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Fourteen Years Experience in the Use of Computers in Structural Engineering

Quatorze années d'expérience dans l'usage des ordinateur chez les ingénieurs de construction

Vierzehn Jahre Erfahrung im Begrauch von Datenverarbeitungsmaschinen im Bauingenieurwesen

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Summary

This paper describes the changes that have taken place in communication between structural design engineers and computer facilities in a Sydney firm of Consulting Engineers over the past 14 years. For the first 4 years, contact was made by means of data delivered to computer centres. The next step was to use an office teletype terminal to transmit data to a large computer. In 1974 the firm installed an "In-House" mini-computer connected to a Graphic Display Terminal and a Key-board printer.

Résumé

Cet article décrit les changements qui ont eu lieu dans une Société d' ingénieurs-conseils à Sydney depuis 14 ans, en ce qui concerne les communications entre les ingénieurs et les ordinateurs disponibles. Pendant les quatre premières années on a travaillé avec des centres de calcul. Puis on a installé un téléimprimeur transmettant les données à un grand ordinateur. En 1974 la Société a installé dans ses propres bureaux un mini-ordinateur, relié à un recepteur pour produire des dessins sur l' écran et à un imprimeur à clavier.

Zusammenfassung

Dieser Beitrag beschreibt die in den letzen 14 Jahren bei einer Sydneyer Firma von technischen Beratern vorgenommenen Veränderungen bei der Ubermittlung von Informationsmaterial von den Konstruktionszeichnern an die Computer- Einrichtungen. In den ersten vier Jahren wurde die Verbindung dadurch hergestellt, dass die Daten an die Computer-Zentralen geliefert wurden. Der nächste Schritt bestand darin, dass man einen für den Bürobetrieb eingerichteten. Anschluss-Fernschreiber verwendete, un die Daten an einen grossen Computer weiterzuleiten. Im Jahre 1974 hat dann die Firma im Betrieb selbst einen Mini-Computer installiert, der mit einem Bildschirm zur Vorführung von Zeichnungen und mit einer Tastatur-Druckmaschine verbunden ist.

1. INTRODUCTION

P.O. Miller Milston & Ferris, a Sydney firm of Consulting Structural Engineers founded in 1946, specializes in the design of building structures. Over the past 14 years they have had an average of 9 engineers engaged on structural design and since 1964 have been using computers for structural analysis.

This paper presents the various stages in the procedure of communication between design engineers and computers starting with the preparation of data on printed forms to be later processed at a computer centre to the present operation of an in-house graphics-oriented mini-computer system.

2. FIRST PERIOD 1964-1967

Large, centralized computing facilities became available in Australia prior to 1963 long before lower cost minicomputers made it possible for smaller firms to install their own equipment to be used on specific tasks. Thus when this firm commenced using electronic computers for the analysis of three-dimensional frames there was no economic alternative to the use of facilities outside the office.

The first project on which use was made of a computer was the structural analysis of a seventeen storey rigid frame building consisting of 28 columns. The structure was designed and analysed as seven two-dimensional, four-bay rigid frames. In January, 1964 the designer in the Sydney office calculated the properties of each proposed member and the results were posted on printed forms to a computer centre in Melbourne about 500 miles away. In the second project some months later, the data was prepared on punch cards and submitted over the counter at a Sydney computer centre and the output collected the following day. As there were frequently errors in the preparation of data on the punch cards, the cards would then be corrected in the designer's office and re-run at the computer centre. In this project the designer wrote some programmes to assist in the preparation of the data and also some portions of the structure were analysed as a three-dimensional framework rather than as a series of independent two-dimensional frames.

Over the next three years considerable use was made of computer centres for the analysis of large frames but because of the turnaround time before obtaining results and the unwillingness of individual engineers to use computers for the analysis of small frames or for any other purposes the usage of computers by this office was limited to the structural analysis of large frames.

