I A B S E	**COLLOQUIUM on:**
A I P C	**"INTERFACE BETWEEN COMPUTING AND DESIGN IN STRUCTURAL ENGINEERING"**
I V B H	August 30, 31 - September 1, 1978 - ISMES - BERGAMO (ITALY)

Professional Responsibility of Engineers

Responsabilité professionnelle des ingénieurs utilisant les moyens informatiques

Verantwortung Der Ingenieur Die Datenverabeitungsmittel Benützen

G. DEPREZ

Docteur en Sciences Appliqées - University of Liège
Director of CEPOC
Liège - Belgium

Summary

As it is practically impossible to check a computer program and to garanty the accuracy of the results only through computation it is nowadays generally admitted that the Consulting engineering overtakes the complete responsibility of the structures for which he ordered computer calculation, and the complete responsibility is a responsibility of results. The calculation center has the duty of performing the calculation with greatest care and to inform the consulting engineers of the limits of the used means (duty of means).

Résumé
Compte tenu de l' impossibilité pratique de vérifier un programme de calcul sur ordinateur et de garantir la précision des résultats par moyen informatique seul, il est actuellement admis dans la plupart des pays que l'ingénieur conseil supporte l' entière responsabilité des ouvrages pour lesquels il fait effectuer des calculs sur ordinateur et qu'il a l' entière responsabilité de la vérification des résultats. Sa responsabilité est une responsabilité de résultats. Le centre de calcul a l'obligation d' effectuer les traitements avec le plus grand soin et d' informer le bureau d' étude des limites des moyens employés (obligation de moyen).

Zusammenfassung
Da es praktisch unmöglich ist eine Berechnung auf Komputer so wie die genauichkeit der Ergebnisse allein durch Datenverarbeitung zu überprufen ist es zur Zeit in den meisten Länden allgemein angenommen dass der beratender Ingenieur die ganze Verantwortung der Bauten für die er komputerrechnungen ausführen lässt trägt und dass er die ganze Verantwortung der Uberprüfung der Ergebnisse übernimmt. Seine Verantwortung ist eine Verantwortung der Ergebnisse. Das Rechen institut hat die Verpflichtung die Datenveravarheitung mit der grössten Sorgfalt auszuführen und dem Ingenieurbüro die Grenzen der gebrauchten Mittel mitzuteilen. (Verpflichtung der Mittel).

1. PRELIMINARY NOTE

Present consideration can be applied to problems met in complex scientific and technical applications. They cannot be extended to accounting and management problems.

Following points will be developed
- purpose of a computer run and its implacations,
- control of results after a computer run,
- tasks of a consulting bureau and computer center seen as distinct or common operations,
- respective responsibilities flowing from the performed tasks.

2. COMPUTER RUN

2.1. Computer and program

A computer is a tool having the capability to perform very quickly a large number of computations and data processings according to a previously coded procedure stored on suitable support. Every coded and stored procedure is called a program.

Therefore :

- a computer can only help if it is given a program defining the flow of operations to be performed to solve the submitted problem ;

- solution of a problem by means of a program is performed without outside intervention ; all decisions to be made must have been foreseen and coded within the program which will make use of the given data as sole information source.

Programs constitute the software accompanying the hardware, i. e. the computer and its peripheral equipment.

2.2. Programs and purpose of a computer run

The writing of a program requires the coding of a calculation procedure based on methods and calculation rules either existing or invented by researchers.

No outside interference being possible during a program run, this procedure must be autonomous ; only information planned during coding can and must be provided as data.

The defined procedure must be coded and stored on informatic support.

In practice, limits imposed by the present state of science, synthesis capability of human mind and hardware contraints prevent the writing of a general purpose program to compute any structure while taking into account all possible types of behaviour.

Except for a few standard structures to be analyzed by a standard method, only program computing some types of behaviour for some parts of structures do exist.

2.3. Correctness of a computer run

The complexity of the procedures to be used to solve these problem leads to programs containing from a few hundreds to several tens of thousands of statements.

No exact method enables one to check the correctness of these programs and the only available checking method consists in testing the program in the maximum number of cases which can be verified by other means in order to acquire a presumption of correctness becoming better and better and tending towards certainty.

Besides, fundamental methods upon which programs are based concern ideal behaviours for which an exact or approximate solution can be found by means of a mathematical theory. If one takes into account the fact that most available methods give approximate solutions and that, even if a correct solution exists, it can only be approximated because of the limitations on computer arithmetic, one must be aware that the computed solution will never be exact. The accuracy will depend upon the method being used and the order of magnitude of numerical values dealt with.

