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Computer Services in an International Consulting Engineers' Office

Ordinateur et prestations de service offertes par un bureau d'ingênier-conseils international

Computer-Dienstleistungen eines internationalen beratender Ingenieurbüros

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Summary
This office has been using computers for twenty years and installed its first in-house machine fourteen years ago. The extent of its application of computers has grown steadily and is now at a point where it is running several different installations. The annual investment in new software is in excess of half a million U. S Dollars. The more popular application programs are each used several hundred times each month. Despite all this activity the benefits of using computers are far from clear.

Résumé
Ce bureau utilise les ordinateurs depuis vingt ans et possède son propre ordinateur depuis quatorze ans. L'application des ordinateurs s'est réellement intensifiée et le bureau utilise maintenant plusieurs installations. L'investissement annuel pour le nouveau logiciel est de plus d' un demi-million de dollars américains. L' application de certains programmes est réalisée plusieurs centaines de fois par mois. Malgré toute cette activité, les bienfaits de l' utilisation des ordinateurs sont loin d' être évidents.

Zusammenfassung
Unser Büro hat Erfahrung in der Anwendung von Computern; seit 20 Jahren werden sie von uns eingesetzt; seit 14 Jahren verfügen wir über hauseigene Anlagen. Das Ausmass der Computer-Anwendung hat seither stetig zugenommen; pro Jahr investieren wir jetzt über eine halbe Million U. S. Dollars in Software und besitzen mehrere EDV-Einrichtungen verschiedener Grösse. Häufig benutzte Programme laufen mehrere hundert Mal pro Monat. Trotz all dieser Aktivität sind Vorteile und Nutzen der Computer-Anwendung keineswegs klar und unbestritten.

IABSE International Colloquium

"Interface between computing and design in structural engineering".

"Computer services in the Ove Arup Partnership"

presented by David Taffs, C. Eng. M.I.C.E., M.I. Struct.E., M.B.C.S.

1. INTRODUCTION

OAP has a staff of over 2,000 who are located in ten offices in the UK and over thirty offices elsewhere in the world. The largest concentration of staff is in London where over 1,000 staff occupy nine separate buildings all within ten minutes walk of each other.

Despite the size of the Partnership each office enjoys a large measure of autonomy. Offices range in size from two to three people up to several hundred. The differences in type of work, office management, office location and environment mean there is no simple solution to the provision of computing facilities. Some offices do not even have a reliable power supply let alone a local hardware maintenance organisation.

Some offices have managements which are anti-computers whereas others are very pro-computers. These attitudes are reflected in the levels of expenditure although one very junior enthusiast in an office can transform its attitude.

2. NATURE OF WORK

Some groups within the firm work exclusively on structural engineering commissions. Other groups provide a combined structural and building services consultancy. One part of the organisation provides a full design service where the teams include architects, quantity surveyors and all required disciplines. There are specialist groups covering geotechnical problems, transmission towers, offshore projects, project planning, transportation, highways, bridges, reinforced concrete detailing, quantity surveying and building services design.

2. NATURE OF WORK (contd.)

A major user of the computer is the Financial Division which has its own remote batch station and terminal concentrator. It monitors expenditure on projects and produces analyses of that part of the workload controlled from the UK. It is of interest to note that the payroll is not processed in-house as for this application it is not possible to match the cost and efficiency of an outside bureau.

Information retrieval by computer is only just beginning on non-financial matters. Often reviews of procedures result in improved manual methods that avoid the need for the large investment common to the introduction of computers.

There are two word processing teams in London. Each has an IBM System 6 and some magnetic card typewriters. They produce reports, specifications and similar size documents.

Current projects in the firm include high rise buildings, bridges, hospitals, universities, conference centres, marine structures, industrial complexes. Each has its own particular requirements. Very intensive computer activity can take place on parts of projects but there is no consistent pattern. Two individuals in the same location given the same small task can obtain solutions but will have used different methods and design aids.

3. COMPUTER HARDWARE

Figure 1 shows the DEC system 10 configuration at March 1978. Upgrading of the system is expected to continue. All standard equipment supports upper and lower case characters and terminals operate at a minimum of thirty character per second.

Drum plotters are used as they are cheaper than flat bed plotters and many plots can be produced without operator intervention. The type of paper, colour of ink and pen sizes vary according to the job being processed.

3. COMPUTER HARDWARE (contd.)

The buildings in London are interconnected by private telephone lines. This permits extension to extension dialling. Some of the extensions are attached to the central computer. In time all UK offices will be interconnected but at present only two have private lines to London. The staff in these offices can dial each other directly and discuss matters or dial the central computer extension and switch to data transmission.

A number of the hardcopy terminals are based on the Diablo printing mechanism. They have, therefore, the ability to produce simple diagrams as well as normal alphanumeric text.

The larger desk top machines are equipped with cassette tape storage, 80 column printers and a small table plotter.

4. ORGANISATION OF COMPUTER SERVICES

A small group was established to run the first in-house computer. As there was little expertise elsewhere in the firm this group took over the entire computing operation on each project when invited to advise a project team. This transfer of work out of the project team was unsatisfactory and progressively it has been corrected. All control is now back in the hands of the designer. He determines how, when and where to use the computer. He knows the status of his work at any time and does not suffer the frustration of working through another person.

The central computer department has a staff of about 23 of which 9 are concerned with the operation and system software of the installation. The rest of the department are concerned with providing technical advice, correcting program errors and developing new applications.

A lot of software has been developed in a casual fashion by engineers with some programming experience. Further effort has then been put into salvageing the programs and trying to adapt them for general use. Invariably the exercise is abortive. Figure 2 shows the latest approach to the organisation of software development.

4. ORGANISATION OF COMPUTER SERVICES (contd.)

The idea for a new application can be put forward by anyone within the organisation. This person establishes support for the idea from others and obtains funds from their local management to prepare a development proposal. This proposal contains a brief description of the application together with cost estimates and names of suitable staff who could prepare a feasibility report. The feasibility report will contain a detailed description of the system, a user manual and cost, manpower and time estimates. Applications for funds are made to a small group of people who administer on an annual basis, the total sum of money that has been allocated to development activities. These people have to share out the fund according to merit on a largely subjective assessment of the proposals submitted.

If approval is given a steering committee is established for each project with the responsibility for monitorying progress, defining the user requirements, validating the software and promoting the finished project so that its full potential is realised. Committees typically have about six members each drawn from different parts of the Partnership.

A project team is set up to work for the steering committee. The team usually consists of between one and six people but typically two or three. The team services the client committee producing reports, system documentation and finally the coding and implementation of the software. Usually at least one member of the project team comes from the central computer department the remainder are on loan from design groups. The computer department also provides the maintenance effort after the initial development is complete.

The principal programming language is Fortran. If the total time spent by the project team, from the moment it is set up to the point where users have tested and accepted the new system, is divided into the number of program statements in the final system a production rate of about 200 statements per man week is expected. Short bursts of activity on simple stand alone programs can achieve twice this rate of production whilst enhancements to existing programs can be as low as one tenth the rate. A development engineer costs around £100 per day so the labour cost approximates to £2.50 per statement. Computer charges add about £0.50 per statement.

4. ORGANISATION OF COMPUTER SERVICES (contd.)

Maintenance costs can be considerable. In general costs increase with frequency of use of the program and decrease with time. The cost of improving quality and accuracy during development is very quickly repaid from reductions in maintenance.

The computer department makes five year forecasts annually and annual forecasts quarterly. Cost reports on labour and all other expenses are produced monthly. Every minute activity on the central computer is recorded. The cost incurred by each person on each project is reported. A project leader can obtain on demand a full report of the computer resources used on his job. It will include who did what, precisely when, the software used and the cost.

