the water level in the canal will reach its upper limit, + 6,50. In this control, it was found that the solution c gives satisfaction. For the two other solutions it was necessary to take into consideration a little movement of the wall toward the fill.

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VI d 3

SITE EXPLORATION FOR FOUNDATIONS AT PORTSMOUTH

J.W. HUNTER

1. INTRODUCTION.

The site at which the examination described in this paper was made lies in the East side of Portsmouth Harbour near its entrance and was originally covered by the sea at high tide and around 1800 was reclaimed and built over. Many of the buildings then erected have now been demolished to enable modern buildings to be provided, the new buildings being mainly of two types:- multistorey offices and single storey workshops, the siting being shown in Figure "A". The old buildings showed considerable settlement and in view of the history of the site, a thorough investigation of the subsoil was considered necessary.

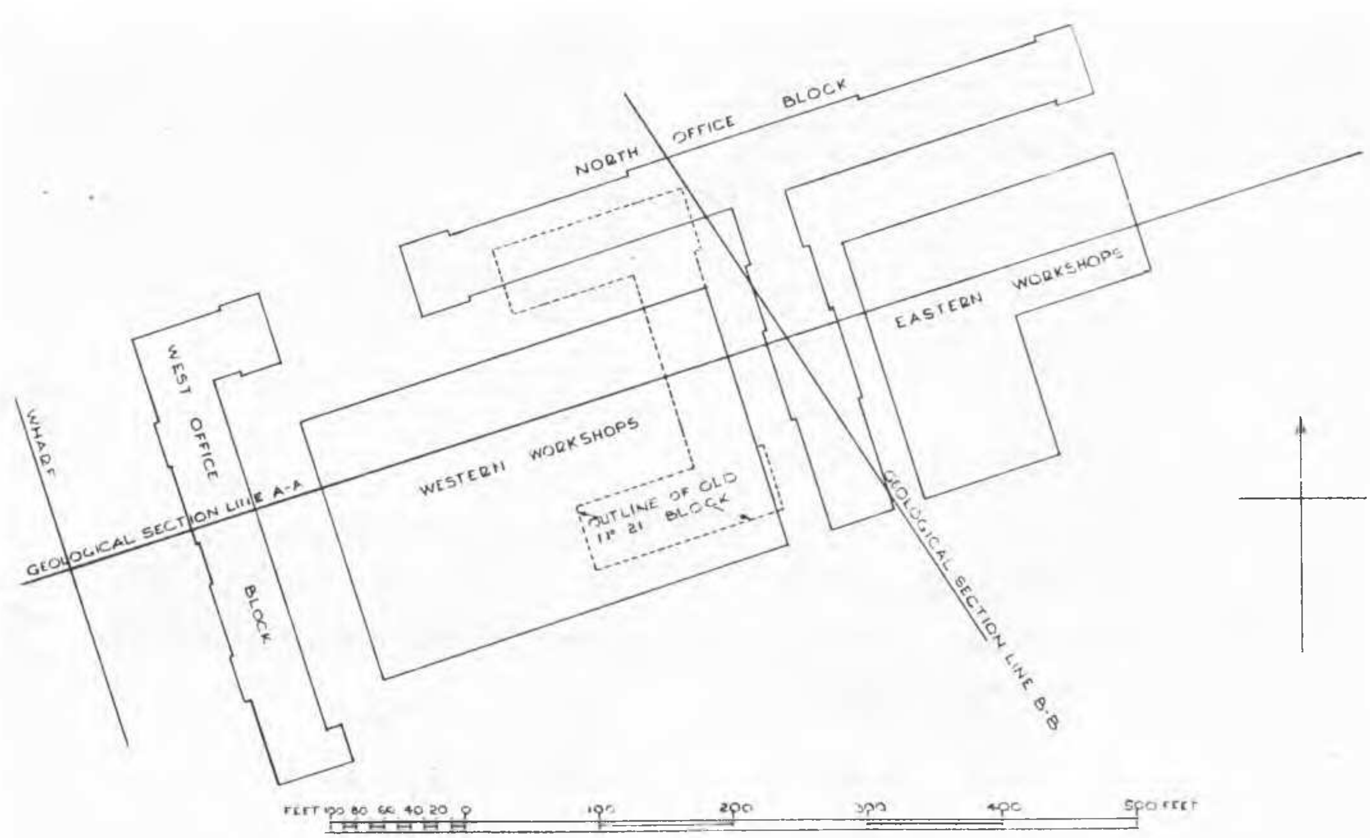
2. SITE INVESTIGATION.

Apart from the usual surface surveys the investigation consisted of three main sections:-

a) 35 trial bores were put down about 62 feet deep, except for four which were bored to 100 feet, so that possible long term consolidation of the material lying below the pile shoes could be considered. Ordinary disturbed samples were taken frequently from all the bores, undisturbed samples 4 ins. diameter by 18 ins. long being taken from suitable strata in 17 bores. The standing water level in the ground was also recorded.

