted for this purpose. Another very important point is that programming a microcomputer is simple because of the excellent tools which are supplied with it.

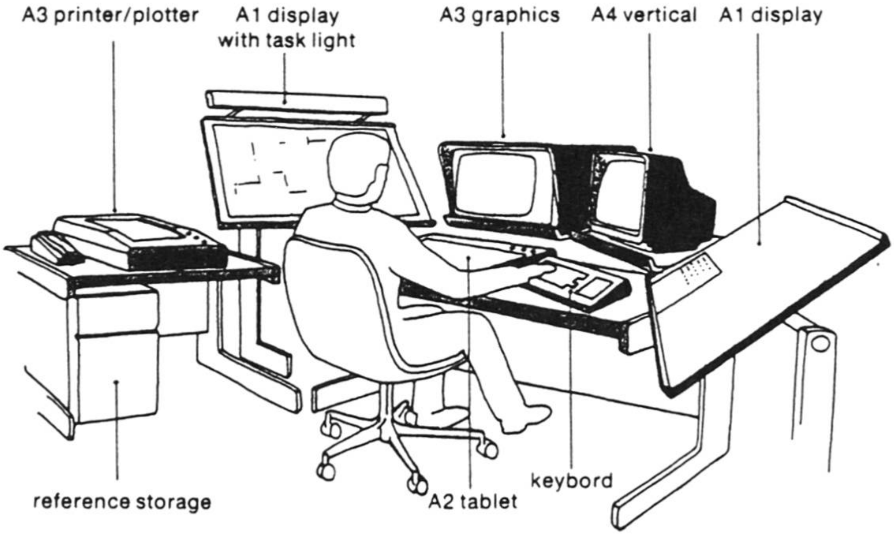

Fig. 2 The work site of the engineer is changing markedly in the eighties. This shows one of the work stations suggested by the European Community. Image plays a large role.

The developments outlined above are leading to radical changes in the designer's work site in the eighties and the European Community in Brussels has set up a working party to produce recommendations. One of the recommended work stations is shown in Fig. 2. It is immediately obvious that graphics is very important. The engineering database is also receiving international attention. Databases with a slightly different structure from those used for administrative purposes are necessary for technical applications although there is a growing conviction that administrative databases can be altered for this purpose. The database chip is on the march and one can guess what this means for the storage potential of a microcomputer.

Intelligence and senses

Future computers will offer more possible applications than we know at present. They will be equipped with "senses" for special applications. They will be able to observe, hear and smell. The benefits of this are abundantly clear in robotics because robots will be able to go round obstacles and pick up -without damaging them- parts which are not lying in precisely the right place. And our car of the future will automatically reduce speed if we come too close to the one in front. Communication with our micro may also change. Input will not be via a keyboard but by talking to the micro. And the micro will answer with its voice, which at the moment is admittedly still tinny. Moreover, the equipment for recognising speech can be much smaller than can ever be achieved for keyboards. Miniaturisation can go so much further that in all probability we shall be staggered by the possibilities of what we now call our wrist watch. This is partly due to the increasing information density of chips. Intensive research will soon make it possible to put an entire book on a single chip and after that a complete encyclopaedia. It is likely that the written word will become less important in the future.

At the same time the 'intelligence' of computers will steadily increase. I do not find it fruitful to discuss whether machines can think or not. What is clear is that the software can be disigned so that a computer reacts in a way which largely corresponds to human behaviour. We then speak of artificial intelligence, abbreviated to AI. Up to now, AI has mainly resulted in chess computers but that will soon change. When one considers that the current chess computers can already beat more than 99.5% of chess players, there is every reason for taking the development seriously.

In his book, Evans indicated in the form of a diagram the intelligence of the current computers on an IQ scale of his own devising, on which the average person scores 100. Fig. 3 shows this IQ scale. The current generation of computers does not do much better than tapeworms but it is expected that there will be ultra-intelligent machines by about 1990 which will match people (at least within the area that Evans defines as intelligence).