The ability to analyse complex frames, led to more complex structures being proposed both by the designer and the clients and with growing availability of programs for complicated structural analysis the computer had become a permanent design tool.

3. THE TIME SHARING ERA 1968-1974

In order to reduce the time necessary to obtain results and to involve more engineers in communicating with a computer, on 17th April, 1968, immediately after the introduction of the first time-sharing system in Australia, the firm installed a Teletype terminal operating at an effective speed of 8 characters per second connected by telephone to a central computer. The immediate result was that this time-sharing terminal was used for the analysis of frames having up to 20 members. Later this was extended to frames with up to 100 members while the analysis of larger frames was carried out by outside computer bureaux

with considerable time delay between writing of data and obtaining usable results.

In 1969 the firm required a dynamic analysis of a 47 storey building in order to estimate the natural period of vibration of the building. No suitable programme was available in Australia so the computer analysis was carried out in London.

By 1970 some design engineers in the firm had commenced writing their own programmes for structural problems other than the structural analysis of frames. One programme was for the analysis of simply supported pre-stressed "T" beams having varying shape throughout the length of the beam. Information was obtained for the stress and deflection in the beam under any condition of loading and the programme was later extended to allow for the design of the drape of the pre-stressed cable so that the stresses at all critical locations in the beam will lie between defined limits.

It was also in 1970 that the firm commenced checking data by plotting before running structural programmes. One particular three dimensional frame had 1400 members and 820 joints. The data was written in the office on coding sheets which were taken to an outside computer bureau which transferred the data to punch cards and ran the cards in a "data check" programme which prepared the plotting tape. This plotting tape then had to be taken to a separate organization which produced drawings on paper using ink pens. Although there was a turnaround time of 3 days the plotting of data was singularly beneficial in lowering the overall cost by reducing the number of computer runs necessary to obtain satisfactory results.

With the 1400 member space frame a programme was written to give for each member its length, "cutting-off angle" at each end and all other information required for the fabrication of the member, thus eliminating the need for member workshop drawings. This data was prepared on paper tape and processed on the office time-sharing terminal with the output printed at the office terminal with a minimum delay.

For the first three years of operation of the office Teletype terminal, communication was made with only one computer but in 1971 the terminal was connected by telephone to two additional computers so that the office had the facility to operate conversationally in either Basic or Fortran, or to write large programmes in Fortran and submit by means of the terminal for batch processing. At about the same time the original terminal was replaced by a new terminal about 50% faster than the one installed three years previously. The following year the second terminal was replaced by a Memorex 1280 Terminal which allowed the use of 30 characters per second on the computers which were connected by telephone but had the capacity of 120 characters per second if connected to a suitable in-house computer.

During the next three years (1971-74), considerable use was made of programmes for frame and finite element analysis but due to the unavailability of reasonable-cost in-house plotting facilities, the office did not make full use of the many advantages of communicating with the computer by graphics. In addition, most design engineers were not comfortable in communicating with the computer solely by means of words and numbers rather than by sketches with calculations and explanations, which is the usual method by which a Structural Design Engineer carries out his computations.

Now that the firm could analyse three-dimensional frames composed of members of any inclination and shape there was an increasing demand for the design of this type of structure and a need by the design engineer, the architect and often by

the client to see the three-dimensional structure from any view-point.

In 1973 the Tektronix 4000 series terminals became available in Australia. These are cathode-ray-tube visual display terminals, screen size 190mm x 140mm, which have the alpha-numeric capabilities of a Teletype terminal with the added ability of fast and accurate plotting. The terminal is capable of operating at 1,000 characters per second but if it were connected to an outside computer bureau by means of telephone lines, as were the existing and previous office terminals, the Tektronix terminal would be limited to 30 characters per second which would be a serious disadvantage when working with an interactive graphics system. Most importantly, the cost of a Tektronix terminal was only a small percentage of the cost of a large plotter using ink pens on paper. Now that comparatively low-cost mini-computers were available it was decided to install an in-house graphics oriented mini-computer system.