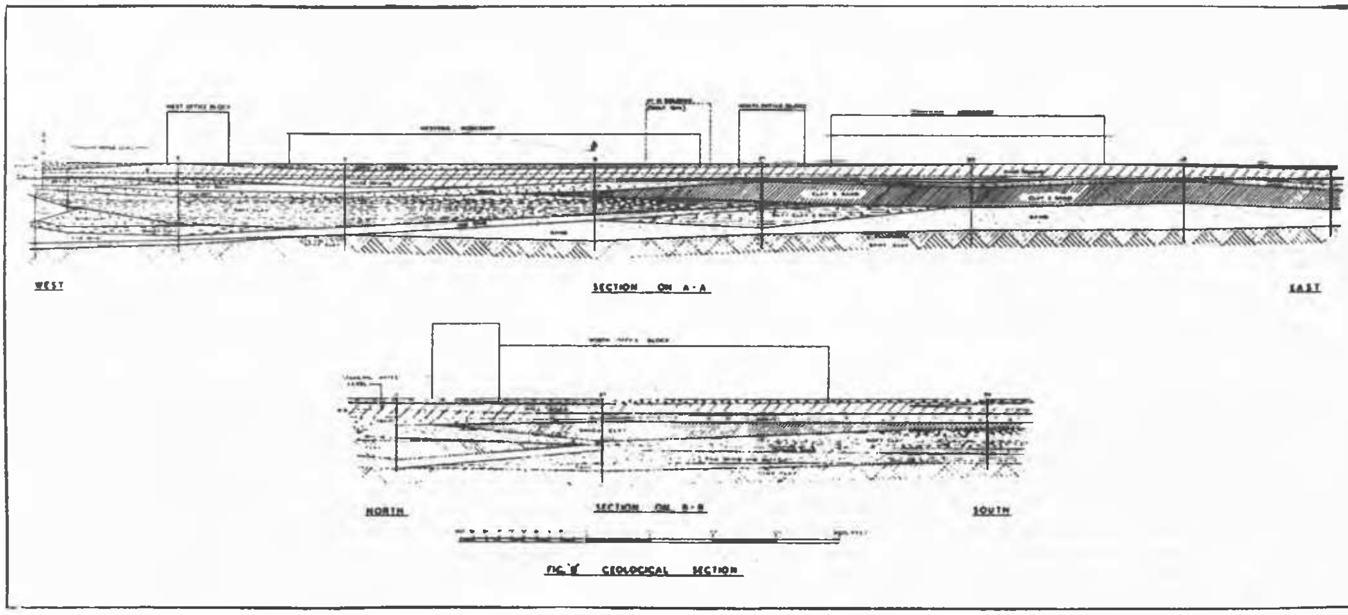
b) Two direct loading tests were carried out on the old filling lying just under the surface to determine its maximum bearing capacity irrespective of any long term effects, the position of the more important test being shown in Figure "A".

c) The settlement of the main old building on the site was measured, the result being described in paragraph 5 below.



Plan of Redevelopment.

FIG. a



Geological Section.

FIG.b

3. <u>SITE GEOLOGY</u>.

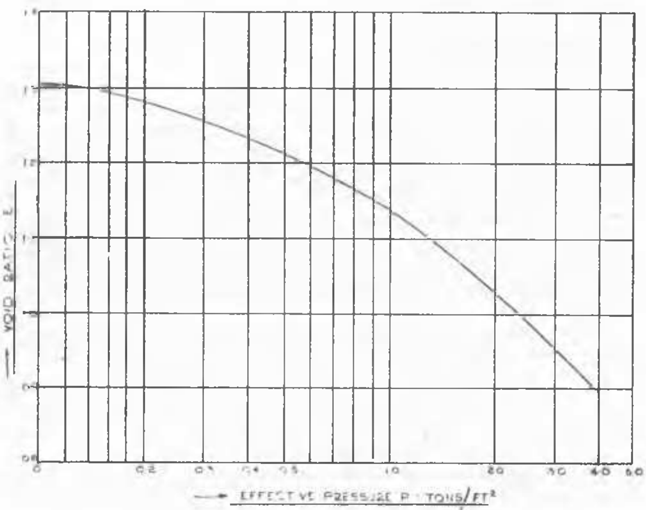
The geological conditions in the area of the new buildings are shown in Figure "B" on the two lines shown on Figure "A". The material for about 20 feet below the surface contains a large proportion of gravel and is in the main filling, below which on the Western part of the site there is a bed of soft clay having a maximum known thickness of 36 feet. Below again are sand beds overlying a thick bed of stiff clay, the thickness of which was proved to exceed 45 feet. On the Eastern side of the site, the bed of soft clay is lost and the fine sand rises to about 20 feet below the surface, the stiff clay there being about 45 feet under the surface, sinking to 72 feet at the Western edge of the site.

