Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 13 (1988)

Artikel: Use of computer simulation in structural design education

Autor: Addis, W.

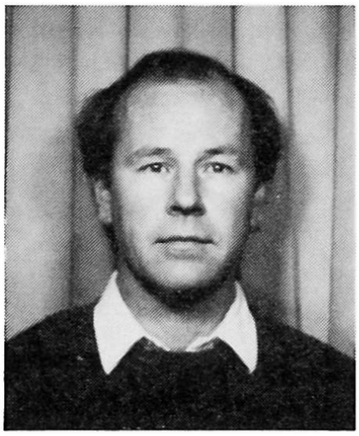
DOI: https://doi.org/10.5169/seals-12994

Use of Computer Simulation in Structural Design Education

Enseignement de la conception des structures par simulation à l'aide de l'ordinateur

Das Lernen des Tragwerkentwurfes durch Computersimulation

W. ADDIS
Lecturer
Reading University,
Reading, UK



Bill Addis studied engineering and philosophy at Cambridge University. Following some years as a designer he has been researching into structural design and lecturing at Reading for 9 years.

SUMMARY
The paper proposes an alternative view of engineering design to the idea that it comprises "putting theory into practice". The notion of the design procedure is introduced and used as the basis for the simulation of the process of structural design. The author's educational use of simulation is summarized and related to the needs of professional structural designers.

RÉSUMÉ
L'exposé propose une optique différente de la conception classique des structures à "mettre la théorie en pratique". L'idée d'une méthode de projet est introduite et utilisée comme base de la simulation du processus de la conception des structures. L'utilisation pédagogique de cette simulation est résumée et mise en rapport avec les besoins des ingénieurs de la pratique.

ZUSAMMENFASSUNG
Zur Auffassung, daß der Entwurf "das Umsetzen der Theorie in die Praxis" sei, schlägt dieser Aufsatz eine alternative Ansicht vor. Der Begriff "Design Procedure" wird vorgestellt und als Basis für eine Simulation des Entwurfsprozesses angewandt. Die pädagogische Anwendung der Simulation wird zusammengefaßt und in Beziehung zur den Bedürfnissen der Fachleute in der Praxis gestellt.

1. THE NATURE OF STRUCTURAL DESIGN

1.1 Putting Theory into Practice

It is a commonly perceived notion that the art of designing structures is a matter of "putting into practice" certain bodies of knowledge known as "theory". This attitude has its roots very firmly established in our culture which has, for several centuries, categorized knowledge as either of a "theoretical" or of a "practical" nature.

In the last century or so there has also developed the notion that "theoretical" knowledge is somehow primary and an antecedent to "practical" knowledge. It has also long been perceived that there is a gap betwen these two types of knowledge.

And yet, there has been no successful intellectual bridging of the gap: there have been no successful explanations as to precisely what "putting theory into practice" actually entails.

Meanwhile, engineers continue to design structures making use of certain "theory", but not taking it as a starting point; and engineering students are taught the "theory" which, they are told, they will later be "putting into practice".

1.2 The Role of Theory

"Theory" is a term which, in recent historical times, is linked to the idea of "a theory" (or hypothesis) and hence to the activities of the natural sciences. However, the natural sciences and engineering design are distinguished sharply in having utterly different aims - the one seeking a deeper understanding of the universe; the other striving towards the manufacture or construction of an artefact. A theory occupies a central role in the pursuit of science, but is only peripheral to the process of engineering design. Engineering design can proceed without theory. Indeed, it did so for many thousands of years and it still does for many structures, such as houses. Science, on the other hand, cannot proceed without theory or hypotheses [1], [2].

The author has elsewhere proposed a resolution to the above epistemological problem in which engineering knowledge is categorized differently from scientific knowledge [3]. Rather than "theory" being of central interest, attention is focussed upon the "design procedure".

2. THE DESIGN PROCEDURE

The design procedure is a statement, or often, since designers seldom write such things down, a potential statement, of how a designer could proceed to arrive at a design for a proposed structure.

