PLANNING AND GEOTECHNICAL CONSIDERATIONS FOR REDEVELOPMENT OF DERELICT INDUSTRIAL LAND IN LONDON DOCKLANDS

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ABSTRACT

The redevelopment of former docklands, with docks frequently backfilled by end tipping through water, requires careful planning and a proper understanding of the geotechnical properties of the materials involved.

An overall scheme for development of part of the former Surrey Commercial Docks Southwark, disused since 1960's, was formulated by London Dockland Development Corporation to provide a new environment encompassing housing, schooling, a shopping centre, social and recreation facilities and light industrial units.

This paper presents a review of the development strategy and planning aspects of the development of Surrey Quays with particular reference to the assessment of the former wharf areas and the quality of the dockfill. Planning considerations along with the rolé of geotechnics within the infrastructure development plan are presented. The results of a geotechnical investigation which included an extensive phase of field and laboratory testing, led to a ground improvement programme consisting of surcharge loading and vibroreplacement.

INTRODUCTION

As a consequence of a government policy of decentralisation there was a general decrease in inner city population throughout Britain during the 1950's and 1960's. Over the same period, but for different reasons, Britain's largest cities lost manufacturing jobs at a much faster rate than the country as a whole. The resulting decline in inner city population has been aggravated by a lack of realisation of the expected benefits of a sustained programme of housing replacement, and concentration on New Town development had resulted in an old, decayed and often inadequate infrastructure, bad physical conditions for the remaining populace and limited job opportunities. Consequently, the government published a White Paper in 1977 to redirect its main policies and programmes in favour of the redevelopment of inner cities. The aim was to develop a unified approach to the problems and to instigate and encourage economic, environmental and social growth. This Urban Programme was implemented under a number of Acts which gave a number of inner city authorities special powers and access to grants.

It was realised that the problems could not be overcome by the public sector alone and that it was vital to involve the private sector. In particular the lending and investing policies of the major financial institutions were of prime consideration for injecting the necessary capital into the inner city. In July 1981 the Secretary of State paid a visit to Merseyside with the Chief Executives of a number of financial Institutions and between 1981 and 1982 they advised the Secretary of State on new ideas to stimulate urban regeneration. Four main policy areas identified were development, small businesses, housing and employment. In the main the initiatives were accommodated by changes in the existing public sector system, but in some areas the scale of the problem was sufficient to warrant a radical approach. This resulted in the establishment of two Urban Development Corporations for Merseyside and the London Docklands.

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The scale of the problems of regeneration in these two areas was considered to be beyond the capacity of the existing local government structure. Therefore, in 1981 the London Docklands Development Corporation (LDDC) and the Merseyside Development Corporation (MDC) were set up under the provisions of the Local Government Planning and Land Act of 1980. The two Corporations were structured on the New Town development bodies but with the added function of development control authority. Their principal activity being the reclamation and servicing of sites for industrial, commercial and housing development together with the wider considerations of providing necessary infrastructure and public amenities.

In London docklands LDDC are responsible for the regeneration and development of an area of about 2000 hectares adjacent to the River Thames to the east of the city. The area for development largely comprises of industrial land left derelict following dock decline from the 1950's. The Chief Executive of LDDC has outlined the principal problems involved with the regeneration of Docklands (Ward, 1983). These relate to the difficulties of widespread land ownership with large tracts of land being controlled by public bodies, along with the inadequate communications and transport systems aggravated by restricted infrastructure. A London Docklands Strategic Plan, published in 1976, was to have been implemented by a Joint Committee consisting of the Greater London Council and the dockland Boroughs, to be superseded by LDDC.

London Docklands Development Corporation came into legal existence on 2nd July 1981. It has a limited life of 10 years and it is essential for it to work alongside the existing local authorities of Newham, Southwark and Tower Hamlets, who retain responsibility for the social services. The important aspect of the LDDC is its planning powers. It is able to formulate planning policy for any land within its jurisdiction irrespective of the local authority boundaries allowing a more comprehensive approach to the problems of the area. The Corporation is not a local housing authority and therefore public sector housing is still in the hands of the dockland Boroughs.

Since inception the LDDC has implemented a major programme of regeneration requiring extensive civil engineering committment which to date among others has included:

- i) construction of a northern relief road
- ii) construction of a light railway connection with the city
- iii) construction of major deep sewers and other services
- iv) provision of a short take off and landing airport (STOLPORT)
- v) provision of a national exhibition centre and indoor sports arena
- vi) proposals for a major high rise development in the Isle of Dogs
- vii) realisation of a housing programme for 2000 units per year.

The geotechnical input into these proposals are paramount. The area is one of natural marsh within the tidal reaches of the Thames which together with the remnants of previous construction has left a legacy of complex relationship between the main components in the subsoil. In order to realise the satisfactory completion of the planning proposals it has been necessary to take a close and careful look at the immediate geological and geotechnical implications.

