The Use of Sand Drains under Buildings at Port Newark

L'utilisation de drains verticaux de sable sous les bâtiments de Port Newark

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Summary

The paper discusses the stabilization of the foundations for a number of transit sheds at Port Newark, New Jersey, U.S.A., by the use of vertical sand drains and surcharge fill. The subsoil analysis method of design and final construction techniques are discussed. The paper concludes that under certain conditions this method of construction results in substantial economy.

Sommaire

L'étude traite le problème posé par la stabilisation des fondations des entrepôts de transit de Port Newark au moyen de drains verticaux de sable et de la surcharge d'un remblai provisoire. La méthode suivie pour élaborer le projet, en tenant compte de l'analyse du sous-sol, ainsi que les éléments techniques appliqués au cours de la construction y sont discutés.

L'auteur conclut en disant que dans les conditions données cette méthode de construction a permis de réaliser une économie appréciable.

In 1947 The Port of New York Authority entered into a 50 year lease for the area known as Port Newark. In line with its lease commitments and in accordance with an agreed plan, the Port Authority immediately undertook a major construction program designed to give this area complete modern marine cargo facilities capable of handling with speed and efficiency the cargoes being carried by modern ships such as the Victory, C4 and Mariner types.

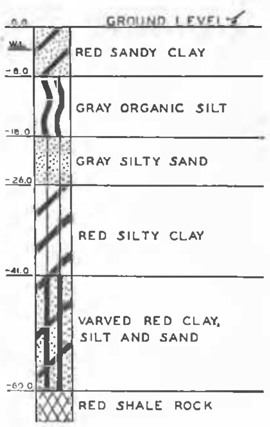


Fig. 1 Typical Port Newark Soil Profile
Section typique du sol à Port Newark

Like the majority of marine terminal sites throughout the world, the foundation conditions at Port Newark were far from ideal from the viewpoint of economical construction. Borings taken at the locations of each of the proposed buildings revealed a reasonably uniform subsurface condition. Analysis of the data and borings, made by the Port Authority Soils Laboratory, indicated that, as shown on Fig. 1, the material underlying the proposed buildings consists of an overlying strata of red sandy clay. This material had been deposited within the area in recent times. Below this lies a compressible gray organic silt which has an L.L. of 115, P.I. of 69 and an average permeability of 2×10^{-7} cm/sec. Below the silt are successive layers of old formations of a relatively incompressible nature. These layers are successively a gray silty sand, a red silty clay and a varved clay. Red shale rock is encountered about elevation minus 60.

For the rapid handling of ships' cargoes; the design of the proposed buildings requires a shedded area of about 90,000 square feet adjacent to each berth. For the effective use of fork lift trucks and palletizing of cargo, the floor must be designed for a load of 600 pounds per square foot. Laboratory tests of the material underlying the transit sheds indicated that a differential settlement of up to 6 inches could be anticipated under the 600 pound load.

In the building of Transit Shed "A" and Transit Shed "B" (Fig. 2), steel H-piles were driven to rock and a concrete beam