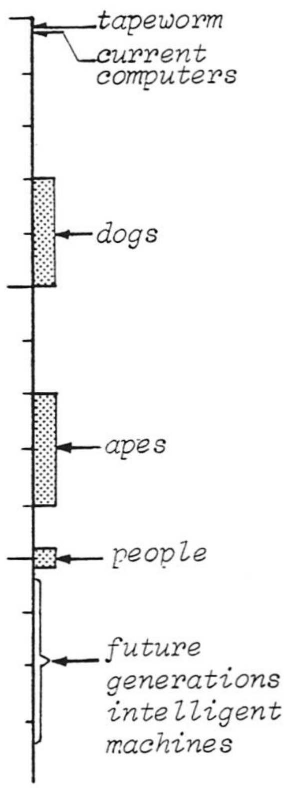

Fig. 3 Hitherto computers have not achieved a high score on the intelligence scale. This is likely to change in the near future with the ultra-intelligent machines.

Intelligent computers equipped with senses will have a major impact on CAD and CAM. The user interface will steadily become more user-friendly by improved presentation techniques, greater scope for language recognition, improved handling of errors and such like. This is a prerequisite of good CAD systems.

One of the existing AI products is called knowledge-based systems or expert systems. These are already used in the medical world to assist in making diagnoses. A large volume of medical knowledge is stored in the database and the computer also acts as an intelligent aid to the user in finding his way through the knowledge. This method is also in the pipeline for CAD and the first results have already been reported. Will this immediately mean a large jump forward? Probably not, but in construction, as in any other area of activity, it pays to look ahead.

3. IMPACT ON CONSTRUCTION INDUSTRY

The computer's advance in construction clearly started with calculations. The numerous programs for strength and vibration problems bear witness to this. Now, however, it is widening its area of application in no uncertain terms. But to confine ourselves to the area of calculating to begin with, there are attractive (and expensive) pre- and post- processors for the finite element method packages which interact impressively with the new screen graphics, which include colour. More generally, the term geometric modelling is used (Fig. 4). The computer is used in many other areas as well. For building contractors the production phase is now unimaginable without this aid. Planning, cost calculations and budgeting, together with a host of support functions, are carried out by the computer. The new aid is also indispensable in the operational area of contractor's work, including the towing into place and positioning of large constructions off-shore.

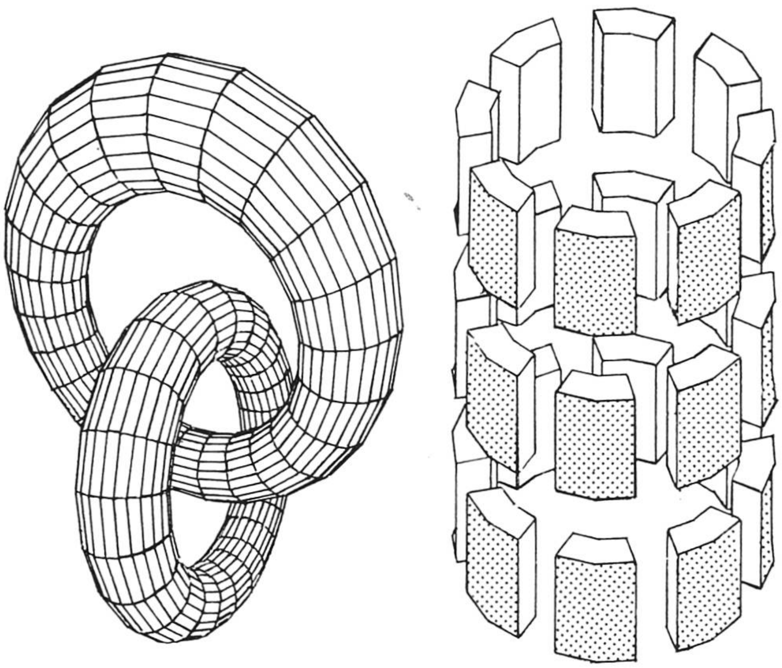

Fig. 4 Graphic aids are becoming ever more powerful. A golden period for product modellers and pre- and post- processors.