HISTORICAL BACKGROUND

The first of London's wet docks for ship building were constructed during the 17th century and by the 18th century the docks were being used for handling goods. London's upper docks were built in the 19th century, the first being the West India Dock opened in 1802 and the last being the Quebec Dock, opened in 1926.

By the middle of the 20th century the prosperity of these docks had declined. The causes of this decline were complex and varied with a major factor being containerisation which required larger ships, deeper water and extensive quayside areas. Container and bulk handling facilities were established at Tilbury and on riverside wharves mainly on Lower Thames. In consequence, the upper docks ceased to be viable and the Port of London Authority (PLA) undertook the demolition of the buildings in the area and commenced filling of the docks in 1967. The East India Docks were closed in 1967, and all of the other upstream docks namely St. Katharine Docks, London Docks, Surrey Docks, West India Docks, Millwall Docks and Royal Docks were closed in the course of the next 15 years.

The history of Surrey Commercial Docks which are sited on the south side of the River Thames about 2.5 km east of the City of London, goes back to the 17th century when they were the heart of the whaling industry (Figs 1 and 2). The docks were mainly constructed in the latter half of the 19th century and in 1908 under an Act of Parliament these docks became part of the operational land of Port of London Authority. The docks ceased to function in 1960's.

Following their closure the PLA began filling the docks (Fig. 3). This commenced in 1967 and went on progressively till 1981 (Table 1). A control to the filling procedures was intended by the Port of London Authority using specifications which required "natural soils with small proportion of brick, stone or concrete" as infill material. A further requirement was that the fill excluded "inflammable, vegetable or noxious materials and was not to have a high clay or silt content". The fill was planned to be end tipped displacing the dock alluvium, the sediment which had collected on the dock floor during the life of the dock, to one end of each dock to be pumped out. Filling materials generally comprised demolition rubble from sites around the London area.

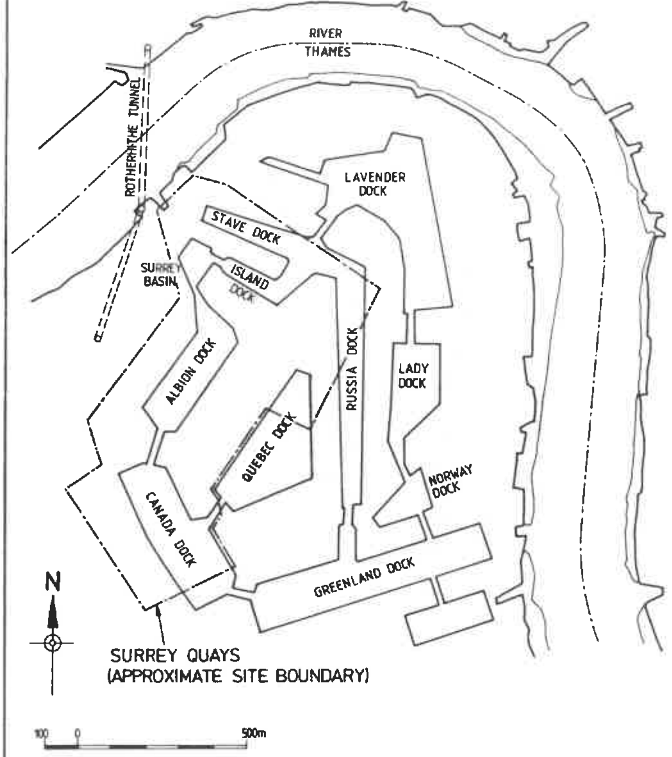
Control of filling was left to the main contractor with minimum supervision. In fact adequate control could not be maintained and eye witness accounts indicate that considerable amount of indiscriminate fly tipping took place (Thomson & Aldridge, 1983). At peak periods about 2300 cubic metres of materials were handled per day.

In 1976 the initial stages of development of Surrey Docks included Norway Dock, Lady Dock, Lavender Dock and parts of Quebec, Russia and Canada Docks (Fig. 1). The land was acquired by the London Borough of Southwark and during their ownership sewers, roads, housing, industrial units and public open spaces were constructed. Ground improvement was required by the London Borough of Southwark for most of the infilled docks, and consisted of dynamic consolidation with use of vibroflotation and in areas of structural sensitivity. The purpose of this treatment was mainly to remove the self weight settlement of the dockfill.

PLANNING AND PROPOSALS FOR REDEVELOPMENT OF SURREY QUAYS

In 1981 a part of the Surrey Docks site hitherto "undeveloped" encompassing Stave Dock, Island Dock, Albion Dock, Surrey Basin and parts of Quebec, Canada and Russia Docks came within the LDDC redevelopment scheme. This proportion of the site within the Surrey Docks complex has been termed "Surrey Quays", (Fig. 1).

The Surrey Quays site lies within a large natural meander of the Thames known as the Rotherhithe Peninsular. The LDDC felt that a number of earlier development schemes had limited success because they relied on improvement to the regional accessibility, in particular a new road crossing of the Thames and extended underground services to link the area to the north side of the river. As it was unlikely that improved access links would be constructed the LDDC decided that a scheme on the current level of accessibility be more realistic.