4. <u>LABORATORY EXAMINATION</u>.

The laboratory examination of the bore samples was carried out by the Building Research Station at Garston near London and the results are shown in Table 1.

<u>TABLE I</u>

Property	Soft Clay	Stiff silty Clay
Average Density (lb/ft^3)	107	128
Water Content : Average (% dry weight)	45	28
ditto : Range	29 - 62	21 - 40
Plastic Limit : Average (% dry Weight)	24	24
ditto : Range	19 - 29	19 - 32
Liquid Limit : Average (% dry weight)	65	66
ditto : Range	49 - 84	51 - 100
Unconfined Compression Strength : Average (lb/in^2)	5.8	45.4
ditto : Range	3.5 - 9.8	18.9 - 113.0
Consolidation Coefficient: Average (sq.cm/min)	0.010	not determined
ditto : Range	0.005 - 0.019	



Pressure - Void Ratio Curve for soft Clay.

FIG.c

Figure "C" shows the relation between the void ratio and superimposed pressure for the soft clay.

5. SETTLEMENT OF EXISTING STRUCTURE ON SITE.

Building No.21 (see Figure "A") was built in 1814, the foundations being taken down to about low water level, which was approximately the level of the foreshore before reclamation and it is probable that the filling was deposited after the foundations were built. In 1945 this building showed a differential settlement of 1.2 feet and Figure "D" shows how the greatest settlement occurred where the foundations were laid on material overlying the thickest part of the soft clay bed. Under the loading imposed by the building and the surrounding filling, it was calculated that the soft clay would in the 131 years since the building was erected, have consolidated to give a differential settlement of about 1 foot, which compares with the observed settlement of 1.2 feet and, as the settlement was estimated to be substantially complete 30 years after the filling was placed, the agreement between the calculated and observed figures gave confidence in the methods of analysis used. Very little differential settlement had latterly been observed in this building; one crack had, however, opened 1/8 inch between 1932 and 1946.

The new buildings, being steel framed, will not have the flexibility of the old buildings, which were in brickwork laid in lime mortar and it was at first thought it would be necessary to use piles under all the major new buildings; investigation, however, showed that piles would not be necessary under the single storey workshop blocks for the reasons set out below.

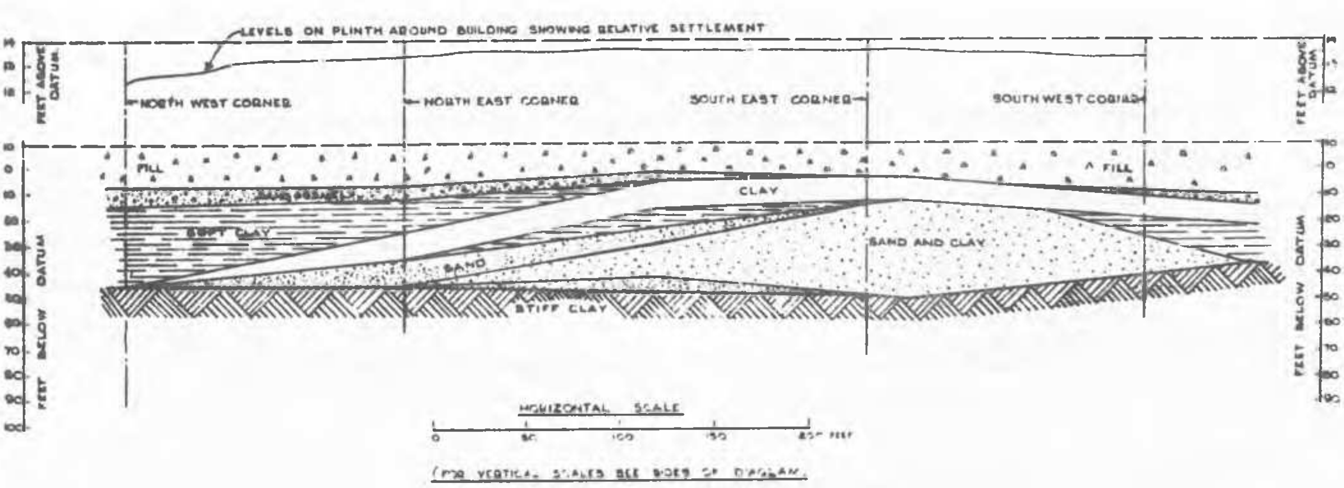
6. DIRECT LOADING TEST ON MADE GROUND.