On the other hand, the use of a computer program implies that

- the structure to be studied must be fitted to the ideal model for which calculation method is available and the program exists.

- the set of data must be prepared for this model respecting the order and presentation requested by the program : they must be recorded on the appropriate support. This tasks leads to measuring, writing, coding and verifying numbers of data which can reach in the thousands. In spite of all safety measures, it is acknowledged that a very small percentage of errors may remain after performing these tasks ; provided they have significant effects, they will be detected because of their consequences on the results of the computer run.

Finally, one cannot forget that computers and their peripherals are subjects to accidents and breakdown as any piece of equipment. Safeties built in by manufacturers are such that most of these are announced to the user or stop execution.

2.4. Constraints imposed on the computer user

The lack of an exact method to check a program, the use of approximate calculation methods, the limits on arithmetic accuracy in the computer, the hypotheses required by the idealization, the risk of undetected errors during data preparation oblige to state that a computer analysis can never be considered as an exact analysis of a structure.

The user of a computer run has the duty to check that the results he receives are satisfactory for the intended purpose at a given point of a consulting job

Several methods exist to verify that. They differ according to the type of used procedure ; their underlying principles are recalled in paragraph 3.

After this realistic and unremitting presentation of the risks involved in a computer run, it is useful to compare them with respect to traditional calculation.

First a computer analysis enables one to find a solution to the analysis of different types of structures the behaviour of which was unmanageable by hand calculations. Second, when used for solutions where it competes with traditional means of calculation a computer analysis is much more efficient, accurate and less error prone than the former methods. This is of course what gives justification to its use. However its solution are more global and error can lead to more severe consequences. This entails the necessity of careful checks which generally happen to be simpler than hand calculations when available verification means are taken into account.

Possible verification means depend on the type of analysis ; they are within the grasp of every engineer. The underlying principles are recalled herebelow.

3. CHECK OF RESULTS GIVEN BY THE COMPUTER

3.1. Preliminary remark

Within the frame of this short note, it cannot be considered that well defined directives be given to the users concerning the results of such or such problem. This could be the purpose of further works of the task group.

One restricts the present paper to hints about :

- the presumptions to assess the quality of informatic means ;

- the verification principles

- the necessary informations to verify results

3.2. Presumptions concerning the quality of informatic means

These can take place at the level of
- the bureau or firm in charge of the analyses

- what is its repute ?
- what is its main sector of activity ?
- does it frequently solve this type of problem ?
- what help does it offer in data preparation and checking of results ?

- the program being used :

- who wrote it ?
- what method is it based upon ?
- is it frequently used ?
- for what kind of problem is it used ?
- on what computer is it processed ?

3.3. Verification principles

The implementation of these principles implies the knowledge of the analyzed behaviour and the method followed in the program.

It also requires an examination of the results given by the computer and their physical interpretation in structural terms.

All these verifications must not be simultaneaously performed ; it is the designer's responsibility to assess the risk of omitting some.

1st principle :
Verify normal excution of the program and fitness of hardware.

2nd principle :
Check agreement between
-the analyzed structure and its idealization,
-the idealization and the data,
-the data and the results.

3rd principle :
Verify physical soundness of the solution
This verification can bear upon, among others :
- static equilibrium,
- continuity or predictable discontinuities of internal forces,
- continuity or predictable discontinuities of displacements at different point of the structure.

4th principle :
Verify numerical results
- by comparison with previously obtained results for similar structures (experience),
- by comparison with a preliminary design or approximate results obtained by traditional means,
- by spot checks,
- by comparison with another analysis perfored by means of another computer program.

3.4. Data needed for the verification

For the verification of a computation to be possible, it is required to dispose of :
- the drawings of the structures
- the idealization scheme of the structure, including the supporting layout and the loading,
- information about the type of behaviour analysed by the program,
- a description of the analysis method used,
- information on how to interpret the computer listing :
  - meaning of symbols,
  - numerical formats,
  - units,
  - sign conventions,
- the listing of the treatment, which must contain :
  -the full set of input data,
  -the requested results,
  -intermediate results enabling the verifications mentioned in 3.3.
- an interpreted output, where only the useful values will appear, eventually composed by manual evaluation

While this is not mandatory, it is also very useful to dispose of automatic graphical output. Such drawings give the results under a synthetic form very convenient for verification. In particular , the idealised layout as introduced into the computer, force distribution diagrams and drawings of deformed shapes allow safe and quick checks which are tedious if the drawings must be handmade.

