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Human Reactions to Automated Design of Concrete Building Structures

Réactions humaines en face de l'automatisation du projet de structures en béton

Menschliche Reaktionen gegenüber automatisierten Entwürfen von Massivbauten

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1. INTRODUCTION

The introduction of computer techniques into almost any human activity seems to generate hostility. This is particularly evident when the computer replaces traditional skill and requires those who practised that skill to modify well-established work patterns. This paper is concerned with the effects of a computer program that carries out the full design, analysis and detailing of the key elements in a reinforced concrete building structure. The program deals therefore with only a part of the structural design which in itself is only part of the total design involved in a construction project. Despite its relatively limited application, it is probably true to say that this program impinges upon a wider variety of people than any other program currently used in the construction industry in Britain. Although the program is constantly being refined and developed it has now been operational for over three years and has been applied to more than 100 projects. In the author's opinion this type of program has wide application throughout the whole design field and it is hoped therefore that the experience described in this paper will be of interest and encouragement to those developing methods of a similar nature.

2. TRADITIONAL DESIGN PROCESS

The traditional design and detailing of reinforced concrete is essentially a product of pencil, paper and slide rule. The engineer selects an arrangement of slabs, beams and columns which in his opinion best suits the particular building and he then chooses the size of each of these elements by a combination of experience and simple calculation. This information is recorded on general arrangement drawings, (framing plans and sections), which are distributed to the other members of the design team to form the basis of their own design work. Apart from this formal distribution of structural information, there is normally an informal flow of freehand sketches used to define those details which are of common interest to other designers. During the process of information exchange, it is to be expected that modifications will be required to the

original structural concept to satisfy other needs. Ideally this should be a self-contained process at the end of which would emerge final agreed general arrangement drawings which would form the basis for the final design and detailing operations. Unfortunately, life is not like that and our traditional methods are invariably bedevilled by the need to produce working information for site whilst at the same time attempting to modify the basic concept to suit non-structural requirements.

The final design and detailing process is to a very large extent standardized by virtue of Building Regulations, Codes of Practice and nationally accepted conventions. Despite standardization this part of the work accounts for roughly two-thirds of the time and manpower used in a structural design office. The processes are completely routine and consist of the preparation of detailed calculations to assess bending moments, shear forces, reactions, deflections and hence areas and positions of all main and secondary reinforcement for each single structural element. With these calculations as a guide, the detailer then prepares true-to-scale drawings indicating the shape of each member and the location of each reinforcing rod. The rods themselves are detailed item by item on separate reinforcement schedules from which the weight of reinforcement is calculated for cost purposes.

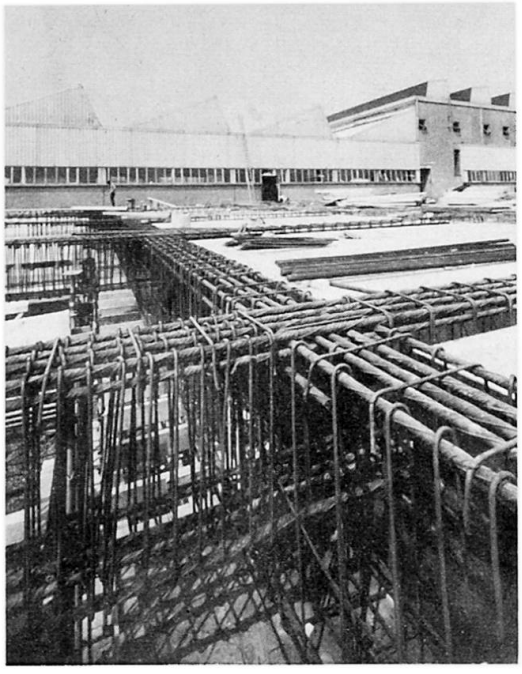
Most members of the construction team regard the end products of this traditional method (that is detailed calculations, true-to-scale drawings and standard reinforcement schedules) as sacred cows which, if they were to be replaced, could only be by means of automated facsimiles. Since the ABCONS program replaces all these traditional items by standard computer print-out, there is initial hostility from all quarters.

