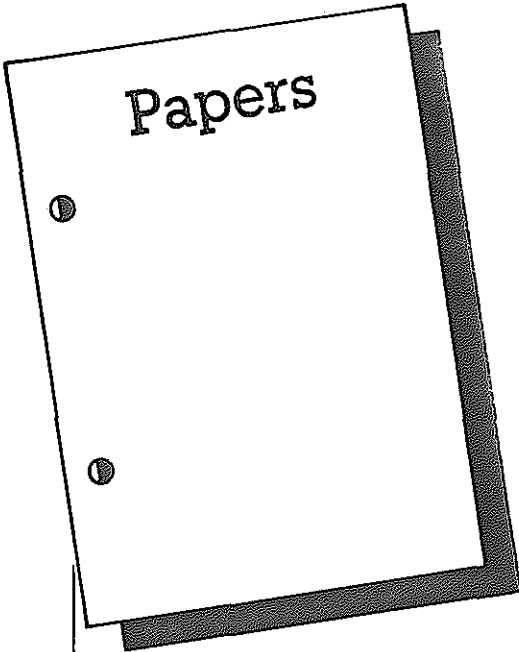




Papers

Integration of the capture, storage and presentation of site investigation data by microcomputer by the London Docklands Development Corporation

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Introduction

Vast amounts of money can be spent on borehole investigations for civil engineering projects. However, once the data has been used for the project in hand it is all too often disregarded in the consideration of future schemes. This is not always because of any lack of foresight by those involved but can be the case because the time required to search for any existing data is often not available. It has been appreciated for a long time that computers would provide a worthwhile means of access to such existing data and that their use could provide significant cost benefits in the site investigation process. Not only could further work be more finely tuned against an improved prior awareness of probable site conditions, but even more exciting is the potential for the immediate availability of the information.

Arguably it has always been possible to carry out a preliminary assessment of existing data based on traditional archiving procedures. Yet such usable archives rarely exist. Where they do the staff commitment necessary to extract the data and correlate the findings for a new

project often makes the exercise difficult and sometimes impossible to contemplate. Microcomputers have given the opportunity to use new technology to provide not only the rapid retrieval of large quantities of stored data from previous site investigations, in the manner traditionally understood of the desk study, but also to allow that data to be accessed by 'interactive interrogation'. This means that the information can be retrieved in a meaningful and useful form and not merely as endless screeds of tabulated numbers.

London Docklands Development Corporation was set up in 1981 by the UK Government to stimulate the regeneration of 2000ha of derelict docks to the east of the City of London. LDDC saw its role was to foster private sector interest. Part of its approach to this was to make geotechnical data available for the area in general and a large number of development sites in particular. LDDC has also undertaken substantial amounts of infrastructure works so that the sites were serviced with communications and public utilities. In order to accommodate the information collected through its own contracts during this process as well, as that from reports submitted to the corporation, it decided that a suitable storage and retrieval system should be devised which would need capacity for a projected 10 000 borehole records and associated laboratory test results. Following a consideration of a number of options it was decided that this should be based on computer.

The Data

Information collected during ground investigation for a civil engineering project principally takes the form of borehole records and associated laboratory data. This is usually supported by a report which describes the subsoil profile, together with an interpretation which assesses how the ground will behave in relation to the intended project. The interpretation will usually include various recommendations to ensure that the response of the ground is acceptable for the serviceability of the project.

Although of interest, this interpretation tends to be specific in its consideration having usually been commissioned for particular purposes. It is therefore not necessarily transferable to other projects, even where these may be located on the

same site. However, this is not so of the boreholes and laboratory data. These are factual in character, forming merely a record of the vertical variation of the material types on the one hand and a quantified assessment of their behavioural characteristics using standardised laboratory techniques on the other.

As the ground at any one location will rarely change with time without some outside influence, the factual data can be used for successive development considerations. In addition, as the natural materials are not controlled by artificial site boundaries, with care, the data can be used to extrapolate to other areas.