4. GRAPHICS-ORIENTED COMPUTER 1975-1978

The new in-house system was based around the Tektronix graphics display terminal which is connected to a hard copy unit and also separately to a tape recorder to obtain permanent records. The mini-computer selected was a Data General Nova 1200 having 64K-byte processor and memory. The mini-computer was attached to the Memorex 1280 terminal which was already in use in the office and could now be operated without the encumbrance of the telephone system at four times its previous speed. Medium speed discs with a total of 2.5 million computer words were selected and the mini-computer was connected by a Synchronous communications line to a Univac 1108 computer approximately five miles away. The hardware for the connection to the Memorex terminal and the Synchronous communications line was supplied by the computer supplier, but the software to drive this hardware was written by this firm and this took a significant amount of the time involved before all the hardware and software were tested and functioned satisfactorily.

One important feature of the in-house system was the establishment of the necessary back-up in order to avoid loss of information and wastage of time through machine or user malfunctions. There was a back-up of two copies of all disc files of important information and one copy is being kept in the safe custody of a bank where it cannot be inadvertently destroyed.

The biggest problem associated with the in-house system was programme development which requires a very great deal of time and over the past three years more time has been spent on programme development and maintenance than on the actual operation of the computer for structural design analysis. Even so, programme development has lagged behind the needs of the Design Engineer.

It was expected that Computer Graphics would be used in the office in three different ways. First to visually check data by plotting it on a screen to ensure that this data represents the actual problem. Secondly to present results from computer designs and analyses such as drawing to scale interaction diagrams to be used for the design of reinforced concrete columns in combined compression and bending and thirdly in an interactive graphical mode in which crosshairs moving across the screen are used to create and modify graphical representations of a structure or a particular element. This use ranges from sketching a tendon profile during a prestressed beam design to constructing a grid for a complex finite element analysis.

While it was expected that the availability of a visual display terminal on which drawings and graphs could be prepared would prove to be worthwhile the advantages of being able to view the structure on the screen exceeded those

anticipated. In several projects in conjunction with Architects and Clients, the Consulting Engineer became involved at the concept stage of building design so that a number of possible structural alternatives were investigated and viewed. A data base of information describing the building was created at the initial concept stage and the design team examined all visual implications of the structural design. The structure was viewed from various points in space, either in perspective or in various projections. The total picture was defined by specifying the co-ordinates in space of various points and then interconnecting these points with lines. When the picture is to be viewed from any given position certain lines or parts of lines should be hidden from view by opaque surfaces which lie between those lines and the observer. A programme was developed so that such lines, or parts of lines, could be deleted by the computer for any view.

After two and one half years of operation the disc space was reaching saturation and at times there were delays to design engineers because of the speed with which the computer processed arithmetic. It was decided therefore to install a tape drive having five times the capacity of the discs and a floating point processor. This enabled large sequential access, which was not previously available, for much bigger structural programmes. In addition, old data files and larger structural programmes were transferred from the discs to the tape drive.

5. THE FUTURE

There are two areas in which the firm intends to improve the facilities for structural engineers to carry out complete designs with interactive programmes on graphics based terminals. At present the mini-computer has only sufficient hardware capacity for one graphics display terminal so it is intended to replace the present Data General Nova 1200 and the tape drive with an Eclipse S130 mini-computer which is capable of supporting the operation of up to 25 graphics terminals, several tape drives and over one hundred times the present disc capacity at a cost of about double the equipment which it will replace. This proposed new system will also enable current programmes to be run considerably faster.

It is also intended to combine and extend the existing analysis and design programmes so that an entire building may be completely analysed and designed by interactive programmes. The designer would have complete control over the design process at all times. He first determines the model of the building and will be free to change this model at any stage of the design process. The final results will be presented on the visual display terminals in the form of sketches to scale and tables which can then be copied and given to draftsmen.

6. ACKNOWLEDGEMENT

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