3. THE ABCONS PROGRAM

The traditional process described above may be thought of in terms of:-

- basic decisions that ought to be taken by an engineer
- consequential decisions that may be delegated to a computer

With a little care it is possible to extract the basic decisions in such a form that



ABCONS DESIGNED & DETAILED FACTORY REINFORCEMENT

they can be made at a very early stage, following which the computer is given complete freedom to develop all the consequential decisions and to record them in a form best suited to the needs of each individual user. What this means in practice is that preliminary calculations and general arrangement drawings proceed in traditional manner using pencil, paper and slide rule following which design data such as loads, stresses and reinforcement patterns are determined by the design engineer and recorded on appropriate data sheets. Once these data sheets have been completed, the design engineer has no further commitment other than recording subsequent structural alterations. From the design data sheets, punch cards are prepared and the computer proceeds to analyse the structure as a whole and each structural element individually. It then calculates the diameter and bending dimensions for each reinforcing bar to ensure maximum economy consistent with the requirements of appropriate regulations, standards and codes of practice. Output includes:-

- comprehensive calculations suitable for submission to local authorities
- reinforcement schedules (one for each element)
- precise fixing instructions for each reinforcing bar
- quantities (with summaries) of formwork, concrete and reinforcement

A feature of particular interest to site management and reinforcement fixers is that each structural element is described and detailed on a separate sheet identified by a comprehensive indexing system. This is a great help to scientific planning and enables the reinforcement for each element to be individually bundled and delivered to its appropriate location during construction.

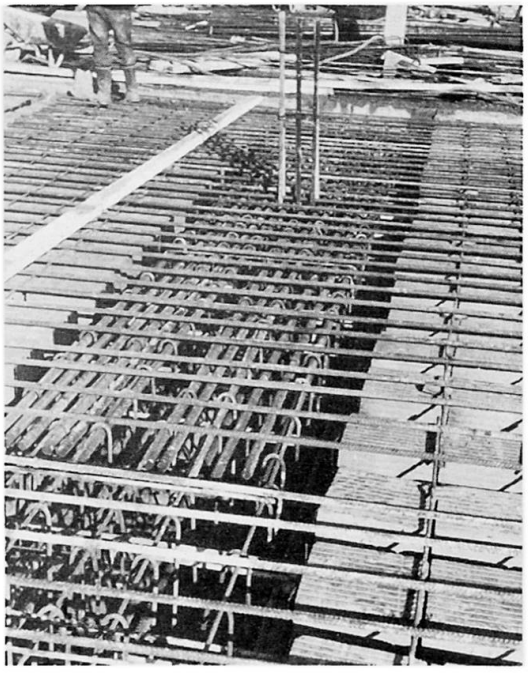
After the initial computer run the design engineer uses the output as a basis for agreeing refinements and alterations to structural members and he records all such decisions on the appropriate output sheet. The ABCONS system includes a second up-dated computer run at about the time the contractor is appointed which incorporates all revisions. Since the computer is only able to deal with structural matters, items of non-structural concrete such as architectural nibs, chases, holes etc. must be superimposed manually and are recorded on output sheets in one of a number of simple ways.

Checking what may be thousands of sheets of computer output is neither attractive nor practical and an alternative procedure has therefore been developed. When completing the data input sheets, the design engineer records his estimate of the main reinforcement required for each individual element. The computer then compares this estimate with its own calculated value and draws attention to any significant discrepancy. A final overall check is obtained by comparing the total quantities

of concrete, reinforcement and formwork calculated by computer with those measured by the Quantity Surveyor. These quick and simple checks have proved far more reliable than any known system of checking traditional designs.