Attention has shifted, therefore, from calculation alone to the integral process of design, drawing, execution, quality control and process control. There are also completely new applications such as integrity monitoring of constructions during their lifetime and inspections to determine the residual lifetime after damage has occurred; this is particularly relevant in earthquake areas. Hydraulic calculations, programs for wave forces and transfer functions and numerical methods in geotechnics can also be included. And, in other areas, controlling the climate in buildings or controlling construction works. The computer can also show layouts and dimensions of navigation routes, ordinary roads, harbours, dykes and such like and is used in designing flexible constructions such as dunes, dams and dykes. Nor must we forget the facilities for 3-dimensional screen displays so that a design can be assessed from various angles for aspects such as safety, aesthetics, appearance and shadows. Rather than mention any more, let us just say that computer simulations are finding increasing application in construction. The term CAD, Computer Aided Design, is no longer sufficient to embrace this kaleidoscopic and certainly incomplete summing up. The more general term CAE, Computer Aided Engineering, is now widely heard or, as I once heard in a somewhat ironic voice, Computer Aided Everything.

Designing

The concept of Computer Aided Design, CAD, suggests a field which can be illuminated by computer science or using the design process, depending on whether you put the emphasis on the C or the D. The computer aspect has been uppermost until now because of the "technology push" from microelectronics. Systems which are presented as design systems are, in many cases, large final checks in fact, applying when the design to all intents and purposes is fixed. Such final check is no longer an irksome task thanks to the fine graphic pre- and post- processors.

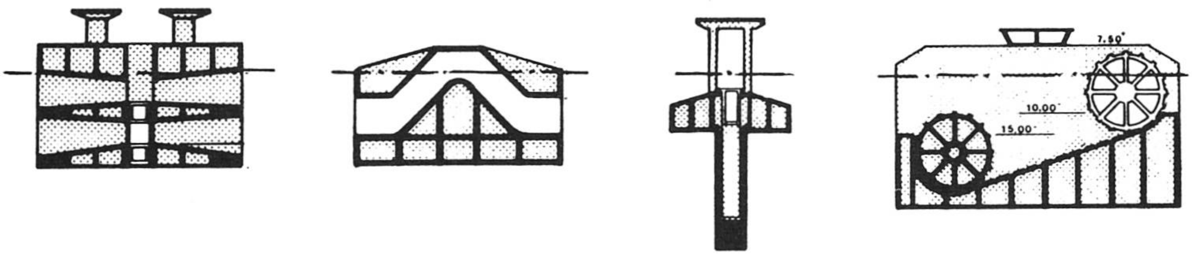

Fig. 5 The design process starts by generating alternatives. This shows several draft designs of a storm surge barrier in Holland. Calculations are not so prominent at this stage.

Designs such as those for construction can be described as a process with a number of steps. Assuming that there is a well-defined brief, the first step is to generate alternatives, the draft designs (Fig. 5). Scarcely any calculations are made at this stage. One or two concepts from the collection are selected for further development and the parameters which will govern the design are identified. These concepts are then further explored using overall calculations. At this stage a high degree of accuracy is not important; the main priority is that all problem areas must be identified. The rules for dimensioning which are used may still be simple. The final draft design is chosen in the third phase and the dimensioning is further optimised by parameter studies (Fig. 6). The result is a definitive design which is subjected to extensive and costly checking calculations in the fourth phase.

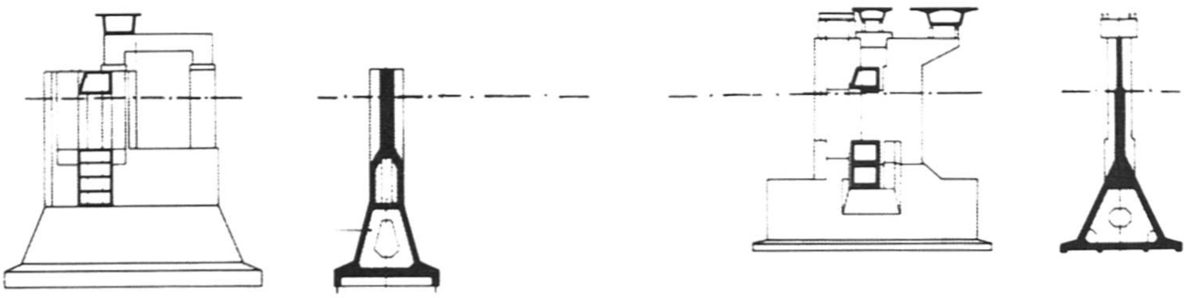

Fig. 6 When a choice has been made between the design alternatives, the definitive choice is optimised. The computer can be of use, depending on the nature of the construction.