Methods of data storage

Traditionally site investigations for civil engineering purposes are carried out piecemeal, on a site by site basis by different interested parties. It is only when there is a concerted interest in a defined area that it is possible to collect and store the data in a way that could be used by others with some advantage. From a practical point of view there are a number of problems associated with the physical accumulation of the large volumes of material that can be generated in any one area, let alone an effective cataloging of that material and making it available for reuse. To be of any value the information must be seen as a resource by its keepers and maintained in a form which is readily available to other interested parties. Any system of data storage which is intended to achieve this should have a number of fundamental attributes.

- It must ensure ready access to the contained information.
- It should be capable of revision on a regular basis.
- In order to ensure that it does not become obsolete it should not be labour intensive in its structure or operation.

The storage of this type of information can be undertaken in a number of ways, each with its own advantages and disadvantages. These are:

- Traditional paper library.
- Microfilm/microfiche.
- Computer.

In the choice of method it is necessary to balance any advantages against the practicalities of later retrieval of the stored data. This will need to take into account the regularity of any enquiry and the form of that enquiry bearing in mind the amount

of data that might be involved. Most importantly it must give due consideration to the resources available to set up and maintain the system.

Although the LDDC is committed to use of computers for its office administration each of the available options for a geotechnical data storage system were considered in the study.

Traditional forms of paper archive were felt to be the most widely used and understood system of storage. However, there were two points of doubt about the long term viability of a conventional library. Firstly the amount of space required could not be guaranteed. Secondly there was also the need to provide a librarian to control and index the material if it was to remain usable and intact.

Microfilm or microfiche systems have the advantage that little space is needed. Also, multiple copies of the data are readily available. This means that lost material can be replaced. It was also concluded that, unlike at a public library, the enquirers were not expected to be casual browsers but would be driven by some specific interest. At times many parties were expected to be interested in the same data, as occurs when a contract is out for tender. Microfilm or microfiche techniques are suitable because of the ability to make multiple copies to satisfy such a demand. However, the systems are restricted to the direct reproduction of the original format and offer no ability for selective retrieval of the data other than at a very simple level. Users of site investigation data continually refer to and cross reference the information contained on more than one page. This cannot be carried out with microfilm or microfiche without the need to make intermediate paper copies. In addition, as they provide no more than a condensed form of the traditional library, they do not eliminate the need for a librarian and an efficient index. Indeed, without the provision of a librarian and index the casual enquirer would very likely end up ignorant of the presence of the information contained in the system.

A computer was concluded to offer the ability to store large quantities of data in small spaces with the added advantage of selective access. Small desk top machines with large internal memories are able to handle very complex and involved storage/retrieval systems and are highly

A. F. HOWLAND ASSOCIATES				SITE		BORNEHOLE			
Telephone (0121) 707070				PARKS PLACE		25			
Client: M. J. B. & S. Ltd.				Borehole No: 25		Sheet No: 1			
Location: 25.00 N 10.00 E				Borehole Depth: 10.00 m		Borehole Type: 1			
Borehole No: 25				Borehole Date: 10.00.00		Borehole Status: 1			
Borehole Date: 10.00.00				Borehole Status: 1		Borehole Type: 1			
Borehole Data				Description of Borehole					
Depth (m)	Soil Type	Soil Colour	Soil Texture	Description of Borehole					
0.00 - 1.00	1.00	1.00	1.00	Soil Type: 1.00					
1.00 - 2.00	1.00	1.00	1.00	Soil Type: 1.00					
2.00 - 3.00	1.00	1.00	1.00	Soil Type: 1.00					
3.00 - 4.00	1.00	1.00	1.00	Soil Type: 1.00					
4.00 - 5.00	1.00	1.00	1.00	Soil Type: 1.00					
5.00 - 6.00	1.00	1.00	1.00	Soil Type: 1.00					
6.00 - 7.00	1.00	1.00	1.00	Soil Type: 1.00					
7.00 - 8.00	1.00	1.00	1.00	Soil Type: 1.00					
8.00 - 9.00	1.00	1.00	1.00	Soil Type: 1.00					
9.00 - 10.00	1.00	1.00	1.00	Soil Type: 1.00					