Software reports produced monthly show the number of runs and scale of use of each application program. Such information is essential when formulating investment plans.

Guidelines or standards for software help to minimise development and maintenance costs. A subset of the available Fortran language is used in order to facilitate conversion to other computers. The style and format of all coding is specified, Figure 3 shows an example of a program.

Libraries of utility routines reduce the time spent on coding, increase the reliability of software and improve portability.

5. SOFTWARE

Computers were initially used for stress analysis and financial accounting. These are still the major activities although decreasing in proportion to the total processing load.

Some applications are best suited to a hands on, immediate response service while others require the assistance of an intermediary and no contact with the computer.

Users have become more discerning in what they will accept from the computer. Figure 4 shows output from an interactive program. Note there is subscripting, superscripting and Greek characters. The computer service has to be reliable in terms of both hardware and software.

5. SOFTWARE (contd.)

Figure 5 shows output from a frame analysis run. Note that it has not been produced in a diagrammatic form that only the program author would understand. It is fully labelled and framed and fits comfortably into the traditional project documentation.

Figure 6 shows a displaced shape plot. The problem concerns the effect of column head in a flat slab.

Figure 7 shows a highway engineering application.

Figure 8 shows the results of a slope stability investigation.

Figure 9 shows the deflections of a structure subjected to a load varying with time. Figure 10 shows similar information but gives a clear indication of the magnitude of movement against time for selected points in the structure.

Figure 11 shows a typical production drawing that can be produced by the automated drafting system. Users can prepare data on punched cards, typwriter terminal or a graphic screen for programs running on the central computer.

The firm became aware of the disruption caused when it changed its computers and programs. About eight years ago a style of input to the structural analysis programs was established and became known as the standard input. This meant that instructions and data sheets could be prepared that would remain valid regardless of the software employed. The average engineer, who might use structural analysis programs once every six months, developed the confidence to know that whatever he had done last time would still work. Data sheets contained diagrams and advice, that meant experienced users seldom had to refer to any other material. When a new program was added to the suite another data conversion routine would be written into the standard input program.

Where possible programs are grouped together into single systems. This helps to minimise the volume of reference material for the potential user. Access to the required software becomes easier. The user need only remember a few program names and once assessed the program is able to guide the user to the specific operation required. The maintenance and general housekeeping of user files e.g. data and results, is made easier.

6. TRAINING & EDUCATION

The effort required to adequately train staff is often underestimated. Staff turnover and movements within the firm demand regular repeats of courses and presentations. Visits to the computer centre are arranged for new staff. Graduate engineers are given lectures on computing when they first join the firm. Classes are held for complete novices and for those with more advanced knowledge.

Each group in the Partnership is encouraged to appoint at least one representative who will co-ordinate computing activities. This person is responsible for disseminating information received from elsewhere in the firm and for collecting and correctly feeding back information from his group.

Open meetings are held where new developments are described or proposals are aired and criticism invited. Although these meetings are held at lunch times and food and drink are provided only about ten percent of potential users attend.

There is a house magazine circulated monthly to each member of staff. Articles on computing activities are regularly included. One page news sheets called Computer Bulletins are circulated to contacts in each part of the firm. The Bulletins draw attention to recent enhancements, error corrections, new manuals etc. In addition to the above there are other presentations and displays all intended to improve communication.

7. ORGANISATION OF USER DEMAND

There is a tendency for departments to be set up around computers however small the equipment may be. Such a department comes to be treated as an elite within the organisation. In the long term this attitude is detrimental to the successful adoption of computer techniques. Arups regularly review and try to improve the organisation of its computing activities so as to strengthen the control the users have over the computer services provided.

Strong user influence resulted in the rejection of the traditional lineprinter size paper many years ago. All output is on A4 landscape or portrait paper prepunched with filing holes. (Sprocket driven devices however dictate the spacing of perforations and as a result the pages on these machines are marginally greater than A4). Matrix printers have been

7. ORGANISATION OF USER DEMAND (contd.)

rejected by most parts of the firm as being of too low a print quality. Software generated character sets supplied by manufacturers have been rejected and replaced by a standard Arup set.

Each group in the firm has a correspondent who deals with computer matters. These people act as focal points and help to maintain an effective chain of communication. The correspondents within a major division of the Partnership meet to discuss their views and proposals. Any issues that need to be taken up with other parts of the firm are then left to a small executive committee to action. In this way large committee meetings are avoided.

Despite all the activity there are still parts of the firm who make little use of the facilities available and certainly a large number of individuals who make no use of them at all.

8. COSTS, BENEFITS AND THE FUTURE

Very little has been published by the industry on assessments of benefits resulting from the use of computers. The few references and claims that have appeared are unconvincing and yet there are so many people advocating wider use.

Some areas of work lend themselves readily to computerization. Financial calculations can be carried out more quickly and reliably and can be better presented by computer than by hand. The design of highways required the collection of enormous quantities of figures, periods of adding additional small volumes of data and assessing results and finally presenting tabulated and graphical production information. Given optimum conditions of software, hardware and environment the computer techniques are better than manual techniques. When one looks at structural analysis the benefits are far less clear.

Similar work can be given to two engineers. The one who uses the computer produces his design for less total cost than the one that does not use the computer. Give the same work to two other engineers and this time the one who does it manually achieves the shorter timescale and lower cost.

8. COSTS, BENEFITS AND THE FUTURE (contd.)

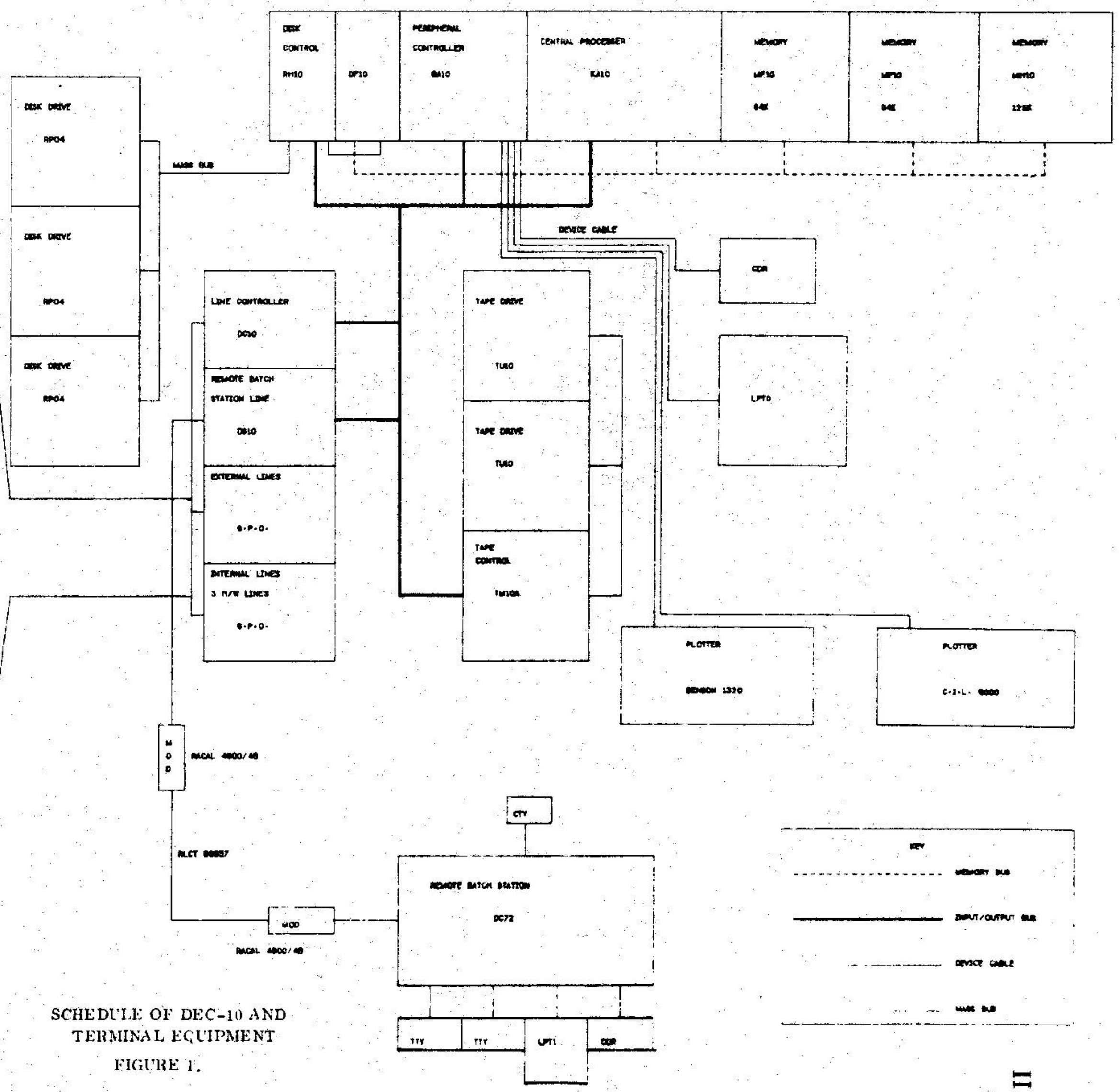
The reason for the anomaly lies in the multitude of variables that affect performance They include the quality, availability, reliability and accessibility of the computer services; the office environment and organisation; the external factors in the form of clients, customers, project location and timescales; human factors including experience, status, personality, emotions and ability. Given that there are so many factors it becomes apparent why the occasional claims of savings, of one sort or another expressed as factors of say 5 to 1 or 100 to 1 are quite absurd.

