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Computer Usage in Building Structural Design

Utilisation de l'ordinateur dans la conception des structures

Computer-Anwendungen im Entwurf

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SUMMARY
This paper describes the present situation of computer usage in the field od structural design and presents several problems in computer application, such as ill effects of computer usage, program reliability and quality assurance, education in computers, and so on.

RESUME
L'auteur expose la situation actuelle de l'utilisation de l'ordinateur dans le domaine de la conception des structures et des bâtiments. Il met en évidence plusieurs problèmes liés à l'application de l'ordinateur, notamment: certains échecs qui peuvent lui être attribués, la confiance et l'assurance du niveau de qualité qui peuvent être accordés aux programmes, ainsi que la formation des utilisateurs.

ZUSAMMENFASSUNG
Dieser Bericht behandelt die gegenwärtige Situation im Entwurf und zeigt einige Probleme bei Computer-Anwendungen, wie z.B. schlechte Auswirkungen infolge Computergebrauchs, Programmverlässlichkeit, Qualitätsabsicherung, Ausbildung auf dem Computer, etc.

1. INTRODUCTION

Based on the experience and knowledge of building failures caused by earthquakes which occurred in these decades in Japan, research and development of a-seismic technology have been well in progress. Depending on the technological progress, the Japanese Building Code was revised in 1981, and accordingly, building structural design procedures are remarkably changed. In addition to examining that the member working stress is less than the material allowable stress, several other checks are needed under specified conditions. For example, the building ultimate resisting capacity to external forces should be estimated. Because of the new requirements, the amount of structural calculation is nearly doubled, and structural engineers can hardly carry out their work without the help of computers.

With such background, the structural calculation programs and computers capable of dealing with such new design requirements as mentioned above, are increasingly in demand. Therefore, the subscribers of TSS service, the users of computer bureaus, and mini- and micro-computers in house are remarkably increased for structural calculation usage. For instance, the number of subscribers of architectural and building engineering firms for DEMOS-E, which is a representative of TSS services in Japan, are over one thousand in January 1982. Further, computer bureaus, which give services of evaluated structural design programs, are on the increase. Micro-computers, excellent in operation and graphical presentation, are remarkably widespread among design firms and their number may exceed two thousands.

Through the diffusion and popularization of computer systems and structural design programs, a growing interest has been created in the problems on computer application to structural design, which are now under review among engineer circles. Namely, they are the problems on ill effect of computer usage, the problems on program quality assurance, the problems on responsibility associated with computer application and so on. In order to discuss and investigate these problems, AIJ (Architectural Institute of Japan) organized a preparatory committee in 1978 and set up a permanent committee in 1980. Under the auspices of this committee, symposiums are held every year. The one held in spring, 1982 was the fourth, in which these problems were keenly discussed, especially program reliability issue in the panel discussion.

In this paper, the present situation of computer usage in the field of building structural design is described first, and then problems on computer application, which are focussed through the discussion in AIJ committee and other circles, are presented.

2. THE FEATURE OF COMPUTER APPLICATION ON BUILDING STRUCTURAL DESIGN

2-1 Popularization of Computer Usage in Building Structural Calculation

As the result of legislative requirements of calculation of building ultimate resisting capacity based on collapse mechanism and due complication of structural calculation procedure, the amount of calculation done by structural engineers has definitely increased. The calculation amount may be doubled in comparison with that required under the conditions of conventional earthquake coefficient

method and during elastic and allowable stress analysis. Further, because of analytical conditions complexity, such as three-dimensional effect depending on eccentricity, the soil deformation effect under the footing and the effect of column-girder connection behavior, calculation work has a tendency to increase steadily. There has been a growing demand for computer usage in order to manage the calculation work efficiently and economically. The fact is confirmed by the increasing trend of TSS subscribers, computer bureau users and micro-computer sets. According to the recent investigation of computer application on structural design, the computer usage ratio in structural calculation ranges from 30% to 90%, and it may be recognized that computers are widely used in structural calculation work.

2-2 Development of Overall and Automated Structural Calculation Programs by Big and Competent Design Firms

Many big design firms, which have technological and economic potential to make up large software, set about developing the overall automated structural calculation programs for supplying the above mentioned computational demand. Most of these programs are qualified by the evaluation procedure and meet the administrative requirements. Up to 1981, the number of evaluated programs have become twenty-four series/thirty-nine programs. In these, six series/nine programs are supplied to the public users. Accompanying this program developing race, several issues on program making, such as efficient programming technique, program module parts, and so on, have been eagerly discussed. In parallel with the matters, such criticism has arisen that a few stereotyped programs will limit the diversity of structural planning and make structural design monolithic.

