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Informatics and the Use of Computers in Structural Engineering

Informatique et emploi des ordinateurs dans le génie civil

Informatik und Anwendung des Computers im Bauingenieurwesen

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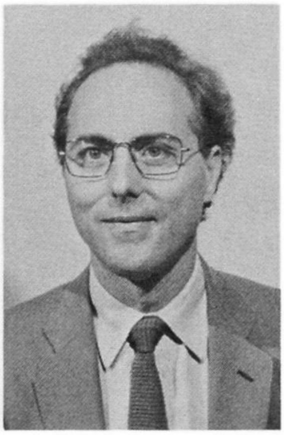

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SUMMARY

A critical appraisal is made of the possibilities and limitations of the use of computers in structural engineering, from different viewpoints. Due consideration is given to technical applications, computer aided design and computer graphics, integrated computer-aided management, educational problems, responsibilities. The aims and role of the new WC VI of IABSE is outlined in relation to this appraisal.

RÉSUMÉ

L'article passe en revue les possibilités ainsi que les limites de l'emploi des ordinateurs dans le génie civil. Il présente les différentes utilisations ayant trait entre autres aux applications techniques, au projet assisté par ordinateur, à la représentation graphique, à la gestion intégrée sur ordinateur des grands projets, aux problèmes d'enseignement, aux responsabilités. Le rôle et les objectifs de la Commission de Travail VI de l'AIPC sont présentés, en vue de ces utilisations.

ZUSAMMENFASSUNG

Die Möglichkeiten und Grenzen der Anwendung des Computers im Bauingenieurwesen werden von verschiedenen Blickwinkeln aus kritisch durchleuchtet. Dabei werden insbesondere technische Anwendungen, computergestütztes Entwerfen und Zeichnen, computergestütztes Management, Fragen der Ausbildung und der Problemkreis Verantwortung betrachtet. Ziele und Aufgaben der neuen Arbeitskommission VI der IVBH werden im Lichte dieser Untersuchungen beschrieben.

1. When speaking of the "Use of Computers in Structural Engineering", the thoughts evoked concern almost always the methods and tools of structural analysis. No doubt that numerical analysis - by computers - of complex structures still carries a large share of the work done in this field, and still poses many technical and non-technical problems. But, besides that very evident case, computers are making their inroad into many other branches of civil engineering.
This is, indeed, all too natural, because computers can streamline, speed up and rationalize any flow of information, be it of a technical, organizational, accounting or financial nature. Civil engineers are only beginning to take full cognizance of these possibilities.
As it is always bound to happen, however, the uncontrolled introduction and proliferation of these new, powerful tools carries with it a host of dangers and difficulties, which have to be clearly identified and coped with. Otherwise, the profession at large could very easily be thrown in a state of confusion. Not only would in this case the opportunities offered by "informatics" be thrown to the winds; great harm could be done, because the old ways of working would be disrupted and no well-defined, reliable new ways would take their place.
IABSE, as the international association embodying the needs, competences and preoccupation of the practicing structural engineers, has long since been considering these problems.
From 1975 to 1981 a Task Group on the "Use of Computers in Structural Engineering" operated within the frame of Technical Commission I. The main outcome of the activity of this Task Group was the organization and carrying out of an International Colloquium on "Interface between Computer and Design" held in Bergamo (Italy) on August 1978 and the organization of a special session on the same subject at the Vienna Congress in September 1980. Very recently, a Second International Symposium, titled: "Informatics: the Use of Computers in Structural Engineering", was organized and held in Bergamo (6-8 Oct. 1982).
Meantime, new aspects and difficulties were at least tentatively identified and the need for a permanent, long-range committee was recognized.
So, in Sept. 1981 in London, the Task Group was officially transformed into a Working Commission (W.C. VI).
The aim of the present paper is to point out the range of interest to be dealt with in the frame of this new Working Commission.
It is to be mentioned that - since its formation - the most immediate goal of the new W.C. has been to organize and carry out the above-cited second International Colloquium on "Informatics: the use of Computers in Structural Engineering". To this Colloquium, renowned international experts were invited who gave their qualified views on the different aspects of the question, among which :
- technical problems
- qualification and diffusion of software (also in relation to low-cost hardware such as microcomputers etc.)
- legal and responsibility problems
- educational problems
- computer graphics

- computer aided design and manufacturing
- integrated computer management of civil engineering construction activities, etc.