The Partnership has its collection of calculators, micros and minis and access to its own and other maxis. Each item of equipment is best at doing something but if that machine operates in isolation the temptation is to extrapolate and give it work for which it is not best suited. Computer networks provide flexibility, a range of power and can be cost effective when compared to other ways of providing computer services.

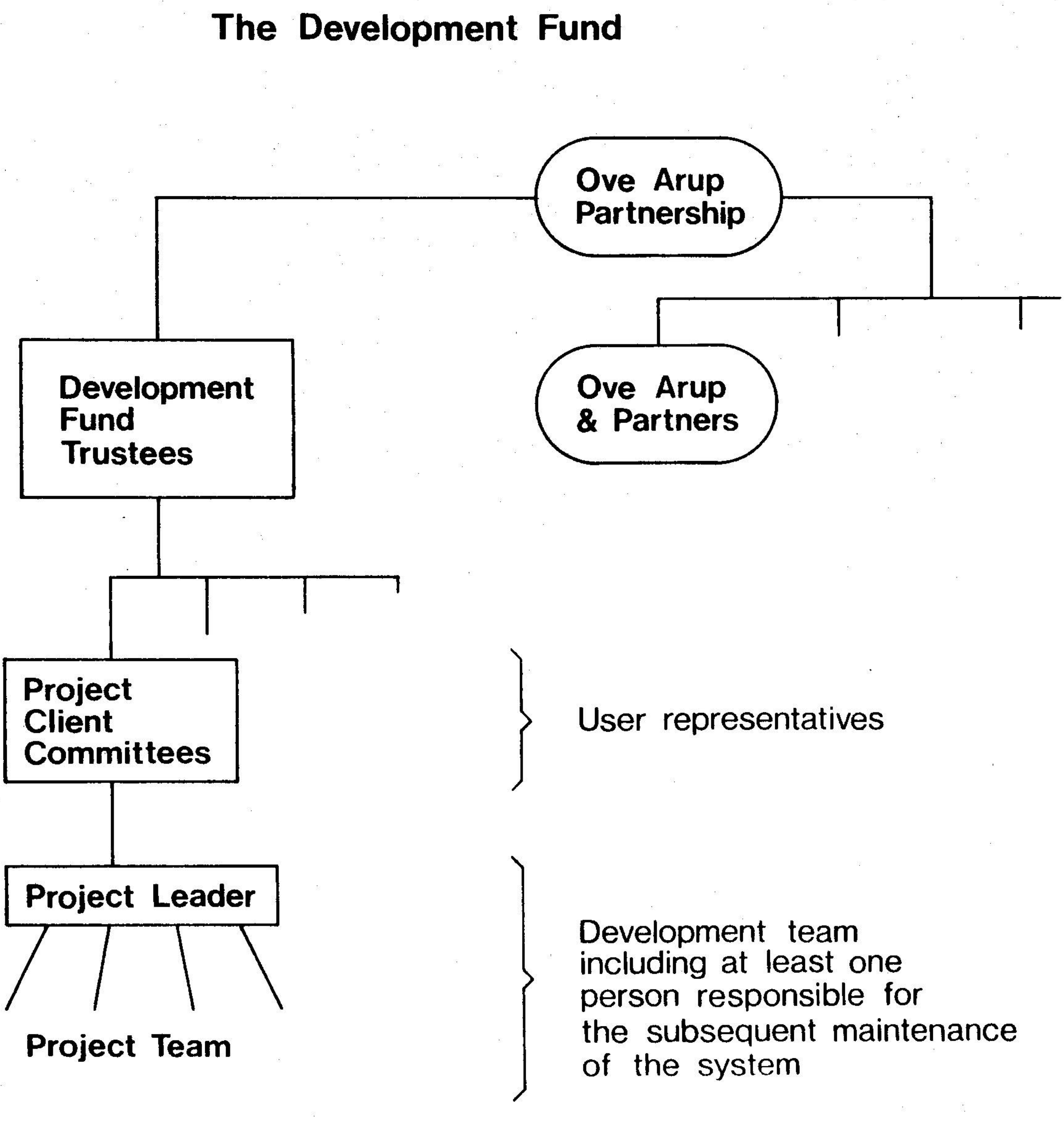
The current review of computing in Arups will not be complete until this autumn but one could hazard a guess at its conclusions. The present network will be extended using a mixture of machine sizes. Guidelines for compatibility of hardware and software will become more rigid. Overseas offices will equip with comparable machines to those employed in the UK. There will be more data transfer between machines.

The consequence of using computers will be that our engineers will become increasingly dependant upon them. There will be less opportunity to develop the alternative manual skills and so the cost benefits will become clearer. If this trend can be recognised the industry could take steps to develop new techniques as otherwise the quality of design and the ability to design might well diminish.