2-3 Popularization of Small Computer

In these days, the popularization of small computer is amazing, because of its performance improvement and lowering price due to electronics development. Supposedly, many architects and building engineers firms possess mini- and micro-computers. This tendency will be much more accelerated, as the building structure automated calculation programs for small computers are evaluated and easily accepted to administrative confirmation. While small computers can function as intelligent terminals connected to a big computer system, it can control its own terminals, such as graphic display equipment, plotters, and digitizers. Utilizing these multifunctions of small computers, construction of integrated and efficient computer system composed of small and big are also tried in design firms. For developing various possibility of small computers in building engineering, a sub-committee is organized in AIJ computer usage committee and starts to study the matters of small computers.

2-4 Distribution of Information, Data, and Programs

With the advance in computer hardware usage environment, there have been growing needs for comprehensive information, and a strong tendency toward open distribution of data and program in building engineering circles. However, the matter of information distribution is at the beginning stage, and it has many problems to be solved. For instance, evaluation of software and data, legal protection of program copyright, standardization of program documents, arrangement of distribution mechanism, and so on. For the sake of treating the issues of information distribution, a sub-committee has

been organized in AIJ computer usage committee. The sub-committee now conducts an investigation of data and programs, such as meteorological, earthquake wave data, and building engineering calculation programs, and plans to promote the distribution of these kinds of information.

2-5 A Growing Concern in the Problems on Computer Usage

Concerning such pivot issues that main procedure becomes black-box in the automated structure calculation programs and how engineers cope with this matter, there have occurred various discussions. They are such problems as responsibility of engineers and programs, abuse and misuse of programs, and education on computer usage in schools and firms. On the issue of program reliability, it was chosen as the main theme of the panel discussion in 1982 AIJ computer application symposium, and discussed from the various standpoints of developers, operators, users, and administrative officers. The important arguing points in the theme are as follows: highly reliable program making technology, confirmation method of program reliability and feasibility of social checking system, way of avoiding program misuse, knowledge of how to use and check programs, and responsibility limits between developers, agents and users.

3. PROBLEMS SUBMITTED ON COMPUTER APPLICATION

3-1 Ill Effects of Computer Usage

3-1-1 Abuse and Misuse of Programs

It is practically impossible for users completely to check and understand the functions and details of building structure automated calculation programs, because these sorts of programs have very complicated and highly developed contents, and besides, they are very big in size. (For example, DEMOS-E BUILD-1 has eleven hundreds kilo statements in FORTRAN) The black-box phenomena of programs cause its misuse because of deviating from the basic preconditions and scope of the programs. Meanwhile, it is a matter of deep concern that unexperienced engineers use automated calculation programs blindly and design structures directly under instructions from the computers. This means abuse of programs. Furthermore, there is another abuse of programs such as applying programs unreasonably after unnatural modeling of design objects.

3-1-2 Monolithic Standardization of Design and Obstruction of Engineer Advancement

Over dependency on programs produces a tendency to do structural design fitting in with the program function and scope, and to confuse means with ends. Consequently, there increases uncharacteristic structure with poor consideration by blindly depending on the evaluated programs. Engineers may become skillful in applying programs. However it is hard for them to develop design ability, such as, of modeling and analyzing structure correctly, and getting at the essence of its behavior.

3-2 Program Reliability and Quality Assurance

3-2-1 Reliability

On program reliability, it is recognized that there exist two facets: (1) correctness of program itself, (2) correctness of program using design. First problem deeply depends on developers.

For decreasing mistakes at designing and programming stages, highly reliable program designing technique, systematic program testing, and exact program documentation are necessary. Second problem is mainly related to users. It is necessary that program users avoid program misuse and check computing results. For correct usage of programs, reliability of users' manual and support of consulting engineer skillful to the programs are important. In Japan, the evaluation system performs an important role to confirm the automated structure calculation program reliability. With regard to program documentation, the sub-committee of document standardization in the AIJ committee has investigated various issues and prepared a guide book "Documentation for program development, maintenance, and usage", which is publicized at 1982 symposium.

3-2-2 Quality Assurance

It is being understood that one hundred percent debugging of programs is impossible in practice, but consciousness of users is severe on program bugs yet. Program users require always to be informed on bugs, and sometimes, to go back to the past and check bug influence. In general, programs debugging and quality improvement are completed the faster, the more frequently programs are used. Furthermore, it can be said that programs service, together with consulting engineer's service, is the best quality assurance.

3-3 Responsibility on Program Usage

An idea that the responsibility on program usage belongs to users, is being fixed. In case of computer bureaus, such contract between user and bureau is becoming popular in Japan that the responsibility of the bureaus on program usage is reasonably limited to, at most, computing charges.

3-4 Program Development

3-4-1 Input Issue

Input data mistakes frequently occur, because the sort and quantity of input records are many, and input regulation is rather complicated, and further, users manual explaining input records is liable to be not understandable. It is said that input data correction frequency necessary to be accepted to programs is from two or three times at least, to five or six times at most. Recently, micro computer is used for input data generation and syntax check especially applying its graphic display function. This technique of input data preparation is very efficient.