PLAN OF SURREY COMMERCIAL DOCKS

FIGURE 1.

TABLE 1

Dock	Approximate Date & method of construction	Approximate Area (m2)	Date Filling Completed	Method of Filling
ALBION	1860*	46,000	NOV 1980	In compacted layers
CANADA	1876**	78,000	JUNE 1981 (partially filled)	end tipped
ISLAND	1860*	15,000	FEB 1974	end tipped
LADY	1876**	34,000	DEC 1968	end tipped
LAVENDER	1860*	90,000	MARCH 1975	end tipped
NORWAY	1860*	15,000	AUG 1980	end tipped
QUEBEC	1926*	49,000	JAN 1977	end tipped
RUSSIA	1876*	60,000	OCT 1973	end tipped
STAVE	1876*	28,000	NOV 1972	end tipped

* timber piled wall with concrete capping

** Mass concrete and masonry walls. 10.7m high; base width 4.45m

Canada Dock, Lady Dock and Quebec Dock had a suspended timber wall along some parts of its length.

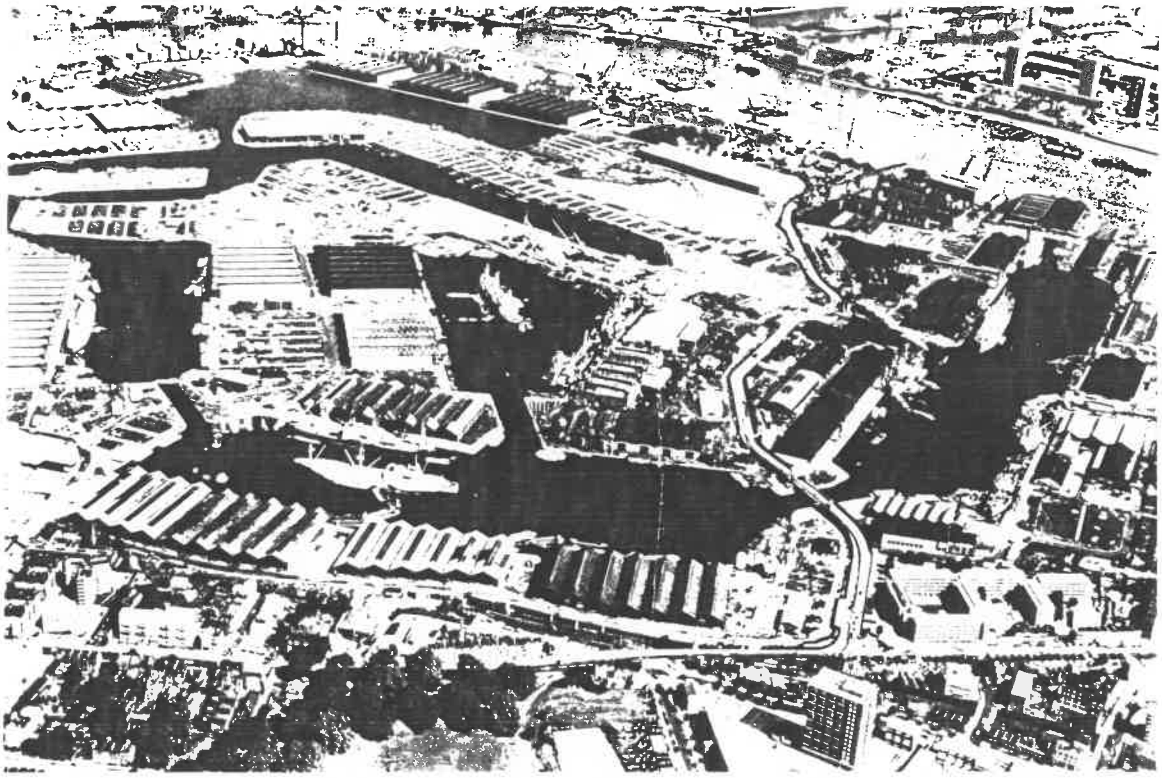


FIGURE 2 - SURREY COMMERCIAL DOCKS (BEFORE FILLING)

FIGURE 3 - SURREY COMMERCIAL DOCKS (AFTER FILLING)

In order to inject new life into the area it was decided to adopt a framework which envisaged some 1000 homes together with schooling, recreation and social facilities, a shopping centre, and commercial and light industrial areas with the necessary infrastructure such as roads, drainage and utilities. Some existing water features namely Surrey Basin and Canada Dock were also to be retained and to be connected by a water channel, with landscaping to provide an attractive footpath/cycleway links and amenity areas. In order to achieve this it was necessary to provide an adequate infrastructure as a sound basis for the proposals.

In 1983 the LDDC published a Development framework for the area. The Corporation would be responsible for the construction of the local roads, sewers and drainage networks as well as river landscape features. It would organise and coordinate the provision of public utilities by the statutory undertakers and implement the general development of the area by a phased disposal of parcels of land with outline planning consent and development layout. The framework could take very little heed of the former pattern of docks which would impose too strict a constraint on the planning concept.