LOCATION	GROUP	TERMINAL	MODEM		MODEM	LINE
8/8	C+6	EA VDU	NONE	HARD/WIRE	NONE	0
6/8	C+8	TEKTRONIX	NONE	HARD/WIRE	NONE	1
6/8	C+8	EA VDU	NONE	HARD/WIRE	NONE	2
2/8	BE+2	DIABLO	NONE	HARD/WIRE	NONE	3
2/8	BE+2	EA VDU	NONE	HARD/WIRE	NONE	4
6/13	R+D	TEKTRONIX	MODEM 2	RLCT 85083	MODEM 2	5
TCR	BE+8	DIABLO	MODEM 2	RLCT 85083	MODEM 2	6
						7
////////	//////////////////	//////////////////	////////		////////	////////
6/8	C+8	EA VDU	NONE	HARD/WIRE	NONE	10
6/8	C+6	EA VDU	NONE	HARD/WIRE	NONE	11
6/8	C+8	EA VDU	NONE	HARD/WIRE	NONE	12
8/8	C+8	EA VDU	NONE	HARD/WIRE	NONE	13
8/8	C+8	EAVDU	MODEM 13		MODEM 2	14
8/8	C+8	TERMINET	MODEM 13		MODEM 2	15
8/13	R + D	EAVDU	MODEM 13		MODEM 2	16
2/13	CEB	EAVDU	ACCOUS		MODEM 2	17
3/13	CEN	DIABLO	MODEM 13		////////	////////
5/13	CEB	EAVDU	ACCOUS		MODEM 2	20
5/13	CEB	DECWRITER	MODEM 13		MODEM 2	21
2/B/HSE	BE+9	HY-PRINT	MODEM 13		MODEM 2	22
2/B/HSE	BE+9	DIABLO	MODEM 13		MODEM 2	23
3/A/HSE	BE+1	EAVDU	ACCOUS		MODEM 2	24
2/A/HSE	BE+5	DIABLO	MODEM 2		MODEM 2	25
3/CH	OFFSETS	DECWRITER	DC72		MODEM 2	26
3/CH	OFFSETS	DECWRITER	DC72		MODEM 2	27
LPS	CEN	DECWRITER	MODEM 13			
3+SS	ARAS	DIABLO	MODEM 13			
2+SS	BE+10	DIABLO	MODEM 2			
4+SS	BE+4	DIABLO	MODEM 2			
8/13	R + D	HP 8830	NONE			
8/8	C+8	TI 745	NONE			
EDIN		HP 8830				
MANCH		HP 8830				
SHEFF		DIABLO				
CARD		HP 8830				
DUBLIN		HP 8830				
8/8		TI 745	NONE			
2/A/HSE	BE+9	DIABLO	MODEM 13			



SCHEDULE OF DEC-10 AND
TERMINAL EQUIPMENT
FIGURE 1.



THE ORGANISATION OF

SOFTWARE DEVELOPMENT

FIGURE 2.

```
C VARIABLES LOCAL TO THE SUBROU[redacted]
C-----------------------------------
C      DIST1 = IS THE CAP DIMENSION AT THE LEVEL BEING CCNSIDERED
C      DIST2 = IS HALF THE ACTUAL BAR LENGTH
C      M     = COUNTER USED IN THE STEPPING RCUTINE
C      THETA = THE ANGLE BETWEEN THE ANGLED SIDE OF THE CAP AND THE
C              VERTICAL
C      YORD  = THE Y ORDINATE OF THE EXTERNAL BAR
C
C-----------------------------
C DECLARE STATEMENT FUNCTIONS
C-----------------------------
      JND5(Y) = (Y+2.5)/5.
      IND5(Z) = 5*JND5(Z)
      JND25(Y) = (Y+12.5)/25.
      IND25(Z) = 25*JND25(Z)
C-----------------------------------------------------------------------
C CALCULATE THE Y ORDINATE OF THE EXTERNAL BAR. THE DIAMETER AND SPACING
C OF THESE EXTERNAL BARS IN THE X DIRECTION ASSUME THE NOMINAL VALUES
C-----------------------------------------------------------------------
      YORD = CAPS(2,4)-SIDCV-(BARS(BARX)/2.)+NOMSP
      THETA = ASIN((CAPS(1,3)-CAPS(1,4))/SGRT((CAPS(1,4)-CAPS(1,3))**2
     1                                      +(CAPS(2,4)-CAPS(2,3))**2))
C---------------------------------------------------------------------
C A STEPPING ROUTINE IS NOW ENTERED IN WHICH THE BAR LENGTHS ARE
C INCREASED PROGRESSIVELY UNTIL A BAR N IS REACHED WHENCE ALL BARS ARE
C THE SAME.
C---------------------------------------------------------------------
      M = 0
   30 M = M+1
      IF (M-30)35,35,34
   34 CALL PCERR (15,1)
   35 IF ((YORD-(M*NOMSP))-(SIDCV+(TOTBX*SPX)))80,40,40
   40 DIST1 = CAPS(1,4)+(((SIDCV+((M-1)*NOMSP))*(CAPS(1,3)-CAPS(1,4)))/
     1                  (CAPS(2,4)-CAPS(2,3)))
      DIST2 = DIST1-((SIDCV*SGRT((CAPS(1,3)-CAPS(1,4))**2
     1                          +(CAPS(2,4)-CAPS(2,3))**2))
     2              /(CAPS(2,4)-CAPS(2,3)))
      IAX(M) = 2.*DIST2+0.5
      IF (IAX(M)-999)70,70,50
   50 IAX(M) = IAX(M)-5
      IF (IAX(M)-1999)70,70,60
   60 IAX(M) = IAX(M)-10
   70 IAX(M) = IND5(IAX(M)+0.001)
      LTHX(M) = IAX(M)+IBOBL+BOBLX-((ITS+3)*BARS(NOMDI))+0.5
      LTHX(M) = IND25(LTHX(M)+12.4)
```

A FORTRAN LISTING

FIGURE 3.

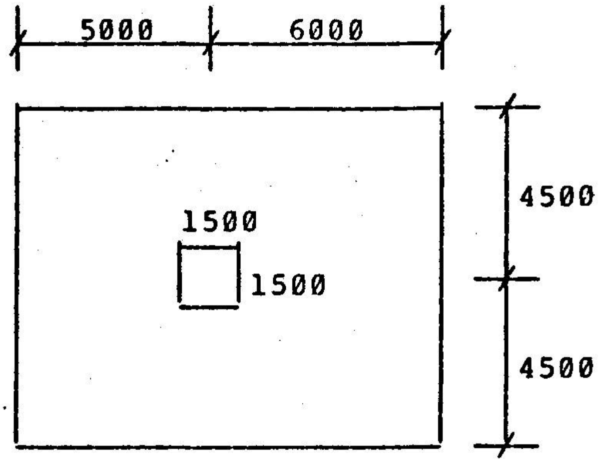
OVE ARUP & PARTNERS
CALCULATION SHEET

Job No.	Sheet No.	Rev.
7985		
Drg.Ref.		
Made by	Date 16-Apr-75	Chd.

GLADYS - SIMULATED OUTPUT

PAD FOOTING PROGRAM

FOOTING Z/7



f_{cu} = 30 N/mm^2 γ_m = 1.50
f_y = 410 N/mm^2 γ_m = 1.15

Deformed Bars Type 1

Local Bond f_{bs} = 2.8 N/mm^2
Anchorage Bond = 2.2 N/mm^2
Allowable Bearing Pressure = 300 kN/m^2

BASE DEPTH = 2000 mm

NOTE: M_x is +ve clockwise about the X-axis
M_y is +ve clockwise about the Y-axis

LOADCASE 1 Full Load + Wind

CHARACTERISTIC LOADS (kN,kNm)

	N	M_x	M_y	γ
DL	10000	100	50	1.2
LL	5000	50	20	1.2
WL	5000	20	20	1.2

LOADCASE 2 Dead Load + Wind

	N	M_x	M_y	γ
DL	10000	100	50	0.9
WL	5000	20	20	1.4

Max Bearing Pressure = 280 kN/m^2 < 300 O.K.