The computer can play a role in the entire process in a number of ways. Network analysis, for example, can be of assistance at the stage of generating draft designs. Computer-based methods can be of service in evaluating the many alternatives, for example with decision techniques on the basis of accepted risks. But even if one does not wish to make use of such a support tool, it is certain that small personal computers will lead to a new approach in the various design phases. The designer can make his own calculations geared to his particular needs case by case and develop his own programs. This is a significant back-up for engineers out in the field, especially if they are working abroad far from the parent company. It is also expected that the micro will be an important instrument in propagating probabilistic design methods and gaining acceptance for them.

Drawing

It is, in fact, a sign of a compartmentalised approach to devote a separate part of the article to drawing. It smacks of the past, when drawing was rigidly divided from design, in organisational terms as well. All the signs are that this will change drastically. The modern CAD installations for professional technical drawing work will give drawing another function. Even more than in the past, a drawing will be the bearer of information - but one which plays a powerful central role. The flow of information in the whole construction process will change radically as a result. It is also emphasised that the new range of graphic CAD tools provides a medium for achieving the best possible view of the construction process. those who talk only about "computerising the drawing office" fail to understand that a much more far-reaching process of change is taking place. The graphic CAD/CAM systems which are now available will certainly develop further in the future, something I feel is necessary to achieve the changes described above. What we are actually waiting for is CAD equipment in which the screen is combined with a keyboard (soon with voice input) and linked to a plotter and a database. If this becomes available during the eighties, the drawing office really will feel the impact.

Simulations and systems

We have already mentioned the importance of simulations in the construction process. One of the applications concerns the execution of large-scale works. In operational affairs, there is human intervention in complex systems. In order to control these interactions properly there is a need for adequate models to study the processes.

We must also mention the growing interest in simulating service systems. This allows one to assess the operation of sluice systems, terminal systems such as container, bulk and general cargo terminals, systems of canals and rivers and harbour systems.

As well as simulations, there is the increasing importance of understanding signals and systems. This comes into play, for example, when the designer is concerned with wind and waves, in off-shore and other large-scale hydraulic engineering works. And more generally, the engineer needs to understand the dynamics of systems. Such knowledge must have a technical foundation. Teams operating on a multi-disciplinary basis must speak the same language. And the structural engineer is working more and more with mechanical engineers, electronic engineers, physicists, or to put it more generally, with systems control staff.

4. EDUCATIONAL ASPECTS

We have discussed in turn the scale of construction in the future, informatics in the wider sense both as it is now and in the form we are likely to witness soon, and the wide spectrum of informatics applications in construction. The article will close with a number of considerations of a more general nature, starting with the training of engineers.

What are the consequences of these developments for technical education? With the growing use of microcomputers, "personal computing" will become much more common. The engineer will have his own microcomputer as part of his personal toolkit. In technical and scientific work the possibilities are increasing fast, and training must now start to make the appropriate response. The student entry in 1983 will enter the labour market in 1987 at the earliest. Four years is a generation in computer terms! By 1987 the microcomputer will be widespread and colleagues all over the world will have become thoroughly familiar with it. Education must also take account of this. It is therefore far preferable to introduce a large number of microcomputers, rather than many terminals with access to one computer. Study assignments must strongly encourage computer use, but at the same time a warning must be given against becoming enslaved to the computer. Some extremely promising students are so under the spell of programming that this problem is already requiring extra attention by university doctors and computer people.

Fig. 7 Some students fall too much under the spell of the computer. They become "dazzled" by it. And forget they are engineer!

True enough, these are only odd cases, probably introverts by nature or with limited social skills, but some caution must be exercised to prevent students becoming "dazzled" by the computer.

Is the young engineer at fault?

Another worry is more general. Is the current generation perhaps developing unduly in an analytical direction at the cost of the capacity to be creative? Are people not becoming so clever at calculating that creativity is withering? This concern is not a new one but it is certainly not disappearing and must be taken seriously. The opportunities afforded by graphics are doing much to break down the one-sideness of calculating as they markedly improve the visual aspect. Would we not stand to gain a lot by according this an important place in education? Cornell University in the United States has deliberately taken this path by making a practical course in interactive computer graphics mandatory for all undergraduates, which gives it a leading position in the world.