With the exception of Albion Dock, all other docks in Surrey Quays had been filled by end tipping. Prior to site acquisition by LDDC it had been planned by PLA and the Borough of Southwark to dewater Albion Dock and backfill in controlled compacted layers of 300mm. However during dewatering a dockwall failure on the west side occurred and subsequently fly tipping took place near the dockwalls and compacted filling was allegedly carried out in the middle. Quebec Dock and the filled portions of Canada Dock had previously been treated using dynamic consolidation and vibroreplacement.

All building structures within the Surrey Quays site required piled foundations in compliance with the Greater London Council District Surveyor's regulations.

The major concern from a site development standpoint was the residual self weight settlement of the dockfill and its consequences upon infrastructure and development.

OVERVIEW OF PLANNING AND SITE ASSESSMENT

Ground Conditions

In order to provide background information on the ground conditions for potential developers as well as to enable LDDC to formulate its own engineering considerations an extensive investigation was carried out under the LDDC term contract. Two hundred and fifty two boreholes were put down supplemented by trial pits. The boreholes were taken to a maximum depth of 25m on an approximate 50m by 50m grid. The boreholes were positioned to provide adequate data on the former wharf and dock areas as well as identifying any variation in the infill material. Typical generalized ground conditions in the dock areas and the adjacent wharf areas are presented in Table 2.

The docks were constructed with a base level ranging from about -2.3 to -4.75m OD. Quay wall cope levels were typically at +4.50 OD.

Underlying the former dock basins the Thames Flood Plain Gravels are generally present across site although with a reduced thickness where they have been removed during dock construction. The thickness of gravel is variable and ranges from zero to about 6.0m in thickness beneath the Wharf areas. These gravels are generally medium dense to dense, rounded, sandy fine to coarse gravels, and extend to an approximate elevation of 7 m below OD. The Woolwich and Reading Beds which are beneath the gravels, extend to about 14m below OD and consist predominantly of stiff to very stiff clays with its uppermost horizon generally firm in consistency. Interbedded with the clays are occasional bands of more silty,

TABLE 2

Generalized Subsurface Profile
(Average thickness in metres)

Dock Areas			Wharf Area	
10m.	Fill:	predominantly mixed soft to firm silty clay and varying proportions of demolition rubble, concrete, brick, sand and gravel, scrap metal and occasional timber.	3.5m. Fill:	Firm brown sandy silty gravelly clay with some masonry rubble.
1.0m		Soft black organic silty CLAY with some sand (Dock Alluvium)	3.5m	Soft to firm grey silty CLAY with plant debris and some soft brown fibrous peat (Thames Alluvium)
1.0m		Medium dense brown sandy fine to medium GRAVEL (Thames Flood Plain Gravel)	6.0m	Medium dense brown Sandy fine to medium GRAVEL (Thames Flood Plain Gravel)

Solid Geology
(Throughout Surrey Quays Site)

7.0m	Stiff to very silty CLAY interbedded with sand and gravel (Woolwich and Reading Beds)
14.0m	Dense to very dense silty fine to medium SAND with some gravel (Thanet Sand)
	CHALK

sandy and gravelly soils. Underlying the Woolwich and Reading Beds are the Thanet sands which extend to about -28m OD and ovelie Chalk of considerable thickness. The Thanet Sands are fairly homogenous, dense to very dense silty fine sands.

The land adjacent to the dock basins has been built up from the original levels of the Thames marshes at between +1 to +4m OD, to the present ground levels which are typically between +5 to +6m OD, with a wide range of fill materials placed over a timespan possibly of several centuries. Most of the fill at lower levels is made up of materials excavated from dock basins; i.e. Alluvium and Flood Plain Gravels, whilst the top two metres typically consist of demolition rubble and other granular materials. Underlying this made ground is the original Alluvium consisting of soft to firm silty clays with peat lenses and bands, now consolidated under the overlying fill materials and any building surcharge pressures. The Alluvium deposits are underlain by Flood Plain Terrace Gravels.

The presence of the dock alluvium within the individual dock basins is variable and where encountered is generally of the order of 1m thick. Depth of the dock alluvium prior to filling operations in the Surrey Docks area averaged 2.5m. High levels of contaminants and methane generation are associated with this deposit. Filling of the docks by end tipping to displace dock alluvium from one end to the other thence to be pumped out, was not wholly successful.

Sampling from boreholes and inspection of trial pits showed that the dockfill typically consists of sands, gravels, cobbles, boulders, bricks, degradable materials, plastic and concrete (some reinforced) in a matrix of silty clay, soft to firm in consistency. Degradable material and plastics were found in limited quantity.

Reports of cars buried within the dockfill were confirmed at least in one instance when the Clerk of Works had observed a car which surfaced with the dock alluvium mudwave generated during filling operations.

Flood Plain Thames Gravel is a local aquifer and subject to tidal fluctuation in piezometric pressure. Generally however groundwater level was encountered at a depth approximately 5m below ground level although perched water levels locally, were encountered randomly above this depth.