LABORATORY TEST RESULTS										Notes
TEST / TEST TYPE		Sample no.		Reactive glassware		Reactive glassware		Reactive glassware		
TEST	TEST TYPE	Sample no.	Sample no.	Reactive glassware	Reactive glassware	Reactive glassware	Reactive glassware	Reactive glassware	Reactive glassware	
TEST	TEST TYPE	Sample no.	Sample no.	Reactive glassware	Reactive glassware	Reactive glassware	Reactive glassware	Reactive glassware	Reactive glassware	
1	1	1	1	1	1	1	1	1	1	
2	2	2	2	2	2	2	2	2	2	
3	3	3	3	3	3	3	3	3	3	
4	4	4	4	4	4	4	4	4	4	
5	5	5	5	5	5	5	5	5	5	
6	6	6	6	6	6	6	6	6	6	
7	7	7	7	7	7	7	7	7	7	
8	8	8	8	8	8	8	8	8	8	
9	9	9	9	9	9	9	9	9	9	
10	10	10	10	10	10	10	10	10	10	
11	11	11	11	11	11	11	11	11	11	
12	12	12	12	12	12	12	12	12	12	
13	13	13	13	13	13	13	13	13	13	
14	14	14	14	14	14	14	14	14	14	
15	15	15	15	15	15	15	15	15	15	
16	16	16	16	16	16	16	16	16	16	
17	17	17	17	17	17	17	17	17	17	
18	18	18	18	18	18	18	18	18	18	
19	19	19	19	19	19	19	19	19	19	
20	20	20	20	20	20	20	20	20	20	
21	21	21	21	21	21	21	21	21	21	
22	22	22	22	22	22	22	22	22	22	
23	23	23	23	23	23	23	23	23	23	
24	24	24	24	24	24	24	24	24	24	
25	25	25	25	25	25	25	25	25	25	
26	26	26	26	26	26	26	26	26	26	
27	27	27	27	27	27	27	27	27	27	
28	28	28	28	28	28	28	28	28	28	
29	29	29	29	29	29	29	29	29	29	
30	30	30	30	30	30	30	30	30	30	
31	31	31	31	31	31	31	31	31	31	
32	32	32	32	32	32	32	32	32	32	
33	33	33	33	33	33	33	33	33	33	
34	34	34	34	34	34	34	34	34	34	
35	35	35	35	35	35	35	35	35	35	
36	36	36	36	36	36	36	36	36	36	
37	37	37	37	37	37	37	37	37	37	
38	38	38	38	38	38	38	38	38	38	
39	39	39	39	39	39	39	39	39	39	
40	40	40	40	40	40	40	40	40	40	
41	41	41	41	41	41	41	41	41	41	
42	42	42	42	42	42	42	42	42	42	
43	43	43	43	43	43	43	43	43	43	
44	44	44	44	44	44	44	44	44	44	
45	45	45	45	45	45	45	45	45	45	
46	46	46	46	46	46	46	46	46	46	
47	47	47	47	47	47	47	47	47	47	
48	48	48	48	48	48	48	48	48	48	
49	49	49	49	49	49	49	49	49	49	
50	50	50	50	50	50	50	50	50	50	
51	51	51	51	51	51	51	51	51	51	
52	52	52	52	52	52	52	52	52	52	
53	53	53	53	53	53	53	53	53	53	
54	54	54	54	54	54	54	54	54	54	
55	55	55	55	55	55	55	55	55	55	
56	56	56	56	56	56	56	56	56	56	
57	57	57	57	57	57	57	57	57	57	
58	58	58	58	58	58	58	58	58	58	
59	59	59	59	59	59	59	59	59	59	
60	60	60	60	60	60	60	60	60	60	
61	61	61	61	61	61	61	61	61	61	
62	62	62	62	62	62	62	62	62	62	
63	63	63	63	63	63	63	63	63	63	
64	64	64	64	64	64	64	64	64	64	
65	65	65	65	65	65	65	65	65	65	
66	66	66	66	66	66	66	66	66	66	
67	67	67	67	67	67	67	67	67	67	
68	68	68	68	68	68	68	68	68	68	
69	69	69	69	69	69	69	69	69	69	
70	70	70	70	70	70	70	70	70	70	
71	71	71	71	71	71	71	71	71	71	
72	72	72	72	72	72	72	72	72	72	
73	73	73	73	73	73	73	73	73	73	
74	74	74	74	74	74	74	74	74	74	
75	75	75	75	75	75	75	75	75	75	
76	76	76	76	76	76	76	76	76	76	
77	77	77	77	77	77	77	77	77	77	
78	78	78	78	78	78	78	78	78	78	
79	79	79	79	79	79	79	79	79	79	
80	80	80	80	80	80	80	80	80	80	
81	81	81	81	81	81	81	81	81	81	
82	82	82	82	82	82	82	82	82	82	
83	83	83	83	83	83	83	83	83	83	
84	84	84	84	84	84	84	84	84	84	
85	85	85	85	85	85	85	85	85	85	
86	86	86	86	86	86	86	86	86	86	
87	87	87	87	87	87	87	87	87	87	
88	88	88	88	88	88	88	88	88	88	
89	89	89	89	89	89	89	89	89	89	
90	90	90	90	90	90	90	90	90	90	
91	91	91	91	91	91	91	91	91	91	
92	92	92	92	92	92	92	92	92	92	
93	93	93	93	93	93	93	93	93	93	
94	94	94	94	94	94	94	94	94	94	
95	95	95	95	95	95	95	95	95	95	
96	96	96	96	96	96	96	96	96	96	
97	97	97	97	97	97	97	97	97	97	
98	98	98	98	98	98	98	98	98	98	
99	99	99	99	99	99	99	99	99	99	
100	100	100	100	100	100	100	100	100	100	