A direct loading test was carried out on the filling about 4 feet below the surface at the position shown in Figure "A", which was considered to be a fair sample of the softer areas of the old filling, the test being made by loading a concrete slab 3 feet square and measuring the settlement at each of the corners. After 7 days with a load of 0.75 ton/sq.ft. the average settlement was 0.04 foot and 9 days later under 1.25 tons/sq.ft. the settlement was 0.07 foot which increased to 0.12 foot in 3 days after the load was increased to 1.5 tons/sq.ft. and with this load one corner of the slab started to settle more rapidly than the other corners and this was assumed to be the highest loading which could be put on the filling near the surface, (if the effect of consolidation of the lower strata could be ignored).

7. DECISIONS TAKEN ON TYPES OF FOUNDATIONS.

a) Multistorey Office Blocks.

The average foundation load worked out at 0.7 ton per square foot over the whole plan area, for each of the multistorey office buildings which, as will be seen from paragraph 6, is approximately half the highest intensity of loading possible on the test slab, ignoring deep seated effects and, while 0.7 ton per square foot was considered to equal the maximum permissible loading for the strata immediately under the foundations, it was considered that, to design foundation slabs covering the whole width of these buildings of sufficient rigidity to prevent cracking in the superstructures, was not practicable and piled foundations were therefore adopted. It was



Building No. 21 (Built 1814). Developed outside section. Showing relative settlement in relation to thickness of soft clay.

FIG.d

then necessary to decide whether the piles could be stopped, if a satisfactory set was reached in the material lying above the thick bed of stiff clay which underlies the site , see Figure "B". Investigation showed that the soft clay bed would cause differential settlement to an extent which would be unacceptable and it was decided to drive the piles through the upper beds (although apparently satisfactory sets might be got there) and to continue driving, until the toes of the piles went into the better strata (i.e. the sand or stiff clay) below the soft clay.

b) Workshop Blocks.

In the workshop blocks the maximum permissible foundation loading was also taken to be 0.7 ton per square foot. Investigation showed that if strip footings were used for the foundations having a maximum loading of approximately 0.6 ton per square foot, for the Western workshop block, there would probably be an average total settlement of 1 inch with a maximum differential settlement of 5/8 inch, the settlement being about 50% complete in the first three years after the block was built, the differential settlement being caused by the thickness of the underlying bed of soft clay varying from about 16 to 37 feet under this block. The differential settlement for the Eastern workshop was estimated at 1 inch, in this case the soft clay bed only being under part of the building and the settlement is expected to be 50% complete in eight months. The estimated quicker settlement was due to the bed of soft clay being less deep and thinner in this area. These differential settlements might be serious, if they occurred in adjacent sections of the buildings but, as the maximum and minimum settlements would occur in widely separated parts of the buildings, it was decided that well reinforced strip footings would provide the continuity required to prevent the buildings cracking. The strip footings were designed varying from 2'6" to 6'0" in width to keep the foundation pressures uniform and within that permissible on the made ground (0.7 ton per square foot).

8. CONCLUSIONS.

The cost of the test borings, direct loading tests, laboratory examination, etc., was approximately £4,000; this may appear high at first sight but the use of piles in the foundations of the single storey workshops would probably have cost £10,000 more than the strip footings now included in the design. If, however, a thorough investigation of the site had not been made, the risk of using strip footings would have been too great to have been practicable.

On the other hand, apart from the thorough site investigation, the piles for the multistorey blocks might well have been stopped as soon as satisfactory sets were reached in the upper gravel beds, the carrying capacity of individual piles being confirmed by loading tests, in which case there would probably have been serious differential settlement and cracking in the multistorey buildings which would have been very difficult to cure, as the settlement would have continued for some years.

Thus proper site investigation permitted, inter alia, a net saving of approximately £6,000 on the single storey blocks and also prevented a possible heavy future liability being incurred for repairs to the multistorey blocks.

9. ACKNOWLEDGEMENT.

During the investigation much help was received from the Director of the Building Research Station and in view of this, where figures were originally calculated by the Building Research Station but which, when recalculated subsequently gave slightly different results, due to adjustments in design, etc., the original Building Research Station's figures have been used in preference to those calculated more recently.

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VI d 4 SOME EXAMPLES OF FOUNDATION MOVEMENTS DUE TO CAUSES OTHER THAN STRUCTURAL LOADS

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SUMMARY.

In the last five years a very large number of examples of building damage due to foundation movement has been encountered in which the effect of the weight of the building on the ground is negligible. Broadly speaking the damage arises from movement of the ground below the level of the foundations due to either climatic changes or the action of heat from industrial buildings.

The movements may be grouped as follows:

1) Natural Drying

Drying shrinkage of clays under structures founded at a shallow depth due to:-

a) Seasonal changes in evaporation and rainfall.

b) Transpiration of trees and shrubs.

2) Artificial Drying

Drying shrinkage of clays under industrial buildings (brick kilns, boiler houses, etc.) due to penetration of heat.

3) Artificial Frost Heave

Frost heave under cold storage buildings due to penetration of frost.