Development Considerations

The difficulties posed by the development of the infrastructure comprising roads and services within the area were:

i) the potential for continuing self weight settlements of the dockfill hereafter referred to as the residual self weight settlement.

ii) the potential for differential settlements associated with the rigid masonry or timber piled quay walls, and adjacent materials.

iii) settlements due to degradable materials within the dockfill.

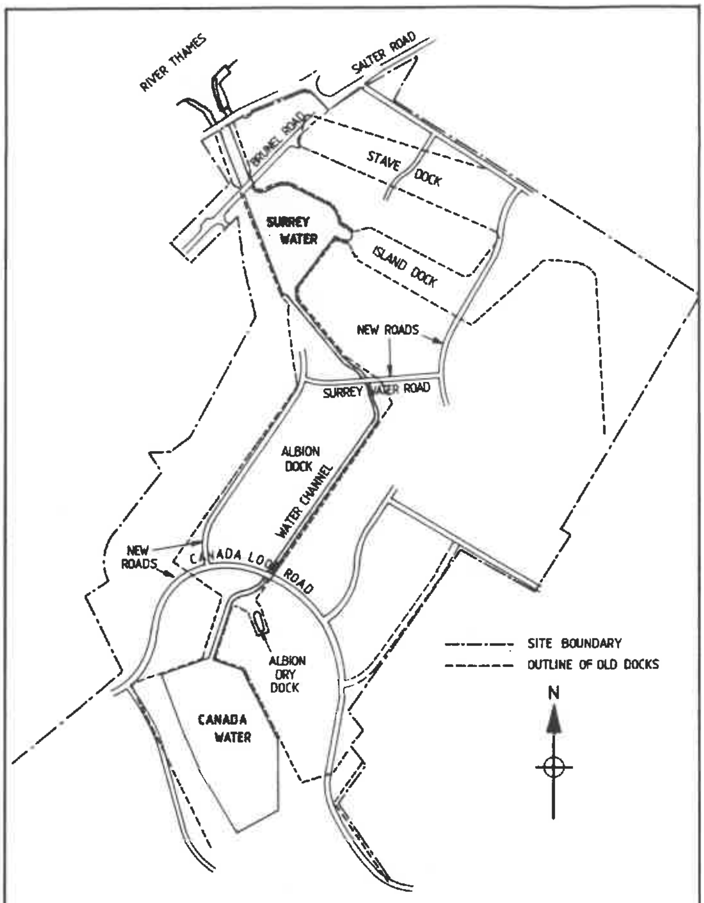
iv) differential settlements between those areas subject to self weight and induced settlement caused by structures.

v) differential settlement between the piled and unpiled areas within the development of the area.

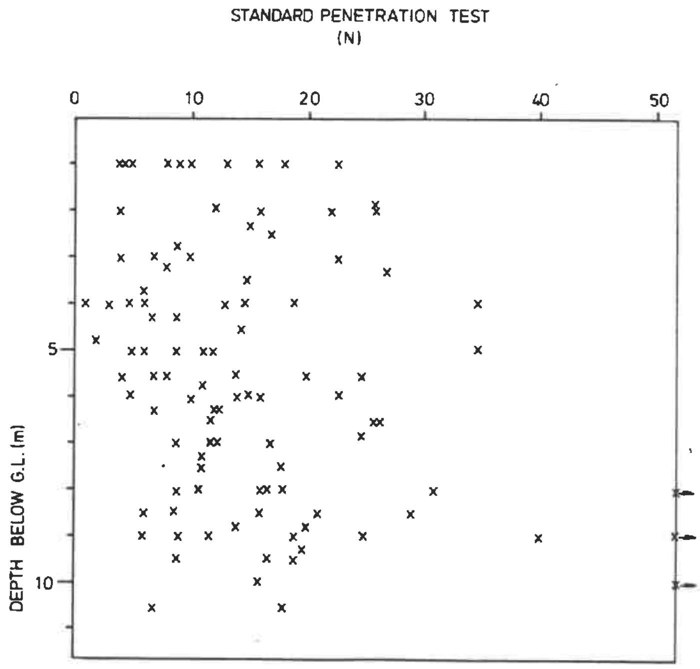
At the time of the study infrastructure layout plans had not been finalized. However it was known that the planned road corridors would involve transition from dock areas to wharf areas, and vice versa, particularly in the vicinity of Stave, Island and Albion Docks (Fig. 4). Due to the uncertainties of the infrastructure layout it was decided that a general approach to the problems outlined above should be adopted. An assessment of the engineering properties of the dockfill was crucial in an attempt to evaluate the magnitude of the residual self weight settlements. The wharf areas were not anticipated to pose any particular problem other than those resulting from the presence of foundations of demolished dock buildings.

SETTLEMENT CHARACTERISTICS OF DOCKFILL

To obtain design data on the self weight settlement characteristics of the dockfill, it would have been preferable in ideal circumstances to monitor the settlement of the dockfill for



SURREY QUAYS - INFRASTRUCTURE LAYOUT
FIGURE 4.