The same question about one-sided development is advanced for applied mechanics. The young engineer supposedly knows everything about matrices, transformations and everything else associated with them but does he understand what he is doing? And can he estimate properly? Indeed, one sometimes fears that all nine figures that appear in the result that comes up on his pocket calculator are slavishly included in a report. Is the young engineer, in fact, not deficient? Concern is expressed about his elementary understanding of the basic behaviour of structures. We all agree that one must first grasp a structure in its qualitative aspects before launching into 'number crunching' . We are certainly prepared to pay lip service to this proposition. But what is the reality? A few years ago, a test was carried out in England to see whether advanced students and young engineers were able to make qualitative assessments. Fig. 8 shows a task that was set of drawing the moments and shear force diagrams. The results were far from satisfactory.

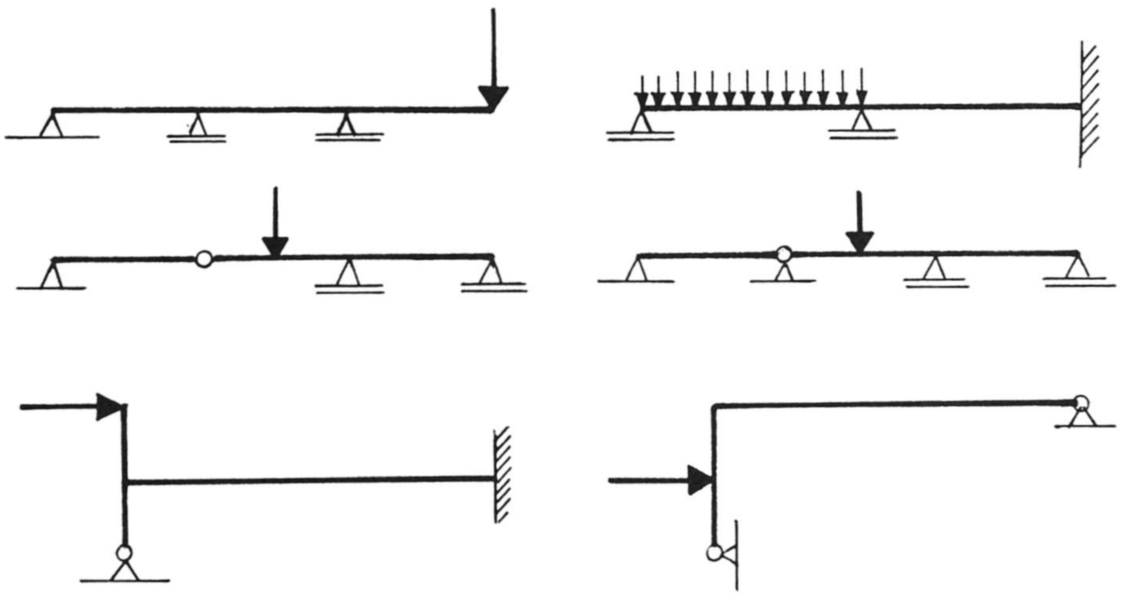

Fig. 8 The capacity of young engineers to describe the behaviour of structures in qualitative terms is limited. This was shown by a test in England in which the students had to draw the moment lines and shear force lines for simple girder configurations. Is the computer to blame?

We must be careful about drawing conclusions too quickly. For a true comparison to be made, a similar test ought to have been carried out 20 years previously. It is still my belief, however, that there has been an actual decline in the ability to make qualitative assessments. But at the same time, I hesitate to associate this too readily with computer usage. One must first know what proportion of the decline can be attributed to the fact that we now have a mass student population. Education has become democratic in the sense that higher education is accessible to a broader cross-section of the population. Moreover, for some years in the past the broad educational effort was not primarily directed at improving achievement. In that sense I am not totally without optimism for the future, although ....

Mechanics and the computer

I do wish to discuss the role of computers in mechanics, however. There is a real possibility, of course, that the correct balance is occasionally forgotten. Then a warning note is justified. But incidents do not form a standard for the whole. What is the situation in general? A difficult question to answer! Could it be that the answer depends on our age? Or on a particular personal preference? That is sometimes the case, because a mechanics lecturer does not get uniform recommendations from all his professional colleague teachers. However, they generally agree about one thing: the previous manual methods of calculating - the Cross method or working with compatibility equations - are supposed to give a greater feel for the structure. They feel, there is a greater sense of talking to the structure and of having much more intensive interaction. In this way one senses more quickly the impact that some changes will have.