3-4-2 Output Issue

As for program output, it is not readable as a structural calculation document, because of a large amount of output and lines of mere characters. According to the use of document, output items should be arranged as serviceable as possible. Even in case of printers, it is necessary that readable output presentation, such as graphically arranged output similar to building plan and plane frame shape is thought out. It is a matter of welcome that graphic and diagram output such as by graphic displayer and plotter is developed.

3-4-3 Program

Self development is ideal, but it is economical to use others' programs when we consider developing and maintenance cost. In case of using others' programs, the programs which are of usually overall

automated structure calculation systems, are package type, and cannot accept users' option, such as linkage of users' sub-programs to the host programs. From this viewpoint, a module type program wherein users can easily link his own module programs to host system and compose a tailor-made program is desirable. Furthermore, most of automated structure calculation programs are generally big in size, and they are redundant in case of rough check at primary design stage. Therefore, such CAD type programs are desirable wherein engineers can freely insert his judgment into the program through man-machine communication in the middle of calculation.

3-5 Evaluation of Programs

It is a general viewpoint that the program evaluation system is not almighty, but effective to guarantee reliability and quality of programs and this is a kind of necessary evil. Especially, building officials strongly support the evaluation system, for the reason that it is difficult to check correctness of the program submitted to officials for building permits. In case of structural calculation being done by computers, building officials usually insist on the use of the evaluated programs. Against this point of view, there are quite a few whose opinions are that responsibility of structural design is not on computer programs but on engineers. Further, there is such another opinion that the procedure of program evaluation is not so clear and accurate.

3-6 Education on Computers

There are such strong opinions and demands that a subject on computer application technology should be added to the curriculum for building engineering. However, education on computers in schools is on a trial stage and far from systematization. Now, it stays mainly in the training level of programming languages, such as FORTRAN. People expect that reasonable computer education should be given in schools for engineers to acquire ability of choosing applicable programs and using computers fast and correctly in practical work. In AIJ, a sub-committee on computer education has been organized and started various activities, such as surveying the state of the art on computer education in schools, setting up a standard curriculum, and editing textbooks for various levels.

4. CONCLUSION

In this paper, the problems on computer usage, focussed on structural design, are discussed, and the demerits of computer usage are exclusively emphasized, but these negative effects never reduce the merits of computer usage at all. On the contrary, it is believed that computer usage, by overcoming the demerits, can contribute to the advancement and rationalization of structural design. The presentation of the problems mentioned in the paper were initially triggered by building officials about ten years ago, and the discussion was held from administrative point of view. At present, the problems are widely investigated in the field of AIJ committee. Few practical solutions are presented in the paper, however steady countermeasures have been considered and they will produce fruitful results in near future.

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Appendix A

Activity of Computer Usage Committee in AIJ

1. Computer usage committee is composed of four sub-committees and their activities are as follows:

(1) Sub-committee of information distribution
 a) Objects: Facilitation of information transfer, such as programs, data on architecture and building engineering.
 b) Results: Surveying the state of the art on computer usage, programs and data in architectural and building engineering firms, and the results being publicized.

(2) Sub-committee of program documentation
 a) Standardization of program documents.
 b) Preparation and publicity of program documentation guide book "Documentation for program development, maintenance and usage". (Ref. Appendix B.)

(3) Sub-committee of education on computer usage
 a) Survey of computer education in architectural and building engineering course of technical school, college and university, and proposal of computer disciplinary curriculum.
 b) Publicity of the surveying results for various educational organizations, and preparation of textbook "Computer application series for architecture and building engineering".

(4) Sub-committee of small computer application technology
 a) Survey and investigation of the matters peculiar to small computer, such as the state of the art of hardware and software, documentation, algorithm, computer aided design, and control technology.

2. Symposiums held by the committee are as follows:

No.	Year	Participants	Papers	Themes of Panel Discussion
1	1979	659	104 (32)*	—
2	1980	600	86 (33)	Information distribution on computer application in building engineering.
3	1981	466	61 (27)	The present situation and the future of education on computer usage.
4	1982	448	64 (27)	1) Investigating the issues on new aseismic structural design code 2) Program reliability

Note. * The figure in parentheses indicates the number of papers on structural design.

Appendix B

Program Documentation for Program Development, Maintenance, and Usage (How to make a good program) (Draft)

Sub-committee of program documents has proposed a guide book on program documentation for improving program reliability and facilitating program distribution. In the following, the table of contents is shown.

1. Necessity of program documentation
2. Variety of documents
3. Documents at program developing
   - 3.1 Surveying and planning stage (Development plan briefing)
   - 3.2 Basic design (Basic design specification)
   - 3.3 Composition design (Composition design specification)
   - 3.4 Detail design (Detail design specification)
   - 3.5 Coding (Program list)
   - 3.6 Module program test (Module test report)
   - 3.7 Integrated program test (Integrated test report)
4. Program manual
5. Users manual
6. Description of program summary

   Standard program description form for common knowledge and program information transfer.

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