Fig. 1. The typical style and format of geotechnical borehole records and laboratory test results showing the strong emphasis of the data to be referenced to depth.

suitable to the character of the geotechnical data contained in site investigation reports.

Geotechnical data and its suitability for computer storage

Geotechnical data from borehole records and laboratory test results provides the variation of a number of discrete parameters each referenced to depth. It is therefore of a form which is very suitable to simple tabulation (Fig. 1). This is the intrinsic format used by computer databases for the storage of information. Their use as the core of a storage and retrieval system allows the contained data to be interrogated and manipulated by any number of output programs. One particular advantage is that such programs are separate from the database and can therefore be developed in time in line with the later perceived needs of the user. In this way the fundamental geotechnical data can be stored from very early on in the concept of the system.

This ability to begin to store data from the outset is most important for two reasons. Firstly, the time and cost involved in the

capture of data, especially that existing in paper formats, is often grossly underestimated. At the very least the data may need to be retyped completely and the input then checked back against the original record. Secondly, any system, no matter how sophisticated, is of little value until it contains sufficient data to be of use to an enquirer.

Nonetheless, the development of a usable system requires careful consideration of the mechanics of its intended purpose. From that the appropriate development software and hardware can be determined. Only then can the application software, with which the user will interface, be written.

The systematic storage and retrieval of borehole data has been attempted at various times using a variety of approaches (see for example Dearman and Strachan 1983¹, Harvey 1973², Lawson et al 1975³, McMillan et al 1984⁴, Wood et al 1982⁵). The best known was perhaps the work by the UK Construction Industry Research & Information Association which undertook a feasibility study of the formation of a national registry of ground investigation reports (Tuckwell and Sadgrove 1977⁶). It considered the development of a data store of civil engineering site investigation records with the view to make that information more readily available to other interested parties. In fact, the study concluded that microfilming would be a better and more appropriate method for storage than computers. The actual storage and retrieval of microfilmed information would then have been carried out by manual filing.

In support of these conclusions the study expressed concern that the extraction of data from the source reports for computer storage would require judgement, introduce scope for errors and be too costly.