COVER
Sides = 75 mm
Bottom = 100 mm

X-Dirn

M= 300 kNm Q = 190 kN

Bending A_s (reqd) = 24500 mm^2
A_s (Provided) = 25000 mm^2 0.93%

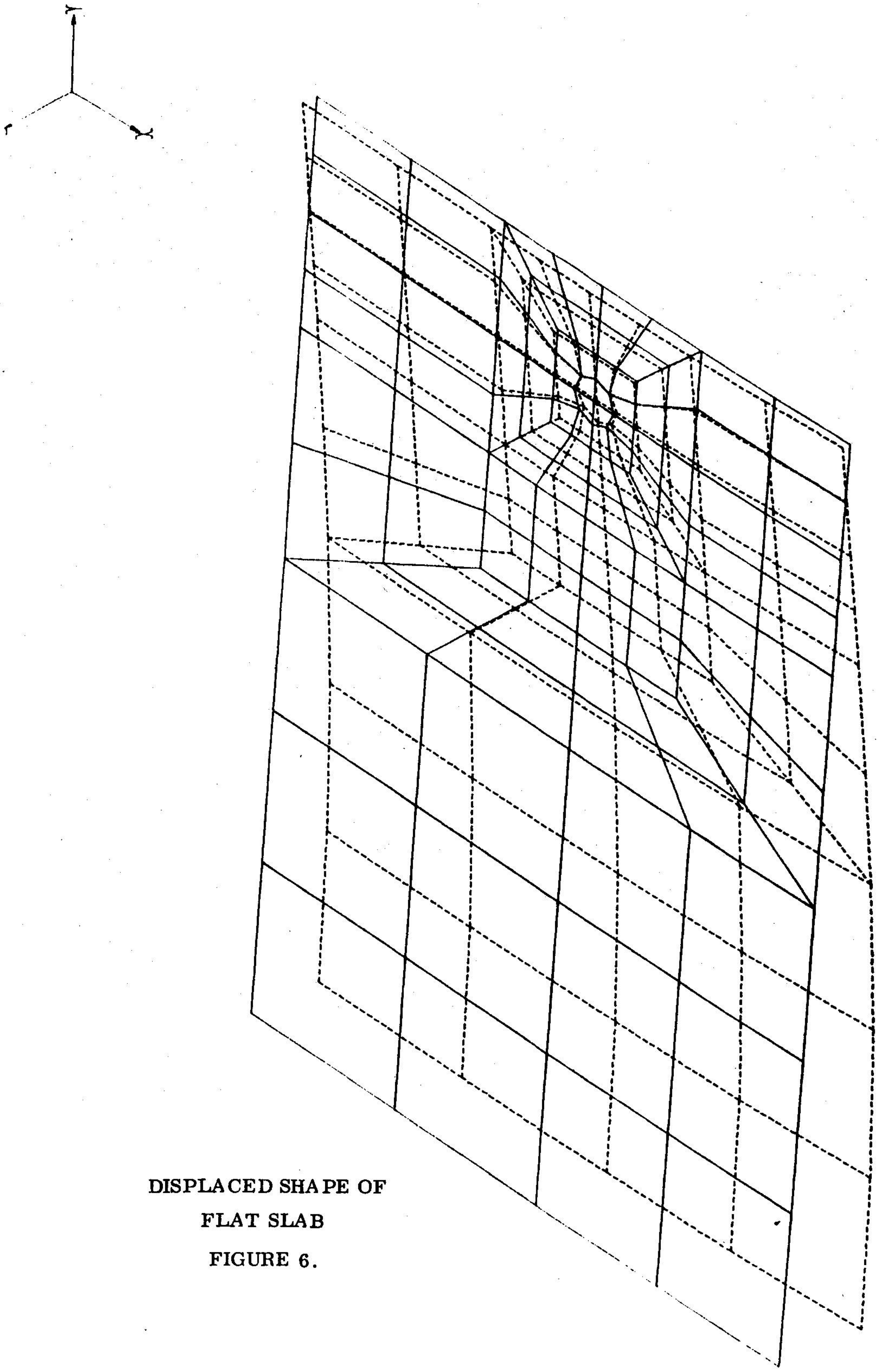
Local bond f_{bs} = 1.93 N/mm^2 < 2.20 O.K.
Shear v = 0.63 N/mm^2 < 0.70 O.K.

REINFORCEMENT

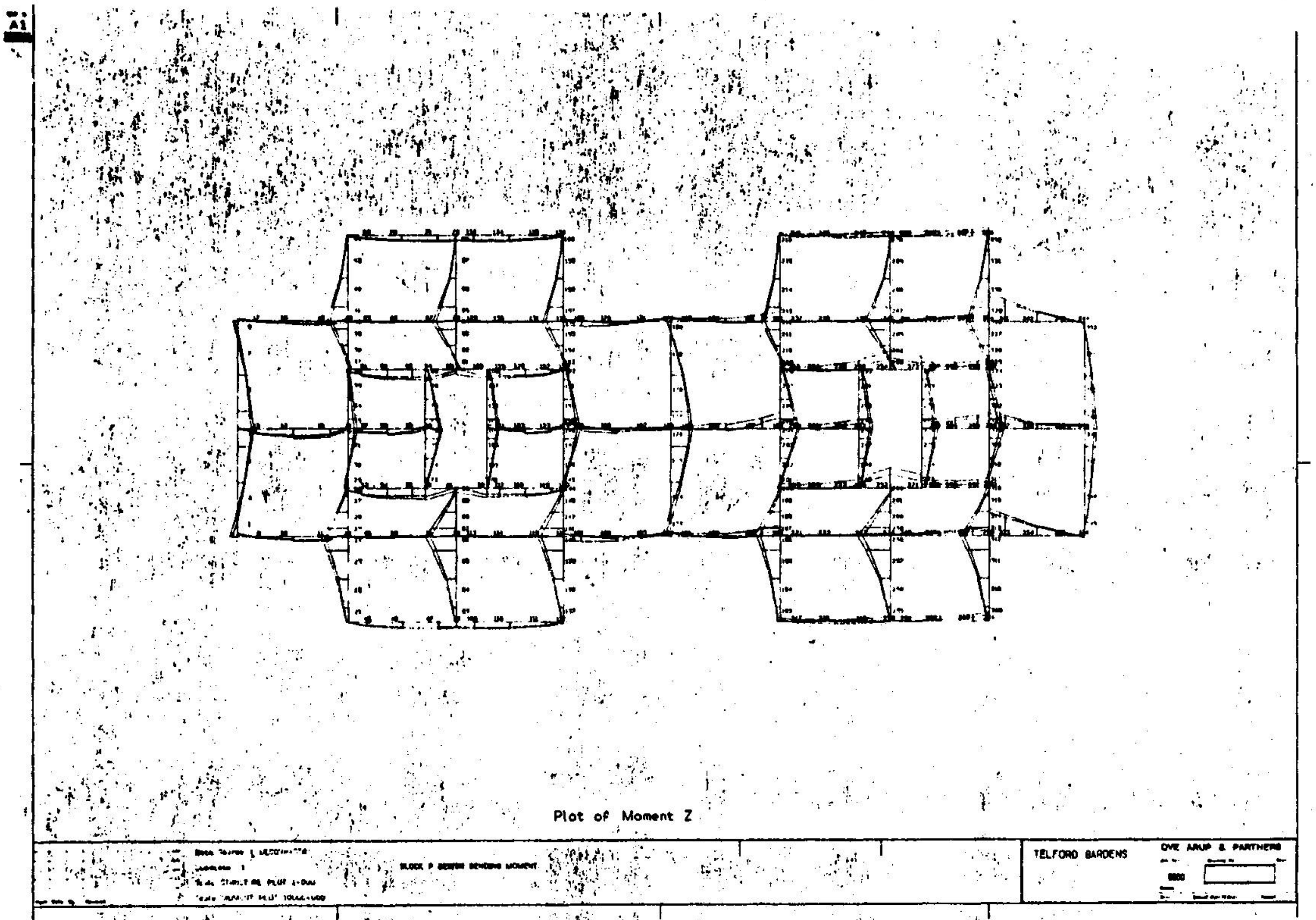
// to X-axis
Provide 40 Y25 BB
@ 125 mm p

COMPUTER PRODUCED FINAL CALCULATIONS

FIGURE 4.



DISPLACED SHAPE OF
FLAT SLAB
FIGURE 6.

