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The Documentation and Cheking of Computer Aided Engineering Computations

Documentation et contrôle des calculs de structures réalisés à l'aide de l'ordinateur

Dokumentation und Kontrolle von Tragwerkberechnungen mit Hilfe des Computers

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Summary

The increasing use being made of computers in engineering analysis and design leads to special considerations in the documentation of the computations and the procedures to be adopted in checking. This checking may cover both the computations and the computer programs used. The adoption by both the original designer and checker of a common basis for documentation and checking would ensure that checking proceeds much more expeditiously. ACADS (The Association for Computer Aided Design) has published a Recommended Standard for Documentation and Checking of Computer Aided Engineering Computations. The background to, and reasons behind, the publication together with a summary of its contents are discussed.

Résumé

L' emploi croissant de l' ordinateur dans le projet et le calcul de structures conduit à une documentation particulière pour le calcul à l'aide de l'ordinateur et pour les procédures de contrôle. Ce contrôle peut concerner aussi bien les calculs que les programmes de calcul eux-mêmes. L'emploi par le projeteur et le contrôleur, d'un document de base identique permettrait un contrôle plus rapide. ACADS (Association for computer aided design, Australie) a publié à cet effet un projet de recommendation. L' historique et les raisons de cette publication sont présentés, de même qu'un résumé de son contenu.

Zusammenfassung

Die verstärkte Anwendung von Computern in Entwurf und Berechnung im Ingenieurwesen führt zu besonderen Ueberlegungen über die Dokumentation dieser Berechnungen and über die Kontrollmöglichkeiten. Die Kontrollen können sich sowohl über das Computerprogramm selbst oder über dessen Resultate erstrecken. Die Anwendung durch den Entwerfer und den kontrolleur dieser gemeinsamen Basisdokumentation, erlaubt eine raschere Kontrolle. ACADS (Association for Computer Aided Design, Australien) hat eine Norm für Dokumentation und Kontrolle von Tragwerkberechnungen mit Hilfe des Computers empfohlen und herausgegeben. Die Begründung und Zusammenfassung des Nrom-Inhalts werden dargestellt.

1 INTRODUCTION

The checking of computer aided computations is part of the total checking process to which engineering designs are usually subjected. The purpose of checking is to detect and correct errors and omissions and to ensure that the design complies with the appropriate statutory and/or code requirements. This reduces the possibility of costly alterations either during construction or manufacture or during the life of the structure or article. It also reduces the possibility of failure or collapse.

The certification of structures, by an organisation independent of the original designers, is a procedure well established in the shipping industry and it could well become common practice elsewhere. In the U.K., offshore installations (e.g. oil drilling platforms) now require certification and the implications of this are very much the concern of design consultants (Ref. 1). Many engineers feel that the design organisations' acceptance of the normal professional responsibility is sufficient and in the U.S.A. the seal of the registered engineer or architect is used for this purpose.

The use of computers and computer programs in no way alters the normal professional responsibility of the design engineer. However, in using such sophisticated tools, he should have some guidelines and standards in order to assess the program's reliability and suitability for his particular problem. Except for the very simplest of programs, it is not feasible for the design engineer thoroughly to check its operation. He also requires guidance on how to incorporate program output in his computations and to give sufficient, though not excessive, detail of the programs used. This provides both a valuable permanent record of the computations and also enables a checker to perform his task efficiently.

2 EXISTING PUBLICATIONS

The validation of computer programs and recommendations on documentation have provoked much discussion in many countries and several articles on the subject have been published. These may be divided into two broad categories, though of course some overlapping does occur:

(a) Problem Documentation
(b) Program Documentation

(a) Problem Documentation

This is defined as the computations, submitted to a checking organisation, which may contain relevant parts from (b). This documentation is done by the program user.

(i) N.C.D.C. - Canberra

The National Capital Development Commission in Canberra have a standard form in which a checking organisation certifies the structural sufficiency of a design. No specific mention is made of computer programs, though they are undoubtedly frequently used in designs. The checking engineer takes full professional responsibility for all aspects of the adequacy of the structural design, no matter what design aids are used.

(ii) Melbourne City Council - Building Surveyors Department

The Building Surveyor has published Draft Guidelines for the submission of structural drawings and computations. A very small section is devoted to computer calculations and summarises the requirements only in broad outline.

(iii) A.C.I. - American Concrete Institute

The A.C.I. initiated a survey in 1967 (Ref. 2) to ascertain the requirements of various city building departments for documentation of computer programs for the structural design of reinforced concrete. These requirements, as might have been expected, varied considerabily between cities. As a result of the survey, the A.C.I. published (Ref. 3) its recommendations on "Documentation for Computer Calculation Submittals to Building Officials". These were very

brief and amounted to less than 200 words.