In view of the similarity if the aims of the LDDC and CIRIA studies those conclusions need to be reviewed in the light of the advances in computer technology – which show CIRIA's misgivings to have become unnecessary. Use of microcomputers to produce conventional borehole records has found to be both practical and to have significant advantages in time and efficiency (Chaplow 1986⁷, Finn and Eldred 1987⁸, Howland 1986⁹, Howland and Podolski 1985¹⁰). However, this general approach

Data Entry		11:06:10 29 MAR 1989	515000
1. Enter Coordinates and Levels (Table 1). 2. Enter Penetration Test Results (Table 2). 3. Enter Strength Test Results (Table 3). 4. Enter Consolidation Test Results (Table 4). 5. Enter Index Test and Chemical Results (Table 5). 6. Enter Borehole Log Data. 7. Enter Laboratory Test Results for August 25th.			
F8=Toggle MAIN/LIST menu CUI=PS-YCL F8=END menu RETURN menu OPTION			

PLOTTING AND DRAWING		08:18:57 01 DEC 1988	515000
1. PLOT BOREHOLES ON A 1/1250 PLAN TO AN A4 SHEET 2. PLOT BOREHOLES ON A 1/1250 PLAN TO AN A3 SHEET 3. PLOT OF BOREHOLE DATA AGAINST DEPTH TO A3/A4 SHEETS 4. PLOT BOREHOLES ON A 1/1250 PLAN WITH A VALUE TO AN A4 SHEET 5. PLOT BOREHOLES ON A 1/1250 PLAN WITH A VALUE TO AN A3 SHEET 6. PLOT BOREHOLES ON A 1/1250 PLAN TO AN A4 SHEET 7. PLOT BOREHOLES ON A 1/1250 PLAN TO AN A3 SHEET 8. PLOT BOREHOLES ON A 1/1250 PLAN WITH A VALUE TO AN A4 SHEET 9. PLOT BOREHOLES ON A 1/1250 PLAN WITH A VALUE TO AN A3 SHEET 10. PLOT ALL BOREHOLES ON A 1/1250 PLAN TO AN A4 SHEET			

LOGS		Enter Borehole Descriptions	11:17:31	515000
LONDON DOCKLANDS DEVELOPMENT CORPORATION		01 Archive Ref.: 1970	02 Borehole No.: 7	
03	Depth (m)	Description of Strata	04	CDP
01	1.35	MAGE GROUND. Soft grey gravelly sandy clay.	A1	
02	1.60	Soft to firm brown mottled orange silty clay with o.c.	B2	
03	2.50	Soft dark brown clay with silty clay.	B1	
04	2.30	Soft grey silty clay with some pebbles.	B2	
05	2.45	Brownish-grey silty clay fine to medium sand.	C1	
06	4.40	Medium dense to dense grey-brown fine to coarse GRAVEL.	C4	
07	6.10	Soft brownish-grey silty sandy clay with some fine sand.	C3	
08	9.30	Dense brown fine to coarse GRAVEL with some silty sand.	C4	
09	13.45	Firm to stiff blue-grey silty clay with occasional qr.	DSE	

Enter Field Number to Add/Change, or 'ENTER' when complete...

TABLES		Enter Laboratory Index Results	12:11	515000
LONDON DOCKLANDS DEVELOPMENT CORPORATION		01 Archive Ref.: 1970	02 Borehole No.: 7	
03	Sample Depth (m)	Molecular Content (%)	Liquid Limit (%)	Plasticity Index (%)
01	1.25	45	43	24
02	1.50	34		
03	3.00			
04	4.00	25	32	10
05	9.30	22		
06	13.00	20		
07	13.50	25	32	20
08	17.30			

Enter Field Number to Add/Change, or 'ENTER' when complete...

Fig. 3. Typical data entry screens for the online entry of information from individual site investigation reports. These are laid out specifically to imitate the tables in each report. The masks are selected from a simple menu by the keyboard operator.

of screen masks which are designed specifically for each report. In this way the various tables and formats are duplicated on the screen and the keyboard operator can enter directly from the report (Fig. 3). The need for any technical understanding is again eliminated. The file is then processed to merge the data and complete file validated and corrected as necessary before entry to the database.

Graphical information can also be entered directly into the system using a digitizing tablet. This procedure allows soil grading details to be abstracted directly from the grading sheets supplied with the reports. The percentage passing any required sieve size is determined by simply digitizing the curve at points representing the sieve sizes. From this the grading characteristics such as D_{10} or D_{60} can be interpolated by the computer. These can be listed as required or the complete grading curve can be replotted singly or in combination. Other suitable data can be similarly plotted, for example grid references can be rapidly lifted from scaled drawings.