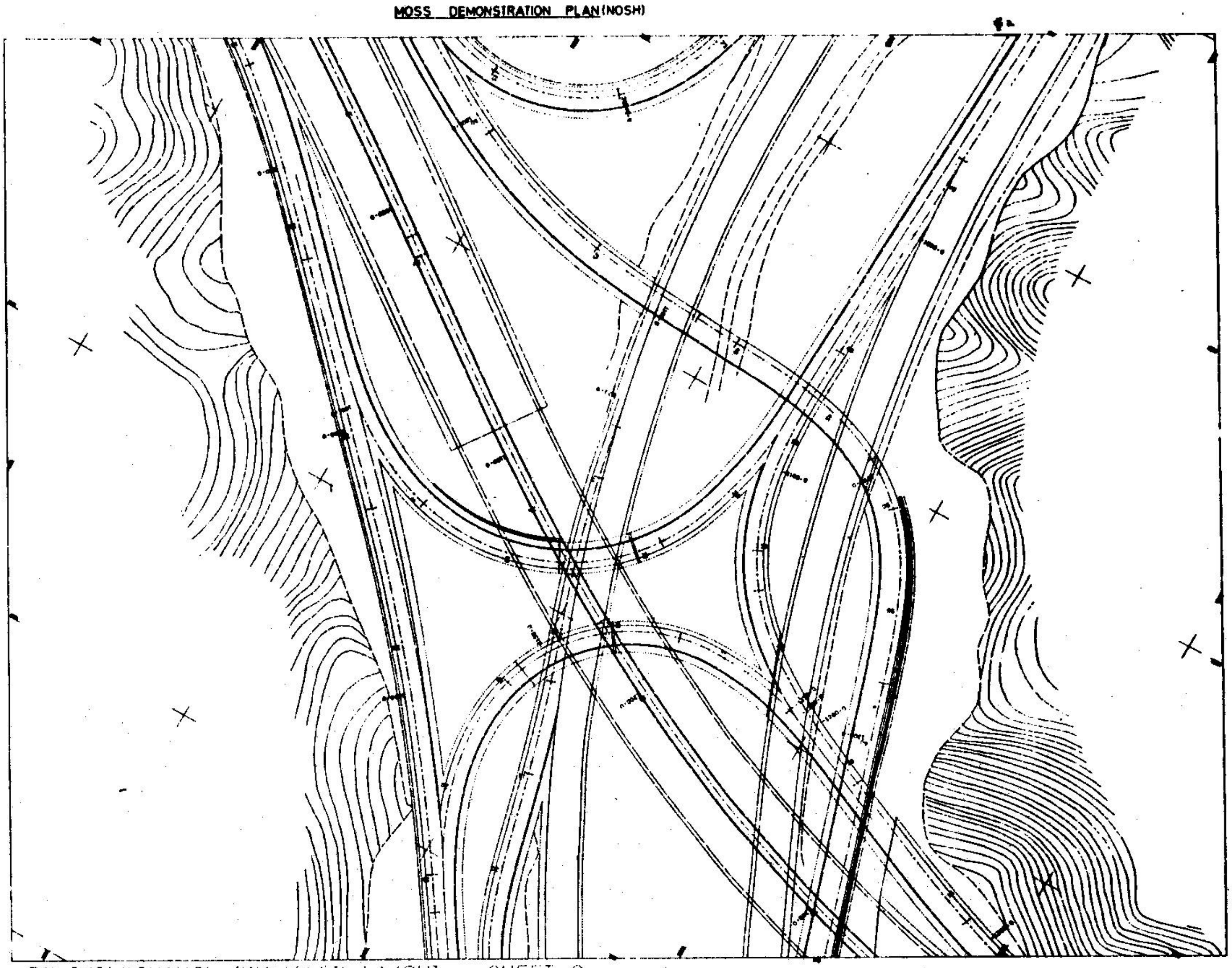


STRESS ANALYSIS RESULTS

FIGURE 5.

Program name:- PAFCO

MOSS DEMONSIRATION PLAN(NOSH)



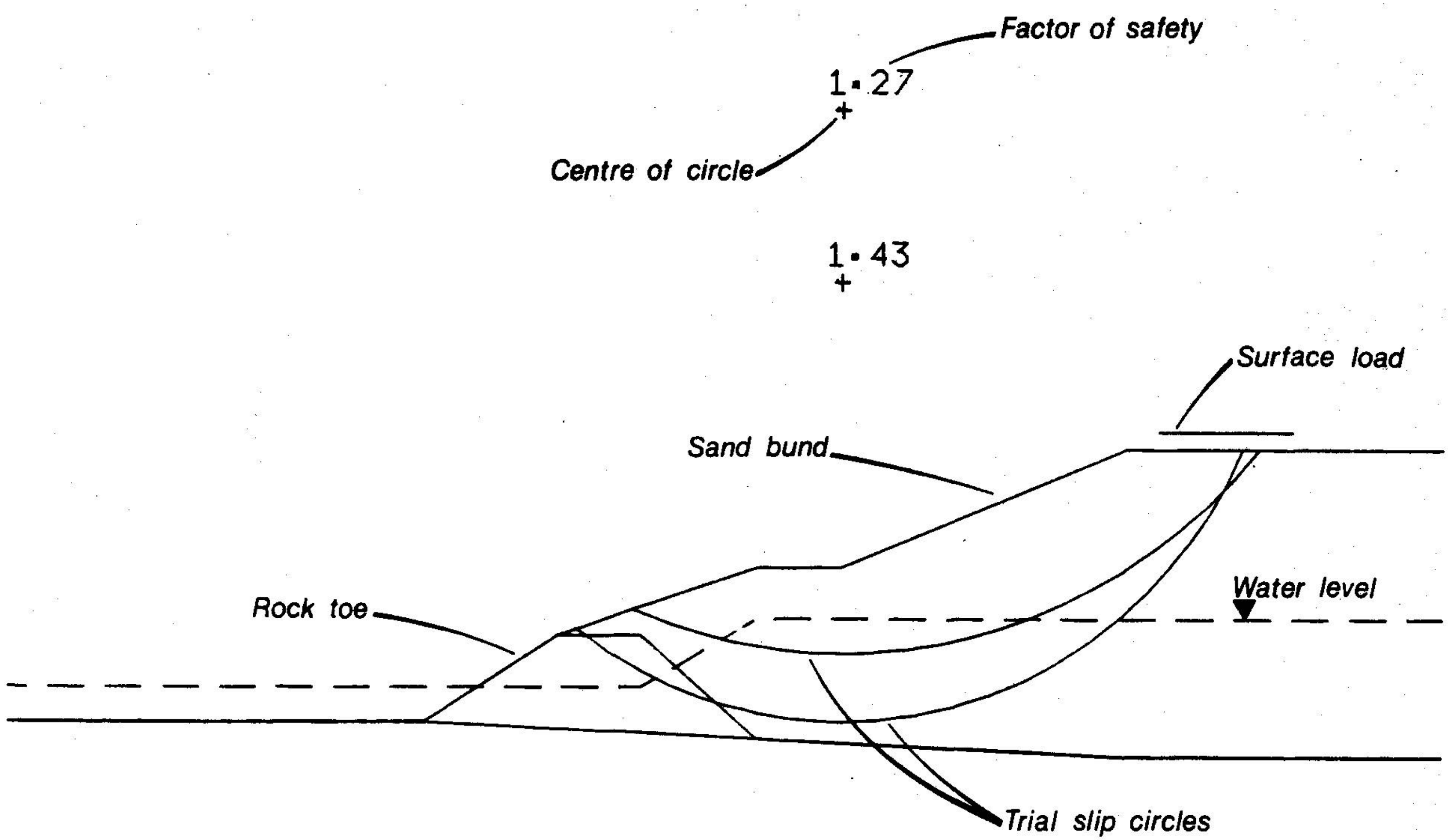
B8 INTERCHANGE PROPOSED LAYOUT , SHEET 2

HIGHWAY INTERSECTION PLAN

FIGURE 7.