(iv) U.K. - Engineering Institutions

A Joint Committee of the Institutions of Civil, Municipal and Structural Engineers in the U.K. submitted a memorandum (Ref. 4) on checking of structural designs submitted under Building Regulations. This suggested the Certification of all structural designs and "Evidence of separate scrutiny and checking of designs and calculations, including computer programs, by professional design staff of comparable qualifications to those carrying out the original work".

(b) Program Documentation

This is defined as the documentation for a particular computer program. This documentation is done by the program author or licensee rather than program user.

(i) A.S.C.E.

A subcommittee of the A.S.C.E. Soil Mechanics and Foundations Division has published their recommendations on "Engineering Computer Program Documentation Standards" (Ref. 5). This is an excellent detailed Standard and there are only a few minor items which require clarification.

(ii) U.K. experience

O'Brien (Ref. 6) succinctly summarises the problems facing the inexperienced engineer computer user and calls for the establishment of a "Consumer's Association" for the validation of computer software. He quotes a U.K. Committee (Ref. 7) as suggesting that the professional bodies concerned in any engineering discipline could act in this capacity for their own field.

(iii) Department of the Environment - U.K.

The Department of the Environment in the U.K. is proposing standardised test problems for checking the programs of consulting engineers where the D.O.E. is the client. The three factors to be checked are:

.1 Numerical accuracy
.2 Engineering assumptions
.3 Correctness of logic

A Report of a meeting on this subject (Ref. 8) revealed concern about excessive standardisation and mentioned a CIRIA project to produce a standard for program documentation.

(iv) Canada

The Association of Professional Engineers of Ontario has published a Document (Ref. 10) which has three sections:

.1 Guidelines to Standards of Practice for the use of Computer Programs in Engineering.

.2 Characteristics of a Good Computer Program for Engineering.

.3 Recommended Documentation of Computer Programs for Engineering.

3 NEED FOR COMPREHENSIVE DOCUMENT

From the preceding section it can be seen that, although much discussion has taken place, little of direct use to the practising engineer or program writer currently exists - the two exceptions being the A.S.C.E. and Canadian recommendations (Refs. 5 and 10). However both these concentrate heavily on the program, rather than the problem, documentation. The A.C.I. recommendations (Ref. 3) are commendable but not given in sufficient detail.

ACADS has published a document (Ref. 9) covering both Problem and Program documentation though the latter coverage pertains only to that generally required by a checking engineer. It is intended to publish a separate, comprehensive manual on this topic at some later stage but, as mentioned above, the A.S.C.E. and Canadian recommendations (Refs. 5 and 10) would appear to be well formulated and worthy of consideration.

4 ACADS DOCUMENT - HISTORY

ACADS is an Australia wide Association of technical computer users with several Affiliates in other countries. In August 1973 a Draft Document was issued to the then forty eight ACADS member organisations for critical review. As a result of the comments received, the Document was revised and published in August 1974. It has been given wide circulation, over six hundred copies having been distributed.

The Document has been accepted in the State of Victoria as the Standard referenced in Amendment No.6 (3/9/1976) to the Uniform Building Regulations and has received widespread interest from the U.S.A. and U.K. It is available from ACADS, price $10,00.

It is not presumed that this Document is the last word on the subject and ACADS will consider all comments received in order that it can keep abreast of new developments. Indeed, the Document is about to undergo minor revisions.

5 ACADS DOCUMENT - CONTENT

The Document comprises ACADS recommendations on the standards of documentation and checking of calculations carried out with the aid of computers. It discusses the purposes of checking, nature of computer programs and possible sources of errors in computer aided design. Methods of checking computer programs and standards for computer output are also detailed. It is intended to be an easy to use reference manual for all engineering designers and checkers using computers.

A summary and discussion of the itemised contents is given below:

(a) Preamble

The purpose and methods of checking are

outlined and it is stressed that responsibility for the design rests squarely on the shoulders of the design engineer. This responsibility is in no way diminished by any amount of checking which may have been carried out by others, or by the presence or absence of any type of warranty on any computer programs used. Most computer bureaux and program authors specifically disclaim any liability or consequential loss. However there are engineers who are beginning to feel that, with their increasing dependence on computer programs, some form of liability should fall on program vendors if they have failed to maintain "adequate standards". These Standards would have to be defined but the ACADS Document would provide a good basis.

(b) Problem Documentation

This deals with the particular use of the computer program(s) for the specific problem.

(i) Problem definition

The basic problem which was solved should be clearly stated; this should include design data and functional requirements.