STANDARD PENETRATION TEST RESULTS
FOR ALBION DOCKFILL
FIGURE 5

extended periods using instrumentation and accurate surveying techniques. However due to the constraints it was not possible to set up such a scheme.

Due to the heterogenous and highly variable nature of the dockfill materials, evaluating their engineering properties presented many problems. It was realised from the outset that standard site investigation techniques would not be wholly satisfactory for analysis and that ideally the data should be supplemented by large scale field load tests. Nevertheless engineering properties of the dockfill were assessed using in situ standard penetration data plus laboratory results from tests on 100 mm diameter samples (see Figure 5 and Table 3). As a result of the physical limitation of obtaining "representative samples" from boreholes it was considered that the laboratory testing data only represented an indication of the compressibility characteristics of the fine grained material of the dockfill, however since the dockfill was generally matrix dominated it was considered reasonable to use this data in estimating self weight settlement.

TABLE 3

	(Range)	(Mean)
Natural Moisture Content (%)	13-150	29
Liquid Limit (%)	16-74	41
Plastic Limit (%)	12-45	23
Plasticity Index (%)	5-32	20
Dry Density (kg/m^3)	530-1810	1400
Organic Content (%)	0.7-11.2	4
Coefficient of compressibility, m_v (m^2/MN)	0.1-1.1	0.4
Coefficient of consolidation, c_v (m^2/yr)	0.2-11	3.5
Standard Compaction max.dry density (kg/m^3)	-	1930
Optimum moisture content (%)	-	11

In an attempt to determine the mass behaviour of the near surface dockfill short term skip tests were carried out (Charles & Driscoll, 1981). A typical test arrangement is presented on Figure 6. Elastic settlements measured under a load of about 30 kN/m^2 were in the range 5 - 10mm. The maximum consolidation settlement observed after a period of 2 weeks, when the tests were terminated due to time constraints, was about 10mm. A downward settlement trend was continuing when the skip tests were terminated.

The skip tests indicated that the coefficient of compressibility, m_v, of the materials tested was in the approximate range 0.1 to 0.3 m^2/MN. It is unlikely that the tests significantly stressed the soil below a depth of 4m. Furthermore the tests were carried out in the long hot summer of 1983 and it is possible that the compressibility of the upper material was reduced due to desiccation. Laboratory consolidation tests had indicated m_v to range from 0.1 to 1.1 m^2/MN.

Residual self weight settlements were considered likely to result both from continuing primary consolidation of the clay matrix of the fill and from creep (BRE Digest 274). Analyses were carried out the results of which indicated that for Stave Dock and Island Dock which were filled in 1972 and 1974 respectively, the residual self weight settlements were unlikely to exceed 30mm and would probably be in the range of 0-15mm. For the Albion dockfill the analysis indicated that total self weight consolidation settlements since the completion of filling in November 1980, was likely to be of the order of 200mm. It was estimated that of this total a significant proportion (approximately 45%) of this settlement would have already occurred and the residual self weight settlement would be of the order of 60 - 120mm. The time period for this additional settlement was estimated to be 10 to 15 years.

FIGURE 6 - TYPICAL SKIP TEST ARRANGEMENT

Thus in order to plan and implement development, the magnitude and duration of settlements were important considerations with respect to the overall programme for rehabilitation of the area. It was considered that the residual settlements calculated for Island Dock and Stave Dock were of the order which could be accommodated in infrastructure design. The magnitude of residual settlements predicted for Albion Dock, approximately 46,000 m^2 in plan area, was considered unacceptable for infrastructure development and consequently methods for reducing or eliminating the self weight settlements were investigated.

METHODS CONSIDERED FOR GROUND IMPROVEMENT

In order to reduce the anticipated residual self weight settlements to acceptable limits various possible methods for improvement of the Albion Dock fill were considered. These included (i) excavation and replacement in compacted layers in a controlled manner (ii) dynamic compaction (iii) surcharging with fill, and (iv) vibroreplacement. Of these excavation and replacement was discounted because of time constraints and the possibility of causing further instability of the dockwalls.

Because dynamic compaction had previously been used by others to treat dockfill areas within the Surrey Docks complex, consideration was given to using this technique for improvement of Albion Dock fill. A major factor in assessing this technique for ground improvement was consideration of the time that would be required for excess pore water pressures to dissipate after each tamping pass. In view of the fine grained nature of the matrix it was known that this form of treatment on 30,000m^2 area of Canada Dock took 9 months to complete. It was concluded that for Albion Dock the period required to carry out this treatment would be too long related to programme constraints.

Previously treatment at Surrey Docks had included vibro-replacement which had been effectively used near slope edges and in areas of structural sensitivity. Vibro-replacement using the wet process with columns terminating in the Flood Plain Gravel was considered a feasible means of overcoming the problem imposed by the long term residual settlements of Albion Dock, although it was considered that the presence of cobbles, boulders and other obstructions could result in some columns not penetrating the full depth of the dockfill.