A design procedure is not an attempt to indicate how to design creatively and with originality; nor is it a set of rules to be followed blindly. As such, a design procedure has something in common with certain Codes of Practice which guide the designers of, for example, steel structures [4]. A design procedure is, however, conceived at a more general and philosophical level than a particular Code of Practice.

A design procedure has an input and an output, and its function is modulated or regulated by a number of influencing factors (Fig 1). The output is the specification and the justification of the design of a proposed structure. The specification comprises sufficient details of the design to meet the needs of the client, architect or builder, as appropriate. The justification consists in the argument that is, or could be, used to defend the adequacy or suitability of the proposed design to whoever may require it.

INPUT	PROCESS	OUTPUT
Engineering and other knowledge	Design	Specification
	Procedure	Justification

REGULATION	client, finance, time, construction method etc.

Figure 1. The Design Procedure

The input to a design procedure is, potentially, the whole of engineering and other relevant knowledge - not just engineering "theory" but also empirical data, well-established empirical rules (rules-of-thumb) and also certain intuitive knowledge about the behaviour of structures which is often difficult to express or communicate.

Finally, a design procedure is regulated by a variety of influences such as the constraints of construction method, time, finance, availability of materials and components, Codes of Practice, building regulations, fashion, current safety standards and so on - what Pugsley has succinctly called the "engineering climatology" [5].

Thus, a design procedure will vary almost infinitely, according to the precise circumstances of a particular design goal. In general terms, it can be seen as a summary of the knowledge which must be taken into account, and what to do with that knowledge, in order to design a structure; and as such, it is an expression of the skill and know-how which a designer of structures possesses over and above a bare knowledge of facts and "theory".

3. STRUCTURAL DESIGN AS A PRACTICAL SKILL

3.1 Learning the Skill of Structural Design

To approach the task of structural design in the above manner is to recognize that it is a practical skill, much in the way that the ability to fly an aeroplane or to manage construction project can be seen as practical skills. This view has important consequences for the manner in which the skill of structural design might be learnt and taught - if it is a skill, then it can only be learnt by doing.

Several writers have conluded that design both can and should be taught to structural engineering sudents [6], [7]. However the comparison of the complex skill of structural design with the skills of flying and managing suggests that similar learning techniques might also be appropriate - particularly the use of techniques analagous to the flight simulator and the management game. Simulation gaming of the role playing variety has already met with some success within the context of a civil engineering department [8].

It is a familiar criticism of young or student structural engineers that, while they might be familiar with many modern techniques of structural analysis and even with the Codes of Practice, they do not have a real feel for the process of designing a structure - indeed the ultimate goal can become lost amid a forest of equations and computer programs. Even more seriously, a young designer can come to believe the results of mathematical equations and computer programs with scant regard to their real significance. Many engineers can relate stories of young designers finding, to their surprise, and yet believing, that the sum of the vertical foundation reactions could exceed the total weight of the building; or that, in certain circumstances, a particular high-rise building could lean into the wind.

3.2 The Teaching of Structural Design

3.2.1 Manual Simulation

At the University of Reading the author has implemented the above ideas in the teaching of structural design to students destined to work in the construction industry, but not as structural designers. So far the design of two types of structure have been selected - a typical steel or concrete framed commercial building, and the load bearing falsework for a reinforced concrete bridge.

Initially students undertook the structural design "manually" using an outline design procedure at a level appropriate to their technical and mathematical knowledge. For a desired building plan and elevation different groups of students investigated different designs for the structural frame in steel or concrete using one of several different types of floor structure - composite (Holorib), precast concrete slabs, flat slab, one-way slab, ribbed slab, waffle slab and so on. They were able to do some of this using genuine structural calculations and the rest using the simple rules often used by professionals, such as deriving the slab thickness as a fraction of the span.