Enquiries

An overriding requirement of the system is the simplicity of its operation by the user. In order to be useful to as wide a range as possible it was necessary to build a system that could be operated by casual enquirers with minimal instruction.

Probably the most important attribute of the data is a grid reference which uniquely identifies its geographical position. Most enquirers will wish to access the data by defined geographical areas to establish whether previous investigations have been carried out. The information extracted from the database can be tabulated in a variety of formats (Fig. 4) and for this reason a number of standard print and enquiry options are available which can be chosen through menu selection procedures. However, the data can often be of more immediate use if the relevant items are plotted and displayed as graphical output. Therefore further menu options are available which can be used separately, or in conjunction with the print facility, in order to select the scale, then area and plot the spatial distribution of a variety of parameters (Fig. 5).

In addition the database also incorporates a powerful dictionary driven report generator and data retrieval command language. By defining simple English commands the more experienced user is able to list data and information in any format required. This offers a further level of interaction with the machine allowing a far greater selection of the data to be retrieved. This can be processed further

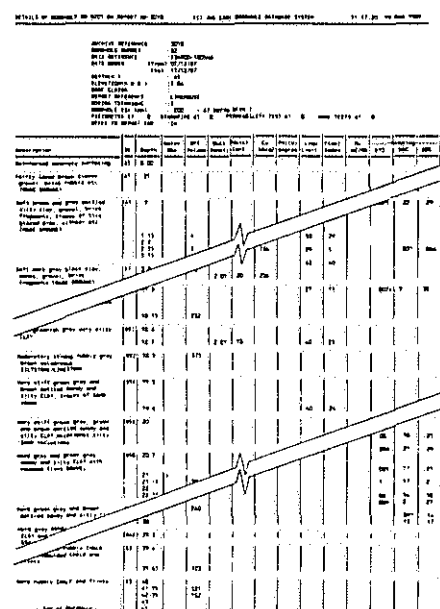


Fig. 4. The information from the database can be tabulated in a variety of formats. This example gives the borehole details and a summary of the laboratory test results.

PLOT OF BOREHOLE TO AN A4 SHEET AT 1/1250 SCALE:
- WILL COVER AN AREA OF 400m E AND 320m N.
FROM THE COORDINATES ENTERED BELOW

PLEASE ENTER:
BOTTOM LEFT GRID REFERENCE:
7840000 N.E. IN THE RANGE 530000 TO 540000
7850000 N.W. IN THE RANGE 170000 TO 180000

Fig. 5. A number of plots can be selected from a menu to give a variety of data plotted at a number of scales. Once the selection is made the program will prompt for the necessary information to begin the plot.

or passed as standardised files to other programmes and utilities for display or use.

Benefits

It is often difficult to quantify the benefits of software, but now that the system has been in virtual continuous use for over two years gives some testimony to its value. It has satisfied external enquiries at a rate of about two per week during that time. As many of these are made by telephone; a procedure has been developed where the enquirer provides the grid reference for the area of interest and can be told almost immediately whether, and how much, information is available. He then has the option of visiting the LDDC offices to make further enquiries of the system or have the data sent by post. Some enquirers have become quite adept at interrogating the system while others prefer to use it to collate all the available data.

The system is also used extensively as an in house tool. This currently provides probably the most taxing demands on its capabilities. During a number of recent potential Clause 12 claim it was able to provide a rapid identification of the data within the problem area which was then available at the initial meetings to review possible modifications to the works. It was also possible to check other areas of the contract for similar ground conditions. One of these occasions in particular required extensive further site investigation. Because the system was able to accommodate additional data items that had not originally been expected, the very detailed aspects of this investigation were rapidly processed. This allowed comparisons both with the data originally contained in the system as well as that established within the specific investigation and proved invaluable during the ensuing discussions.

Although the system does not purport to eliminate the need for a conventional site investigation it has been found that the ability to have immediate access to soil information has become a valuable additional tool for the process of redevelopment. Reliable information is readily available at the first stages of consideration. This benefits the planners, architects and engineers alike. While beyond this the ability to process and manipulate the data very rapidly has significant advantages in the detailed consideration in large scale projects currently being undertaken in the Docklands area and which have a significant interaction with ground conditions.

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