Due to the presence on site of a stockpile of suitable fill material surcharging was considered to be a cost effective option for treating Albion dockfill. Surcharging has been successfully used on other sites, for example in the treatment of deep cohesive fill left by mining operations (Charles et al, 1978), and is referred to in BRE Digest 275 as a means of improving fill materials. BRE digest 275 however indicates that surcharge need not be left in position for an extended period and a large site could be treated using a rolling surcharge.

For the treatment of Albion dockfill it was considered that to achieve the required improvement the surcharge would have to be left in place for a period of several months. It was decided that if this option was utilized the decision to remove the surcharge would be based on the observed rates of settlements. There was sufficient volume of material stockpiled on the site to enable a 3m high surcharge to be placed over most of Albion Dock. The use of vertical drains to increase the rate of consolidation under the surcharge loading was considered but was discarded from cost/benefit considerations and possible difficulty in installation.

Decisions regarding the method for ground treatment had to be made in November 1983 shortly after completion of the site investigation. It was considered that surcharging the area was the most cost effective and appropriate method of treatment where sufficient time was available before the start of site development. Housing construction was due to start in late Summer 1984 and the construction of Canada Loop Road and Surrey Water Road (Fig. 4) was scheduled to be started in Spring 1984. Because of the short period available before the scheduled start of the road construction it was judged that in these areas there would probably be insufficient time for a surcharge loading to provide adequate improvement of the dockfill. It was therefore decided to treat these two road corridors both approximately 100m long and 30m wide using the vibro-replacement technique.

The contract was awarded for improvement of Albion Dock fill and the works commenced at the end of January 1984.

GROUND IMPROVEMENT WORKS

Surcharge loading

To monitor the effectiveness of the surcharge instrumentation comprising magnetic probe extensometers, settlement plates, hydraulic settlement cells, and pneumatic piezometers were installed prior to placement of the surcharge. Rod extensometers were installed soon after the surcharge was in place. Significant settlements were recorded immediately upon loading and settlements continued at a reducing rate for several months. The surcharge was left on for a duration of 8 months at which time it was considered that sufficient improvement had been achieved to ensure that any future settlement would be small, and could be accommodated within the engineering design of the infrastructure. The range of settlements observed under surcharge loading is shown on Figure 7. The maximum settlement observed after 8 months under the surcharge was about 160 mm. Back analysis of the observations of rate and magnitude of settlement indicated that the settlement characteristics deduced for the dockfill from the site investigation and skip load testing were reasonable. Figure 8 presents the settlements recorded at different depths within the dockfill.

An increase in pore water pressure was recorded almost immediately upon loading. Dissipation of pore pressures were recorded for up to 6 months.

Vibro-replacement

One thousand three hundred and ninety three stone columns of 450mm nominal diameter were installed, on a triangular grid at 2.5m spacing in the area of the two road corridors using the wet process. Some columns could not penetrate the full depth at their designated location in a small area within the north corridor and alternative or additional columns were installed in this vicinity. Vibro-replacement works took about 3 months to complete.

ROAD DESIGN CONSIDERATIONS

To minimise the potential for differential settlements in the areas where roads cross from dock areas to quay areas and vice versa, the rigid masonry quay wall cope, was removed to a depth of 0.5m below the formation level, and the sides of the excavation battered back at a slope of 1:4. The base and the sides of the resulting excavation was proof rolled to detect soft horizons, and compacted granular backfill was utilised to achieve the desired grade. Road design was based on CBR values ranging from 2% to 5%.

A road corridor traversing the link between Canada and Quebec Docks was successfully designed and filled during the course of site improvement works. 3,000m^2 of dock area was thus reclaimed. The grading of the free draining fill material complied with the following specification.

BS Sieve Size	% Passing (by mass)
10mm	up to 100
5mm	not more than 85
600 micron	not more than 45
75 micron	not more than 5

Above the water line the material was compacted using a heavy vibratory roller.