4. REACTIONS - DESIGN ENGINEER

The reactions of the design engineer during trial runs of the program were so disturbing as to require a reappraisal of how the system should operate. The original intention was for the design engineer to be given a simple manual instructing him how to complete the data input forms. In the event this was unworkable because of the underlying hostility of human beings to automated systems. It quickly became apparent that the design engineer wanted to do battle with the system and was anxious to discover and exploit all its weaknesses. He went out of his way to mis-read instructions and was always looking for design combinations that were unacceptable to the computer. After this initial experience it was felt that no amount of education could guarantee a smooth transition from traditional to automated methods for the older, experienced design engineer, although these same techniques might be acceptable to a young, inexperienced man. To overcome the problem it was decided to introduce an ABCONS systems engineer who would act as the interface between the design engineer and the computer. ABCONS is now therefore built up around systems engineers who are experienced structural designers specially trained to understand and to be in sympathy with ABCONS procedures. By introducing a systems engineer, the problem of the design engineer has been solved and he now readily accepts the system and is appreciative of its benefits. In particular he enjoys the concentration of "real engineering" into a period of a few days as opposed to spreading it out over several and he is thankful to be relieved of the customary tedious checking activities. The greatest benefit, however, is the elimination of the detailing process which is a nightmare in most offices because sufficient good and reliable detailers no longer exist. The bane of most engineers' lives is to supervise an extensive detailing operation carried out by inexperienced students or disgruntled junior engineers.



ABCONS DESIGNED & DETAILED SHOP REINFORCEMENT

During the design development stage, the design engineer discovers substantial

benefits from having clearly referenced calculations and construction details for each individual element available to him. With this information he is able to agree and record all necessary modifications, confident in the knowledge that his data are reliable and that his decisions will be properly incorporated in the final design taking account of all the consequential effects of those decisions.

Despite these acknowledged benefits, the inate hostility is readily evident. The slightest flaw in the program, or a breakdown of the computer, will produce the most unreasonable outburst from a man who spends the rest of his life happily accepting the failings of his own and allied professions.

5. REACTIONS - CHECKING AUTHORITY

During the development of the program it was thought that checking authorities would be reluctant to accept computer output in place of conventional calculations since the output does not provide the step-by-step working of ordinary arithmetic. The computer gives only the loading patterns and the final critical bending moments, shear forces and deflections together with moments of resistance, reinforcement areas, etc. In practice, however, local authorities have received these calculations with enthusiasm since the information given is all they require. Few checking authorities will attempt to unravel another man's arithmetic and they therefore welcome a system that provides readily referenced data in respect of each single structural element.

6. REACTIONS - ARCHITECT

If you ask an architect, he is most unhappy about the system since he is essentially visually orientated and therefore mistrusts information supplied in alpha-numeric form. If, on the other hand, you do not consult the architect, he is unaware that you are using the system since in practice he is concerned only with general arrangement drawings and those items of non-structural concrete which can best be defined on freehand sketches. Indirectly, the architect benefits because framing plans can be drawn up at a far earlier stage in the process whilst alterations can be accommodated up until a far later date.

7. REACTIONS - SERVICES ENGINEER

Like the architect the services engineer benefits from an earlier release of general arrangement drawings but in particular he finds that it is much easier to agree positions, sizes and details of holes for services because the structural engineer has all necessary data at his fingertips.

8. REACTIONS - QUANTITY SURVEYOR

Although the ABCONS system produces both individual and summarised quantities for reinforcement, concrete and formwork, this is of relatively limited value to the man measuring the job. Just as the form of an animal depends upon the nature of its bone

structure so does the measurement of a building derive from the proportions of its structure and therefore the starting point for any building measurement is the structure itself. Thus, although all the quantities are available they are only used by the Quantity Surveyor as a check on his arithmetic. Similarly his measurement provides a valuable check on the computer output.