The above approach has had greater success than previous approaches based only upon the conventional teaching of the theory of structures and the relevant Codes of Practice. The students were able to complete more of the total design, albeit approximately. They ended up with a deeper understanding of the whole process of structural design and were also able to see the context into which more advanced techniques of structural analysis and design would fit.

3.2.2 Computer Simulation

Following these successes, a computer program has been written to avoid the need to do some of the tedious mathematics and hence to speed up the process. The program allows someone effectively to "experience" the process of structural design by means of a simulation of the real process. By "experience" is meant the production of a specification and a justification of a proposed design, making use of certain bodies of engineering knowledge under the influence of a particular "engineering climatology", and being faced with real choices as to how to proceed and what knowledge to use. These are similar to the choices which face a "real" structural designers designing a ral building. In the educational environment the whole process is, of course, much simplified compared to the real world; but the differences are of degree of complexity and sophistication, not of type.

4. CONCLUSIONS

4.1 Progress in Structural Engineering Design

In order to detect and to evaluate progress in any field, it is essential to identify suitable criteria by which change can be assessed [3]. By focussing upon the central activity of engineering design, the design procedure can help to identify such criteria.

While some major developments in structural design do indeed result from new theories of engineering science and new data, other developments come about through making new use of old knowledge and theories. These latter developments are not recorded in new methods of modelling the behaviour of structures and thus progress is not necessarily perceived.

The design procedure can be viewed rather as a sort of model of the behaviour of structural designers. This can enable developments in design method to be perceived both in their very first use by students learning their art through simulation, and by professionals who come to perceive their activity in terms of the design procedure.

4.2 Comparison with Other Uses of Computing in Structural Design.

Current developments in the use of computing in structural design are along five main paths:

- techniques of structural analysis and modelling structural behaviour;
- computer aided drafting;
- detail design and specification of structural members;
- computerizing the Codes of Practice;
- expert systems.

The work described in the present parper is believed to be different from all of these. It seeks directly to reflect the needs of structural designers, be they students of professionals; it takes direct account of how designers design - identifying problems, proposing solutions and evaluating the consequences of these proposed solutions. It aims to help them to do this more effectively while not seeking to replace the skills of the designer, as complex structural analysis programs and expert systems often seek to do [9].

4.3 Future Developments

The result of the above work is believed to have great potential. In the educational context, the program is being further developed to suit different types of student with different aims and levels of technical mathematical and structural design skills. And in the professional environment, the program is already helping designers in their early-stage investigations of different proposed designs for a building.

REFERENCES

1. KUHN T.S., The Structure of Scientific Revolutions. 2nd Edition, University of Chicago Press, Chicago & London, 1970.

2. POPPER K., The Logic of Scientific Discovery. Hutchison, London, 1959.

3. ADDIS W, Theory and Design in Civil and Structural Engineering. Ph.D. Thesis, University of Reading, 1986.

4. BS 5950. Structural Use of Steelwork in Building: Part 1. Code of Practice for Design in Simple and Continuous Constructions: Hot Rolled Sections. British Standards Institution. London, 1985.

5. PUGSLEY A, The Engineering Climatology of Structural Accidents. See FREUDENTHAL A.M., International Conference on Structural Safety and Reliability (Washington, 1969). Pergamon, Oxford & New York, 1972, pp. 335-340.

6. HARRIS A.J., Can Design be Taught? Proceedings of Institution of Civil Engineers, Part 1, 1980, vol.68, pp. 409-416.

7. COWAN J., Design Education based on an Expressed Statement of the Design Process, Proceedings of Institution of Civil Engineers, Part 1, 1981, vol.70, pp.743-753.

8. HOLGATE A., Simulation Gaming in the Design Course. Internal Report, Department of Civil Engineering, Monash University, Australia, September 1974.

9. SRIRAM D., MAHER M.L., & FENVES S.J., Knowledge-based Expert Systems in Structural Design. Computers and Structures vol.20, No.1-3, pp.1-9, 1985.