Program name:- **MOSS**

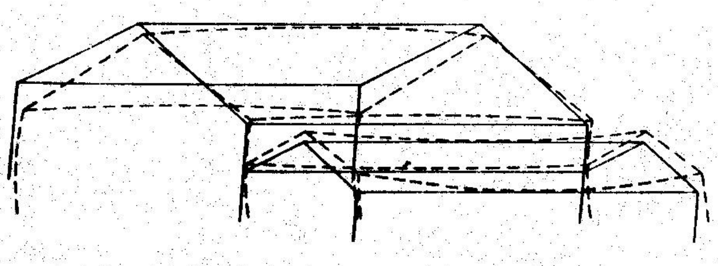
5495 DUBAI DRY DOCK. COFFERDAM BUND STABILIY.
PARTIALLY SUBMERGED SLOPE.



METHOD *** BISHOP (GEOTECHNIQUE,1955) - HORIZONTAL INTERSLICE FORCES :

SLOPE STABILITY ANALYSIS

FIGURE 8.



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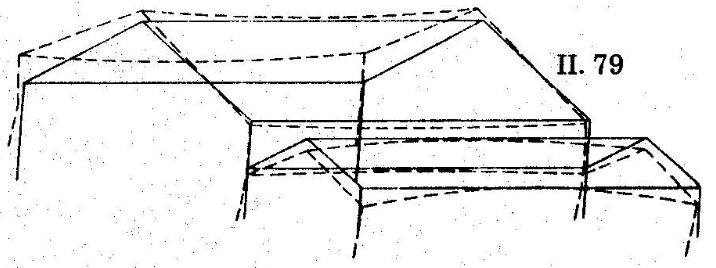

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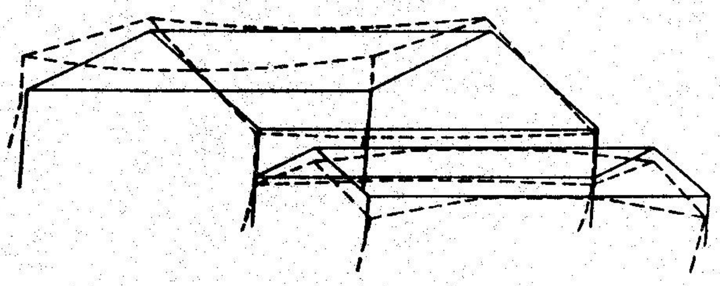

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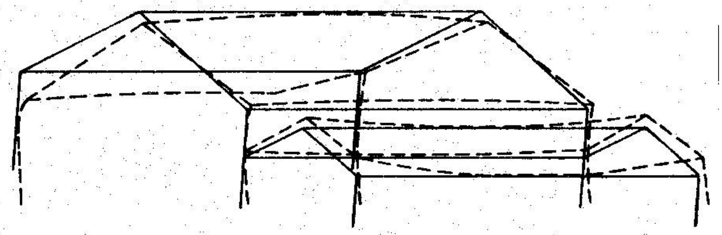
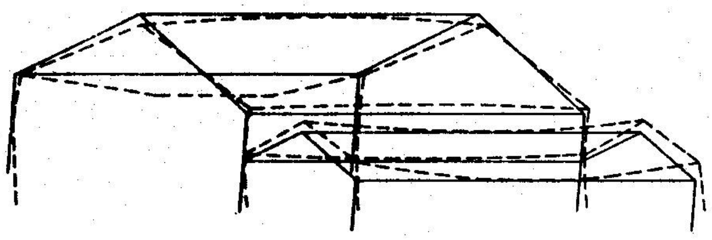


T = 7



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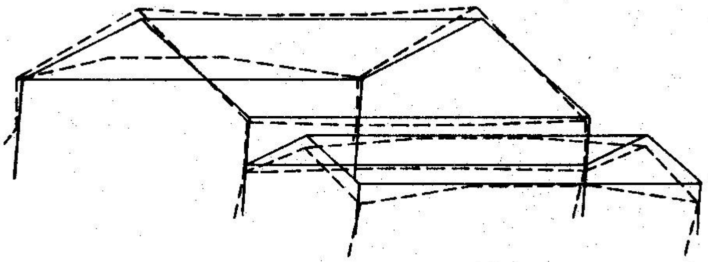

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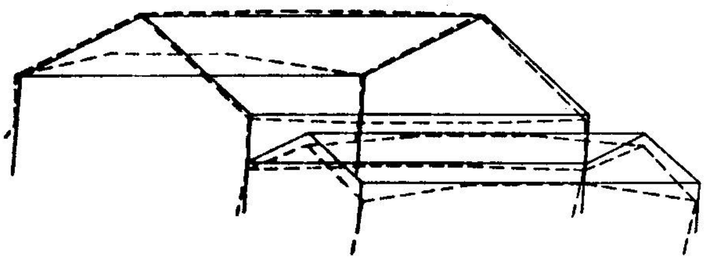
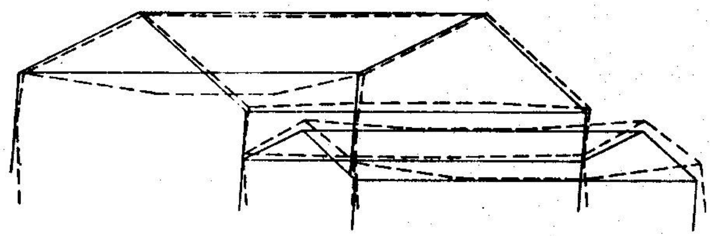
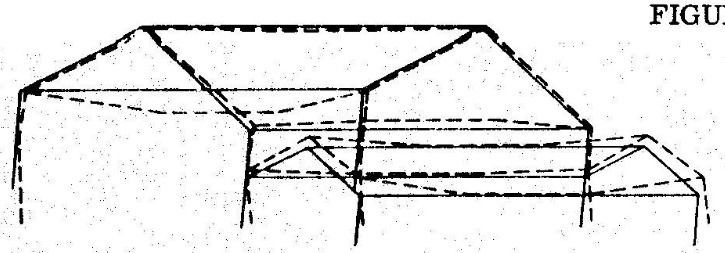