This is a strong argument that we cannot simply wave aside. Particularly at a stage in which alternative designs are being surveyed from all points of view, such a - I would almost term it - 'structural' intuition is essential. I believe, moreover, that there is no conflict between the standpoints of the practical exponent and the modern mechanics lecturer. At least there does not need to be. Let the students practise basic mechanics thoroughly and intensively and as classically as possible. But, at the same time, use this phase in education as a simple first introduction to more general computer methods to be studied later. The fear is that computer-based methods are too often taught at the end of the course as if they are completely different techniques without any relation to the classical methods of mechanics taught previously. In this way major opportunities are lost. A simple Cross calculation can be presented within the reference framework of the displacement method, and a girder calculation with compatibility equations is nothing less than an application of the force method. Old wine goes perfectly well into new bottles!

I sometimes think, too, that we overestimate the value of the classical methods. They are considered to further knowledge and we attribute this to manual calculating. I am not convinced of this. We must take account of the fact that a large proportion of the presumed knowledge can in fact be traced back to the presentation of the answers. It is second nature to people used to calculating manually to present the results visually with moment diagrams and shear force diagrams. Was that not entirely fundamental to classical calculating and was it not lost precisely through the grey computer lists with numerical output? But then there is hope! The strength of the personal microcomputer is precisely that it has such powerful graphics facilities. Let us profit from this and use it as early as possible in education. Our universities are screaming for a host of micros in each department. Such modern teaching tools should be made available to students of civil engineering. You should give each student enough assignments to allow him to develop a feel for the changes that occur in the moment diagrams and shear force diagrams if essential parameters in the structure are varied. It must be possible to do this to a high degree with the personal micro.

Validation of programs

There is another problem in studying mechanics, and that is the use of complex and advanced finite element method programs at the end of the design process. The young engineer must be able to handle the results in a responsible way. Great care must be taken in validating results and must cover two areas. On the one hand, there are the computer programs themselves. Graphic displays of the results can help a great deal but there must also be internal controls within the programs and statements of their results. On the other hand, the young engineer must be trained to interpret his results and to carry out equilibrium checks or to determine the orders of magnitude by estimates. The student must be more thoroughly practised in carrying out simple shadow calculations, in order to be able to test the credibility and reliability of large complex computer calculations. In future this will be possible on a micro and it must become second nature to the future generation of engineers to carry out these checks and/or design calculations.

5. PROFESSION

There is no simple way of showing how the profession of engineer will change, but no detailed argument is necessary to show that a different profile fits all the developments that have been described. The method of working will change and elements of the job will disappear, to be replaced by new activities such as the CAD consultancy. Nevertheless, concern is expressed in certain quarters about the future of the profession. Doctors and solicitors already have knowledge stored in expert systems, and CAD is now heading in the same direction. And the common thread through all this is the general decline in employment. Perhaps this is partly a cyclical phenomenon but an important part of it is certainly structural, for one thing because of microelectronics. The developments cannot be ignored as employment will then become even more unfavourable. It is sometimes disquieting to see that the computer revolution is somewhat autonomous in nature so that everything and everyone has but one choice and this is to follow it. The question is no longer whether I follow but how I follow. Broadly-based systems spanning large parts of the engineering profession are no longer applicable. Such large-scale thinking has been shown to be a dead end because it has so far been unable to provide cohesion with regard to the continuous process of development that is required. I also happen to think it is impossible in a structural sense because of the need for wide-ranging and frequent discussion.

CONCLUSION

Computer tools and working methods based on them are widely used in construction and this fact is best acknowledged by referring to informatics in construction. Informatics is still developing and will make increasing inroads, even if construction remains at a lower level. The microcomputer and the growing facilities are providing a major boost. The screen, the plotter and database will radically affect the information flow in construction. The process which we call design will make intensive use of the new possibilities and the drawing will have a different function. This will certainly leave its mark on the training of engineers. The scope for visualisation will help to eliminate the concerns about one-sided analytical skill. It is likely that preference will be given to small-scale practical projects in a clearly defined framework rather than broadly based, all-embracing, large-scale engineering systems. The profession of engineer will be influenced.