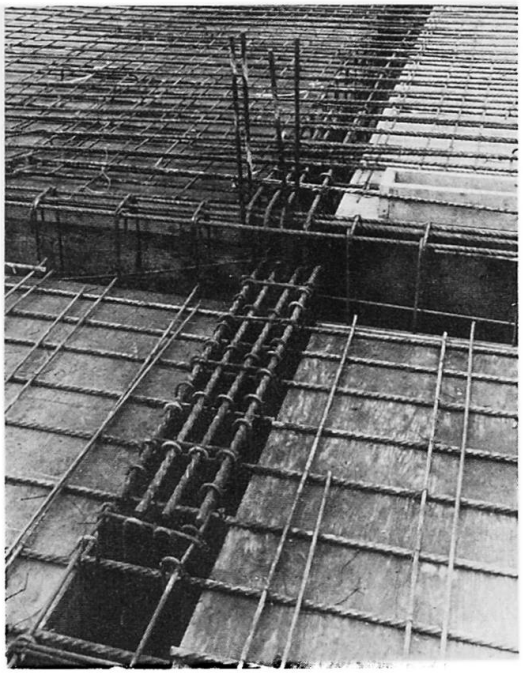
9. REACTIONS - GENERAL CONTRACTOR

General contractors are not renowned for progressive attitudes and they therefore generally start by being suspicious of anything that replaces conventional drawings. Their typical reaction is to assume that any such system makes life easier for the designer at the expense of the contractor. Unfortunately contractors speak with many voices and have their own communications problems so that by the end of most jobs it is quite common to find those who have been directly involved with the system reacting favourably whilst others cling to their original misgivings. In fact the planning engineer has available to him a great deal of valuable information that previously did not exist. He can therefore program work and order materials confident in the knowledge that his information is reliable.

Clearly a favourable reaction from the main contractor is essential to the success of any automated design system but it cannot be assumed that he will always appreciate the benefits that flow from it. Occasionally a contractor lacks the management skills necessary to utilize available information and sometimes he is unwilling to deviate in any way from traditional procedures. Our experience is that progressive contractors, willing to co-operate, gradually recognize the unsatisfactory nature of the existing information system based upon drawings. When this fact is established, they begin to appreciate the full benefits of automation

10. REACTIONS - REINFORCEMENT SUPPLIER

Of all those concerned, the reinforcement supplier is the one person who suffers by the system. Previously all similar bars in similar structural members were bundled together and delivered in large unsorted piles for site



ABCONS TYPICAL BAR DETAIL AT CHANGE OF LEVEL

to unravel. With the ABCONS system, the reinforcement for each element is bundled separately thus eliminating the sorting process on site. Although this adds additional labours to the reinforcement suppliers' work, he does not complain but accepts the system without fuss. The reinforcement schedules appear in a form to which he is accustomed and it may not be immediately apparent to him that their requirements differ from traditional ones.

11. REACTIONS - REINFORCEMENT FIXER

At first sight, the reinforcement fixer could be expected to be least happy with the system. He is not a highly educated man and he has trained himself to work from traditional drawings and conventional bar schedules so it would not be surprising to find him hostile to sheaves of computer output. In fact the reinforcement fixer has proved without exception to be an enthusiast for the system which was devised to suit his needs. Although he uses traditional drawings, he cannot in fact use them directly since his work involves climbing ladders and contending with wind and rain. In practice therefore he has carried up the ladder a piece of paper or notebook with a simple shorthand notation describing the position of each rod. The ABCONS system merely prints out that shorthand notation in a standardized form which can be readily understood by any experienced bar fixer. Since each output form relates only to one structural element, the fixer can take it with him on to the job and it matters little if it gets wet or torn since after the element is complete, the piece of paper is disposable. In practice the reinforcement fixer does not throw the sheet away since it gives him an accurate record of the weight of reinforcement fixed, which forms the basis of his weekly pay packet. Most reinforcement fixers find it difficult to calculate weights of reinforcement and they appreciate a system which gives them, for the first time, a reliable check upon their employer's arithmetic.

12. CONCLUSIONS

This paper describes a variety of reactions and it is therefore perhaps inappropriate to attempt to draw conclusions. It may however be of interest to note that we were unable to find any solution to the interface problem between a traditional design engineer and the computer system. Since we could not solve the problem we had to eliminate it by introducing a computer systems engineer. Those most affected by the system liked it best, whereas those remote from it tended to be more critical. Finally, if the system fails everyone is only too willing to mistrust an alien technology.

13. REFERENCE

Field experience of replacing conventional detailed drawings

J. Seifert
The Concrete Society Symposium
Bristol
December 1970

14. SUMMARY

This paper describes an automated process for design, analysis and detailing of concrete building structures. It highlights the difference between this system and traditional methods and describes individual reactions of those most involved both within the design team and on site.