T = 4

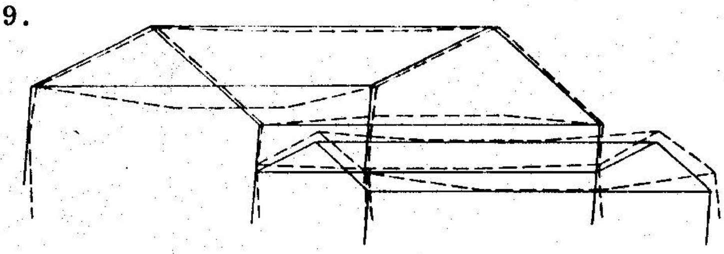


T = 9

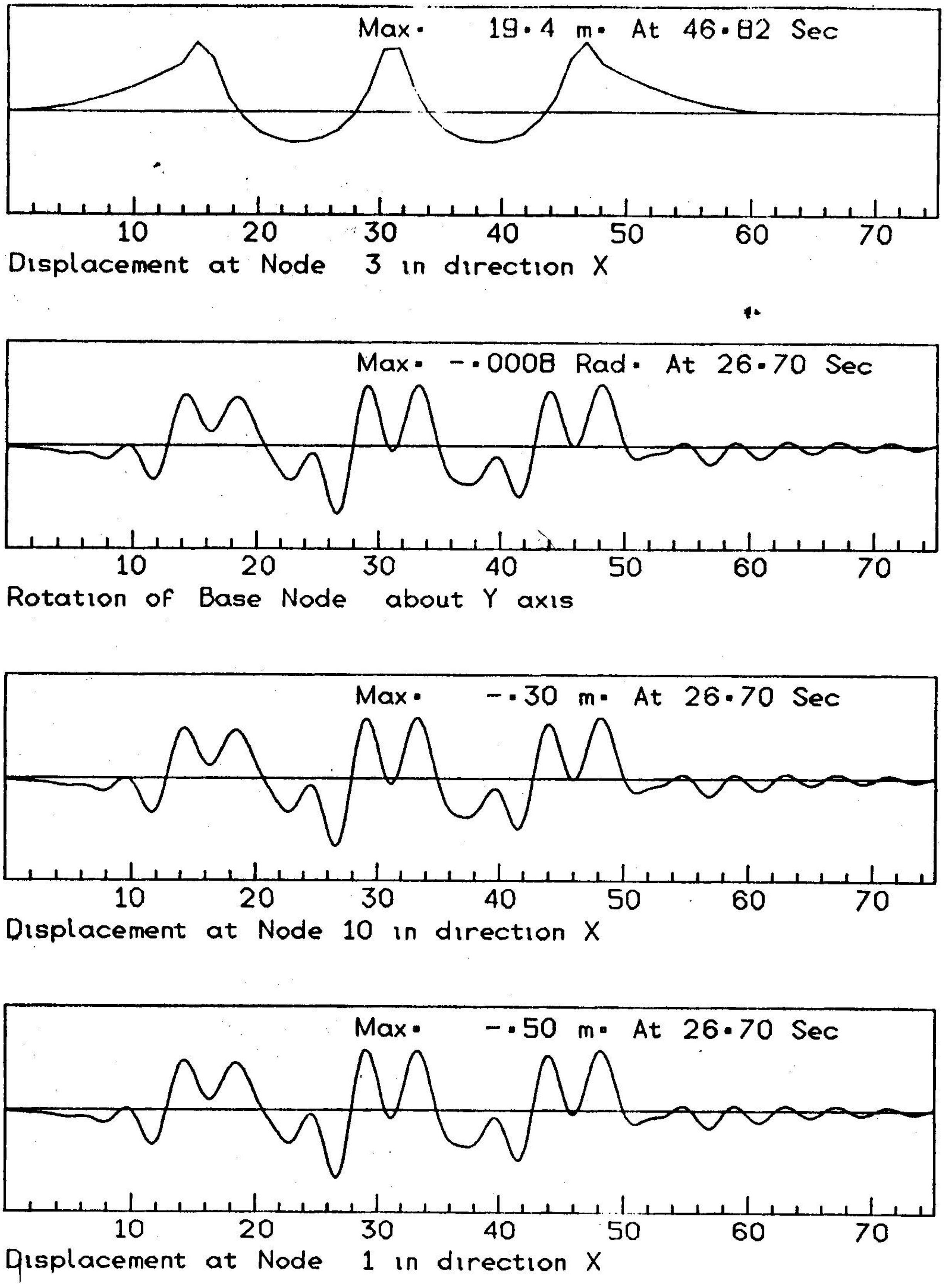
DYNAMIC ANALYSIS SHOWING
DEFLECTION AT TIME
INTERVALS
FIGURE 9.



T = 5



T = 10



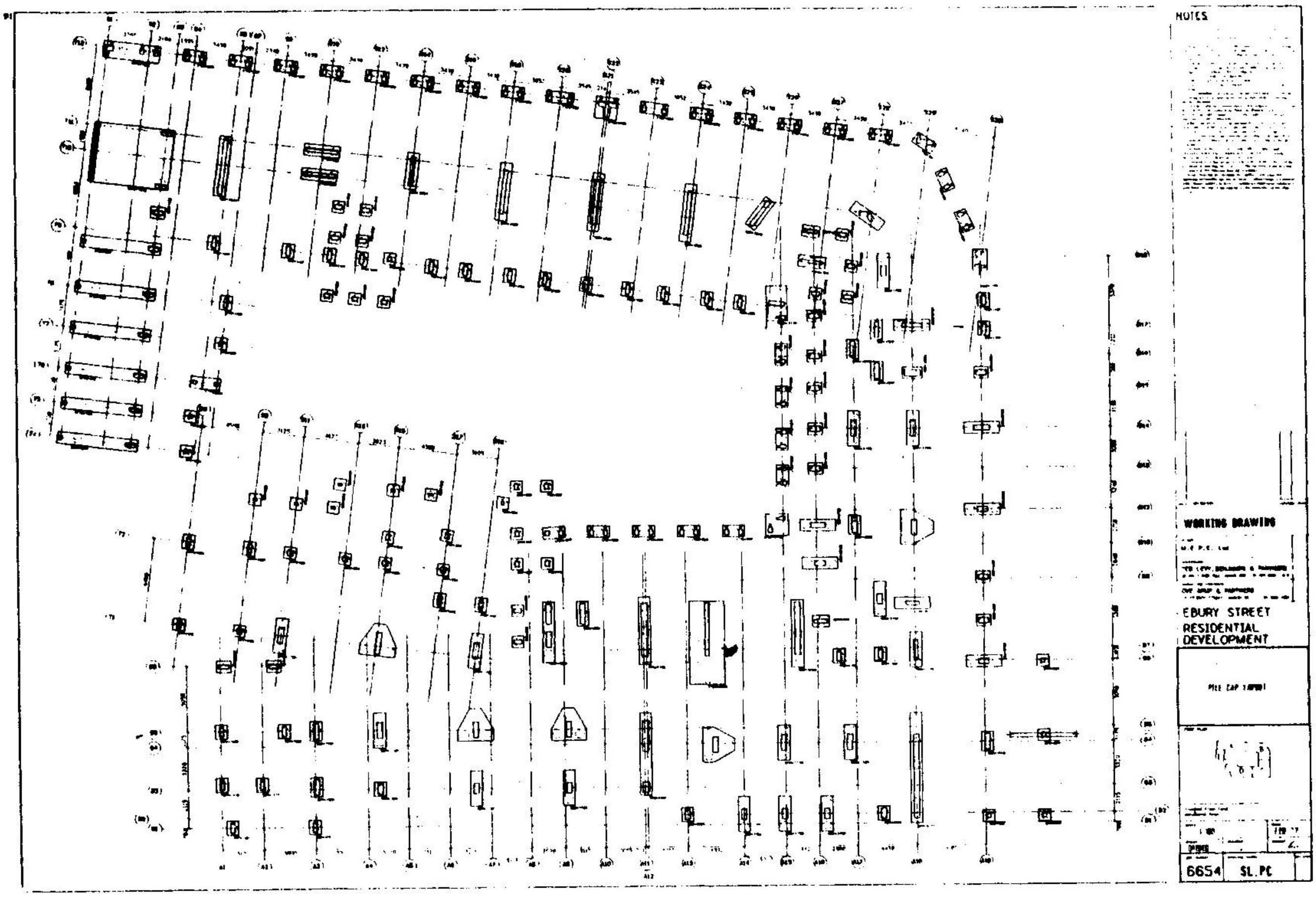
WAVE LOAD ON AN OILRIG

Ove Arup & Partners• Job No• 8421/02A
Program D•A•F•T• 15:37 1-Mar-78

VARIATION OF DISPLACEMENT WITH TIME FOR SELECTED NODES WITHIN A STRUCTURE

FIGURE 10.

Program name:- **DAFT**



AUTOMATED DRAUGHTING

EXAMPLE

FIGURE 11.

Program name:- CADRAW

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