Now the WC VI is engaged in the preparation of a specialized half-day session- as well as a specialized half-day Poster Session - in the frame of the IABSE Congress to be held in Vancouver (Can.), 1984.
Further activities will include: the writing of "state of the art" papers summarizing the contributions on the above topics; the study of feasibility and proposals toward the establishment of international "Data Bases" on structural behaviour; the discussion of important critical aspects of automatic structural analysis; etc.

2. THE FIELD OF TECHNICAL APPLICATIONS

In the almost "traditional" field of structural analysis, the use of computers has gained widespread diffusion.
"Mainframe" computers are used with sophisticated programs, e.g.F.E. analyses for big, complicated structures either in the linear range or for non-linear stress analysis.
But also minicomputers, and especially micro and personal computers, are gaining a massive dissemination in every country and in every branch of the profession. With those, also a host of "short", or "unsophisticated" programs are being diffused, practically from hand to hand or on a commercial basis, but with hardly any control on the quality of the software or on the degree of reliability of results.
In the future world of informatics and telematics, almost everybody will gain access to medium - and large - size computers through office (or even home) terminals, telephonic lines, video screen output etc.
How will the user be able to discriminate between "good" and "bad" software? How can he be made at least aware that such a problem of technically correct choice exists? What are, furthermore, the criteria allowing the proper technical/economical choice between computer programs performing "essentially" the same kind of structural analysis, but with widely different methods and -possibly- with computing times and costs of completely different orders of magnitude?
How can this vital information on existing software be orderly transmitted to the professionals most in need of it?
How, furthermore, can meaningful "states of the art" be drawn up in the present conditions of breakneck-pace development?
These, and many other ones, are the problems of a more technical nature that still await for a provisional answer, if not for a solution. Very powerful forces are operating in the software and hardware market, vying for the attention and the favors of structural design organizations as well as of individual structural analysts. It is an unpalatable truth, but a truth nonetheless, that a large share of this market is developing wildly without any serious technical control.

3. THE QUALIFICATION OF SOFTWARE IN RELATION TO THE INCREASED DIFFUSION OF PROGRAMS FROM UNCONTROLLED SOURCES

Especially with the advent of minis, micros and "personal" computers, the production of software was largely taken away from the hands of specialists and was laid open to the inventiveness of every gifted individual. On one hand, this trend is beneficial because the structural engineer needs no longer a go-between in order to translate the analytical tools of his profession into computer programs, and can instead effect this translation himself. Potentially this could ensure a much greater knowledge of the possibilities and limitations of each particular program, so as to afford a much better use; but it also affords the birth of ill-conceived, error-ridden or simply uneconomical, unreliable software.
This software can, moreover, be easily "pirated" or transmitted informally among individuals, leading to widespread "wild-fire" diffusion of a faulty program before its shortcomings are ever detected. So the further problem arises as to how to reach every user of a faulty program and warn him (or her) of the attending risks.
A mechanism of protection against use of faulty programs (or misuse of otherwise "good" programs) could lay in strict requirements as to "qualification", by properly empowered technical bodies, of software to be used in structural analysis.
In other words, every computer - generated structural analysis presented to a technical bureau or to a Control Authority should indicate the kind of software used and quote the qualification - or "validation" - previously obtained by the software in question. Of course this system would present the drawback of putting obstacles in the path of recognition of brand-new, worthwhile software that has not yet been certified. The onus of proof would, indeed, lay with the authors of new software, who not always are in a position to obtain quick official certification. Moreover, official certifying bodies would have to be established and universally recognized. The more technologically advanced societies could in this way easily gain an irreversible lead on the rest of the world.
However, future installation of open-access computer networks and program libraries will undoubtedly call for a screening of software to be accepted into those libraries and put at the disposal of practically everybody. Again, IABSE could -and should- be in a position to be involved actively in any such enterprise, so as to protect the real interests of the civil engineering profession.

4. LEGAL AND RESPONSIBILITY PROBLEMS

Here we are leaving the purely technical field to enter very difficult, tangled questions; but also questions involving large interests and proportionate amounts of money.
Different kinds of risks and responsibilities are incurred in the use of computers and software.
For instance, incorrect or incomplete data can be used; a faulty program can be applied to correct data; finally, even with correct data and a correct