4. RESPECTIVE MISSIONS OF THE CONSULTING FIRM AND THE DATA PROCESSING CENTER

4.1. Preliminary remark

There are presently in the different countries represented in the IABSE organizations of various form and by laws which perform studies or computations using date processing. The functions they perform are sometimes difficult to compare.

In order to allow a comparison of these activities, it is necessary to tackle first a basic case where the analysis and data processing aspects are clearly distinct and then to examine how such activities may interfere within organizations performing both activities simultaneously, This method also allows to define the tasks of the different branches of a given organization.
The basic case will be that of a consulting firm using the services of an external computing center.

4.2. Mission of the Consulting bureau

The mission of a consulting bureau consists in the elaboration of a project on account of the customer and the control of the realization. The elaboration of the project involves design, anlaysis, calculation, drawing...
which result in the final plans used for execution.

The project progresses by successive steps ; preliminary studies, draft, project. it is during these steps that the project takes shape, the calculations become more refined and the different types of behaviour are examined.

The justification of the chosen solution and the set of calculations are recorded in the report established by the Consulting bureau.
This note is eventually submitted to an administration or to a controlling office.

The work of the Consulting bureau is rewarded on the basis of a percentage of the cost of the structure.

4.3. Mission of the data processing Center

A data processing Center writes programs or implements existing programs on a computer. The Center makes the program maintenance, brings the improvements needed by the accumulated experience or the evolution of the hardware, writes the user's manuals, runs the programs, records the eventual malfunctions, corrects the programs accordingly when possible and eventually brings some help to the user for the preparation of input data and the interpretation of results.

At the data processing Center level, the calcultation of a structure consists in running the program or programs selected by the Consulting bureau to analyse some behaviour, and eventually, in helping in the preparation of input and the interpretation of output.

The results of the calculation are recorded on listings and drawings produced by the computer's peripheral devices, and transmitted to the Consulting bureau.

The work of the data processing Center is rewarded on the basis of the resources used : use of the computer, of peripheral units, preparation of input, analysis of output. Such costs are independent of the cost of the structure and depend

only on the importance of the data processing Center resources involved.

4.4. Mixed missions

Some organizations perform mixed missions which are generally of on of the following forms :

a)Consulting bureau with its own Computer Center. Its is obvious that in this case, the main function is that of Consulting bureau while the data processing branch is just a tool.

b) Bureau specialised in computer-aided studies, limiting its activity to some types or parts of structures, and working as a contractor for other Consulting bureau.
What distinguishes this type of bureau from a data processing Center is that the study of the structure is entirely made by the bureau. The bureau is enti - rely free of the means to use to perform the study ; it must also select the behaviours to analyze and the assumptions to make. It acts in fact as a sub-contractor.

c) Society of one of the previous types a) or b), offering data processing services in parallel with its main activity. This case occurs for instance when a Consulting bureau puts at the disposition of another bureau its own programs without participating to the study. This may be an exceptional, occasional or current activity and it is necessary that no confusion may exist concerning the performed mission.

5. RESPONSIBILITIES OF THE CONSULTING BUREAU AND THE DATA PROCESSING CENTER

5.1. Responsibility attached to the mission of the consultant

Rewarded on the basis of a percentage of the cost of the structure, this mission requires that the adequate means be activated to complete it.
In particular, the Consulting bureau must : select the behaviours to be analysed by computer, select the data processing Center according to its possi-bilities, decide on the expenses which may be allocated to data processing, fix the assumptions, chooses an idealization, interpret the computer results. Being alone able to judge of the adequacy of the modelization, of input and output data, it is its responsibility to check the results coming from the Computer and, if needed, to refuse them. It must have the necessary means to perform this check and it belongs to the bureau to require them from the data processing Center.

5.2. Responsibility attached to the mission of the data processing Center

Rewarded on the basis of the cost of the prestations, the data processing Center must take any measure required by their good execution. This implies the obligation for the Center : to check the error-free execution of the program by a sufficient number of tests ; to bring the outmost care to the preparation of input data, to make sure that the hardware is in perfect working condition and that the computation was executed normally, to place at the disposition of the customers all information needed for checking and interpreting the results, to rerun any processing where an anomaly imputable to the Center might be detected, to respect its engagements about delay and prices, to inform clearly the Consulting bureau on the nature of its prestations.

It is important to precise that a program in perfect working condition may give useless results for some given numerical values. It may therefore be impossible to the data processing Center to furnish useful results to the Consulting bureau and it is important that the retribution process in exceptional cases be defined in advance.
In the absence of precisions on that point, it is normal to admit that the Consulting bureau might refuse to make any payment for the dubious processing.