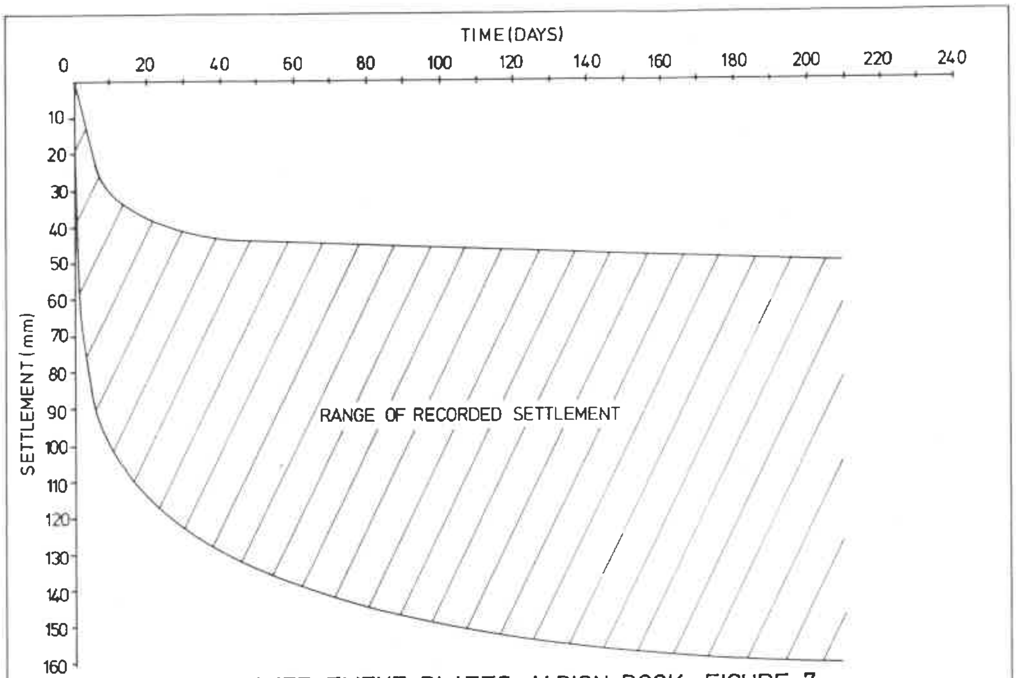
SUMMARY AND CONCLUSIONS

The planning of the infrastructure development was made in the knowledge of the results of the site investigation but was not governed by geological or geotechnical considerations.

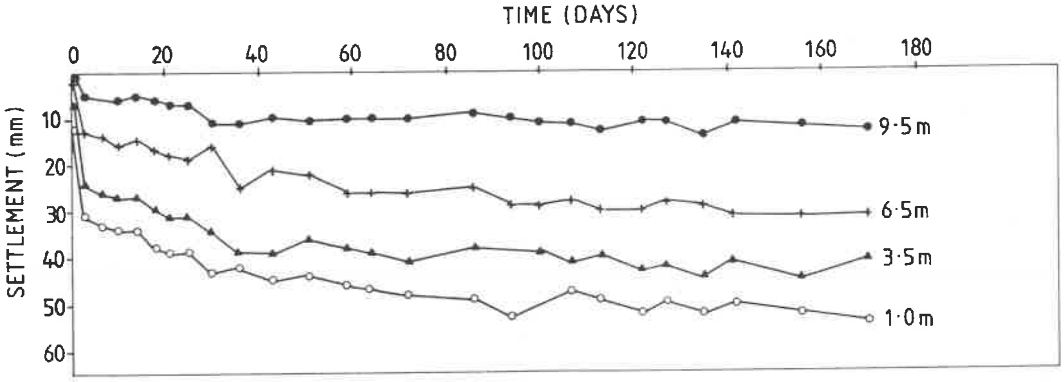
Information was obtained from field work and laboratory testing to enable engineering solutions to be found for the design of the infrastructure, over former dock and wharf areas which were suitable for the limited time available within the overall programme for development.

The investigations of the infilled docks enabled decisions to be made on the need for ground treatment prior to development.

Ground treatment was carried out for Albion Dock to overcome the problem of residual settlement and to enable design and construction of infrastructure to proceed.



SETTLEMENT PLATES ALBION DOCK FIGURE 7



MAGNETIC EXTENSOMETER E1. ALBION DOCK

FIGURE 8

REFERENCES

WARD, A.J.R. 1983. The Resurrection of London Docklands: An exemplar for the 80's. Proceedings Conference on Reclamation 1983. Pub. Industrial Seminars Ltd., Tunbridge Wells. 434-441.

THOMSON, G.H. and ALDRIDGE J.A. 1983. London Dock Lands - Problems associated with their development with special reference to the Surrey Docks Scheme. Proceedings Conference on Reclamation 1983. Pub. Industrial Seminars Ltd., Tunbridge Wells. 124-132.

CHARLES J.A. and DRISCOLL R. 1981. A simple in-situ load test for shallow fill. Ground Engineering. January 1981. 31-36.

BUILDING RESEARCH ESTABLISHMENT. 1983. Fill, Part I Classification and load carrying characteristics. BRE Digest 274, June 1983. H.M.S.O.

BUILDING RESEARCH ESTABLISHMENT. 1983. Fill Part 2: Site Investigation, ground improvement and foundation design. BRE Digest 275, July 1983. H.M.S.O.

CHARLES J.A. 1979. Geotechnical Problems of building on deep fill. Proceedings of the Society of Chemical Industry's Conference on Reclamation of Contaminated Land. Eastbourne. October 1979.

CHARLES, J.A. EARLE, E.W. AND BURFORD, D. 1978. Treatment and subsequent performance of cohesive fill left by opencast ironstone mining at Snatchill experimental housing site, Corby. Proc. conference on Clay Fills July 1978. pp. 64-72. Institution of Civil Engineers, London.

VAUGHAN P.R. 1983. Surrey Docks backfill. (personal communication).