program, a faulty analysis can be performed (e.g.because the schematization used for the analysis does not apply properly to the case in hand), or the results can be incorrectly appraised.
Evidently, the error incurred and the approximations made could lead in some cases to underestimation of structural dangers; in some other cases, to overestimation of structural dangers, namely to uneconomical overdesign of structures. In both cases, economical damages are incurred.
But it is easy to figure out many cases in which it would be objectively difficult to locate the responsibility of an error: in case of a faulty program, clearly the responsibility lies with the program originators;but in the case of faulty application of an essentially "good" program, things are less clear. What, for instance, if the user's manual is written in a way that leaves open even slight possibilities of error? Can a fool proof user's manual ever be written?
What are the legal Authorities able to pass a competent judgment on the subdivision of responsibilities (and attending financial liabilities) between the different parties involved in a litigation concerning a disputed structural analysis? What kind of technical experts should be consulted or approached by the judiciary?
What kind of insurance, if any, could be provided against risks and liabilities connected with the use of computers and software?
These are but a few of the questions that spring naturally to mind.
No short-cuts are in sight; every step of the road will have to be painfully and painstakingly cleared of the many obscurities and side-issues involved. The interaction between structural engineers, hardware and software experts and lawyers could prove especially difficult to straighten out.

5. EDUCATIONAL PROBLEMS

Of course, the curricula of present-day civil engineers should include some basic courses on informatics, such as :
- numerical calculus
- electronic computers
- programming
- finite element structural analysis; and, in the near future, possibly also:
- CAD (computer-assisted design)
- CAM (computer-assisted management), etc.

But one cannot think that passing a few exams, however well-centered the relevant courses, can solve the educational problem in the sense of making the freshly minted engineer fully competent to use the computer in the right way and to the best possible advantage.
As in any field of practical endeavour, experience will be a vital ingredient of success and this can be supplied only to a very limited extent by learning institutions.
However, the study of case histories about successful, and especially unsuccessful, use of computers in structural engineering should be seriously considered.The taking apart, by careful critical analysis, of typical "failures" - not only structural failures, but planning and management failures - would provide the gifted student with some measure of sensitivity to the potentialities as well as the limitations and dangers of computer use.

6. COMPUTER GRAPHICS

Ever since the beginnings of civil engineering applications, the need for graphic representation of results was keenly and widely felt. The structural engineer is accustomed to assimilate the salient features of his analysis through diagrams, charts etc. Moreover, the final data, from which one defines the structures to be erected, must be put under the form of detailed scale drawings, according to certain established rules.

So there has been a steady pressure to obtain, as the end result of computations, just this kind of graphic output.

Hardware (plotters, cathode ray tubes with or without hardcopy attachment; with back -and- white or color capabilities, etc.) and software packages (perspective and assonometric drawings, with or without the removal of "hidden lines", etc.) have been, and are still being, produced in a wide variety of forms to satisfy the most diverse needs. It is not easy, for the average customer, to evaluate from a technical and economical viewpoint what is exactly the most convenient solution among those on the market, or, in the case of software, to decide whether his particular "solution" already exists or it must be developed anew.

Also the preparation of input data can be heavy on the utilizers, and also in this field graphic, semi-graphic or "interactive" products have been forthcoming in great abundance. From digitizing tables for F.E. mesh definition, to light-pens allowing one to modify data displayed on a C.R.T., to complete "interactive" system allowing the user to define and store his data on mag-disks, the choice is again a very rich one.

In a general way, it might be said that every effort directed at making the computer accept graphical input - through a proper interface - or to yield the results of numerical analyses under graphical form, is potentially able to improve the efficiency of man/machine communication: a critical link in the chain of the engineer's activity.

At the same time, it should be borne in mind that many commercially offered options (many tens of different color hues, for instance, on some C.R.T.'s ; characters available in many fonts on some plotter software, etc.) will not normally be of interest to the structural engineer.

A no-nonsense graphical system, with efficient yet spartan peripheral units, will, most of the times, cover all the essential needs of the profession.

The civil engineer of the future will, no doubt, be able to use as proficiently and adroitly his plotter and/or C.R.T. as his forerunner of yesteryear used pencil and T-rule, but with great savings of time and effort and with much greater efficiency in terms of data storage and retrieval. Graphical information will be kept and updated not as a collection of perishable paper sheets, but as a full-fledged "Data Base" on magnetic support.

7. COMPUTER-AIDED DESIGN AND MANUFACTURING (C.A.D.; C.A.M.)

If all the phases of design (from data collection and check to their input into appropriate structural analysis programs, to printing and graphical presentation of results, to eventual preparation of final drawings for actual construction) are carried out with the systematic, orderly use of appropriate hardware and software-packages, we can properly speak of "computer-aided", or "computer-assisted", design.