(ii) Modelling - link between problem and computer application

It should be clearly shown how the problem has been modelled for computer analysis. This may include justifications for the choice of certain parameters: e.g. coefficient of subgrade reaction for a foundation problem.

This can often best be done in diagrammatic form and in complex analyses and simulation problems additional explanations of techniques used may be necessary.

Computer programs can only give the answers to the problem as stated and realistic modelling is a prerequisite for meaningful results. The extraction of the essential elements and their incorporation in the mathematical model are almost as much an art as a science and this is where engineering judgement and experience are essential.

(iii) Computer printout

The problem documentation may include all or only relevant extracts from the printout; however the complete printout should always be kept for record purposes. Printout should include all input data used.

(iv) Design values

The design values adopted as a result of the computer application should be clearly set out.

(v) Checking

The documentation should clearly show where and how checking has been carried out as part of the design process prior to submission of the computations for independent checking. This enables the checker to gauge the extent and nature of prior checking; particularly as to whether it has been of an arithmetic or more "engineering" quality.

(c) Program Documentation

This is the documentation of a particular computer program.

(i) General requirements

The precise version of the particular program used must be clearly stated and the documentation should enable a checking engineer (in conjunction with the problem documentation) to assess:

.1 The technical content of the program and its suitability for the problem for which it was used.

.2 Whether the data input was appropriate and correct.

.3 Whether the output was commensurate with the design requirements.

.4 Whether the program functioned correctly.

(ii) Types of program documentation

There should be four types of documentation, each one suited to a particular degree of interest. As a person identifies an interest in a program he will find a need to progress to a more detailed level.

.1 Program Description: a brief 1-4 line summary, suitable for inclusion in a comprehensive program list.

.2 Program Abstracts: three separate one page abstracts of the program features from which a potential user should be able to judge the program's likely applicability to his problem. These abstracts are detailed in Ref. 11.

.3 User manual: to enable a user to code the input and interpret the output.

.4 Full documentation: full details of the program listings, flow charts etc.

(iii) Extent of program documentation required.

For the purposes of inclusion with problem documentation, only relevant items of the above are necessary, although a checker may need access to more detailed information on request.

The Program Abstract(s) should always be included and these will detail

precisely which program has been used; their restriction to one page facilitates incorporation. It would be infeasible to include a user manual with each use of a program but a checker must have access to one if requested, either from the designer or a computer bureau. A similar requirement applies to the full documentation, but in many cases listings are not generally available as they are of a proprietary nature.

(d) Methods of Checking

There are two basic methods available for checking calculations carried out with the aid of computers:

(i) Independent recomputation

This requires that the original problem is recalculated with or without the aid of a computer. If a computer is used then an alternative program should preferably be used.

(ii) Sensibility and spot checks

This method implies that a general, rather than a detailed, check is performed.

Sensibility checks can be used to show that computed results are rational and consistent with the input data. For example the calculated deflection profile of a structure should be consistent with the loads applied.

Spot checks can be used to verify in detail that certain parts of the computations are logically consistent. For example joint and overall equilibrium in frame analyses.

(e) Use of Methods of Checking

(i) Common applications

Where a computation uses a program which has previously been successfully applied to very similar problems, the checking engineer may rely on method (d)-(ii) (Sensibility and spot checks) above for checking purposes.

(ii) Special or new applications

Where a relatively new program or system is used or where the application differs from previous use of the program, independent recomputation is more appropriate and indeed may be the only reliable method of checking.

(f) Reliability of computer programs and computers

Any checking of a computer application must depend on assumptions regarding the reliability of the programs and computers used. The Document has four Appendices dealing with these and other relevant matters. These may well be part of the checking engineer's responsibility, and should also be considered by the design engineer when choosing an appropriate program to use.

(g) Appendices

These provide supporting or substantiating material.

(i) Recommended Presentation of Computer Printouts.

This details the requirements to be fulfilled to enable computer printout to be used correctly and meaningfully.

(ii) Recommendations for Checking and Testing Computer Programs.

(iii) The Nature of a Computer Program.

(iv) Possible sources of Error in Computer Results.

These are due to computer, computer program and use of program related factors. These factors are detailed and their significance discussed.

The final Appendix is a "Checklist for the Documentation of Computer Aided Computations".

6 CONCLUSIONS

Computers are being used more and more extensively in engineering design. Their meaningful incorporation into the design process requires that a generally accepted standard for the documentation and checking of computations be available: a recommended standard has been published by ACADS. That the computer programs be documented comprehensively, at various levels of detail, is of paramount importance if they are to be used correctly and effectively. Good program documentation and validation by independent organisations should ensure both better programs and less duplication of program writing and effort.

7 ACKNOWLEDGEMENTS

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