But the process of passing from the traditional, or "manual", design process to the C.A.D. is not a bed of roses. It calls for a complete, analytical, painstaking rethinking of the different steps of design; an accurate, unambiguous definition of all the elementary activities to be carried out, as well as of the logical order of all operations; a re-casting of all information, and information processing, in forms suitable to automatic elaboration. This is quite difficult, because in the "traditional" approach many steps are carried out more or less simultaneously, many difficulties are solved by means of intuition or previous experience, without even a formal thought process, etc. Moreover, the design produced in a C.A.D. environment should comply in a reliable, consistent way with existing official regulations, recommendations of practice and building codes. This entails the need for updating of the C.A.D. procedures every time these rules are changed or added to. All of the above requirements call for numerous constraints, hence for a certain rigidity of the whole C.A.D. process, as contrasted with the great flexibility achieved by experienced designers of old. How to reconcile the necessity for rigid definitions and information flow-paths with functional flexibility of use and results will be the great challenge of future C.A.D. systems and procedures.

When the flow of automatically processed information does not stop at the production of constructional drawings, but goes further to the numerical control of equipment and machines actually producing the end goods or operating on raw materials, then it is proper to speak of "computer-aided manufacturing".
This ultimate stage of penetration of the computer is made more difficult in the field of structural engineering than, e.g., in mechanical engineering, because of the often "once only" nature of the good to be produced and of the wide variety, and poorly defined qualities, of the materials and processes used. However, some of the constructional activities could easily be "computerized" even in civil engineering: suffice it to indicate the possibility of feeding automatic bending machines, for reinforced-concrete steel bar bending, with mag-tapes or punched-tapes produced by the computer during the design of the reinforced-concrete members.
It is to be noted, once again, that every further step into automation introduces additional constraints and rigidities. In the case in hand, it would become much more difficult to allow for the now quite commonplace practice of substituting -on the job site- bars of a diameter different from the required one.

8. INTEGRATED COMPUTER-ASSISTED MANAGEMENT OF CIVIL ENGINEERING CONSTRUCTION ACTIVITIES

Once design is automated (or, much better, computer-assisted!), and possibly, even certain activities at the construction site are linked to, and to some extent controlled by, a computer system, it is all too natural to think of integrating into this information-processing network all other pertinent informations, be they relevant to C.P.M. evaluations, planning, accounting, budgeting, financial flows, stocking and transportation, etc.

For instance, from the information introduced, processed and stored during C.A.D. activities it is easy to derive reliable estimates of material quantities (tons of steel bars, cubic meters of concrete, cubic meters of excavations/earth movements, square meters of scaffolding etc.) to be used in purchase planning, transportation scheduling, expense forecasting, financial planning etc.
Moreover, the possibility arises - thanks to the availability of so-called remote work-stations - of providing the C.A.D. environment with real-time site feedback (for instance, about on-site alterations to design made necessary by unforeseen local conditions etc.). In this way, the loop of information flow is closed and all pertinent data relating to the "as built" structure can be systematically stored for future reference and retrieval).
Once more, it is good to emphasize that constraints and additional rigidity would thus be built into the system: a failure of the computer-assisted system, to cite only a trivial instance, could disrupt the most carefully contrived construction schedule.
Also, it is good to keep in mind that the trend is doubtless in the direction of the above outlined "computer-assisted integrated management".
Solutions are being developed, and no doubt will be aggressively proposed and marketed, by hardware and software producers: there is no assurance, of course, that these solutions will be the "best" ones, i.e. those best serving the needs and purposes of structural engineers.

9. CONCLUSIONS

From all the foregoing, however sketchy and generic, considerations, the opportunity for the establishment of an International Working Commission on the part of IABSE stands out very clearly. Such a commission should attempt to monitor the developments in the field, through the dedicated work of its members, proper liaisons with kindred international organizations, through the dissemination of information on national journals, and, last but not least, through the convening of specialized Symposia, Colloquia and Special Sessions of the wider IABSE Congresses - as already done in the past.
On course, even this monitoring of the developments is all but easy.
Suffice it to consider the number of journals, magazines etc. exclusively devoted not only to computers, but more specifically to computer graphics, computer-aided design etc. Much less can it be hoped to "control" these developments through the agency of a W.C. which convenes once - or at most twice - a year and whose members work on an entirely voluntary basis.
To plan an orderly development of this field, indeed, a full-time study organization, duly staffed and funded, would be necessary.
On this sober, but, alas! only too realistic note, I choose to end this short presentation.