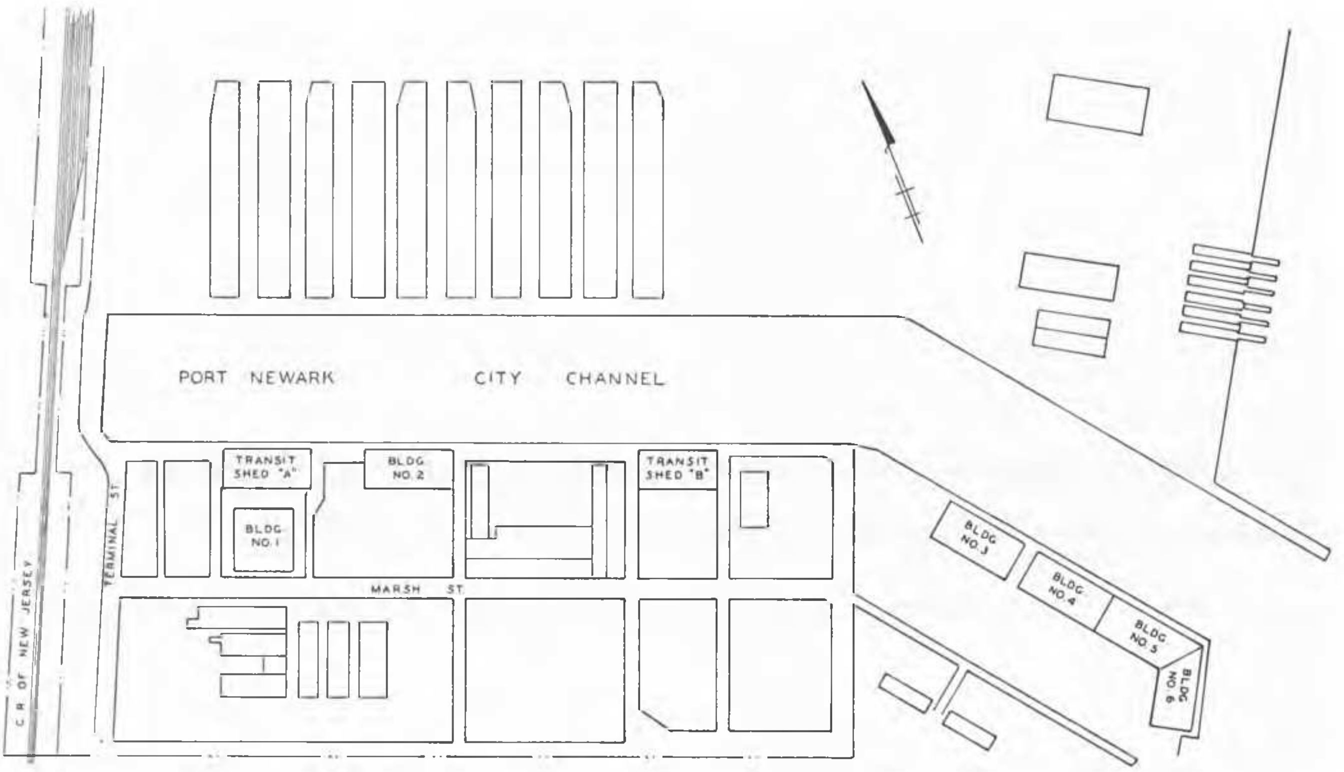


Fig. 2 Location Plan of Buildings at Port Newark
Emplacement des bâtiments à Port Newark

and slab floor was supported on these piles. With this type of construction, only minor complications due to consolidation of the subgrade could be anticipated. As work in this area progressed, it was apparent that a more economical type of floor construction would be desirable. The following possibilities were explored:—

(1) Excavation of compressible silt and backfilling with suitable material. Column loads to be supported on spread footings. Floor to be placed directly on fill. Because of the thickness and depth of organic silt, the costs would make this type of construction uneconomical.

(2) Supporting column loads on piles and setting concrete floor directly on filled surface. Allowance would be made for periodic mudjacking of the floor after settlement had occurred. Costs for this maintenance operation would be high but a more important factor is that this method would seriously interfere with normal tenant operations.

(3) Surcharging the building area with fill equivalent to or above the expected floor loading and allowing the compressible organic silt to consolidate under this load. After consolidation takes place, surcharge fill is removed. Piles would then be driven to support building column loads. Floor would be placed on consolidated fill. This method would work satisfactorily but laboratory tests disclosed that the time necessary for consolidation to take place would be too long.

(4) Method similar to (3) using sand drains to accelerate consolidation.

After careful evaluation of the costs of all methods, Number 4 was selected for the construction of the remainder of the transit sheds at Port Newark. Actual experience has indicated that the construction for these buildings will cost approximately $1.74 per square foot less than the concrete beam and girder construction used on Transit Sheds A and B.

Fig. 3 represents graphically the experience in the placing of surcharge fill and the resulting consolidations for Buildings 1 and 2.

It is to be noted that with the construction of buildings scheduled at regular intervals, it has been possible to move the surcharge fill from building to building and so to reduce costs. If only one building were to be erected, the costs of supplying surcharge fill without any re-use might prove to be prohibitive.

The spacing of the sand drains for the buildings was based on experience gained in the Port Authority's experimental work

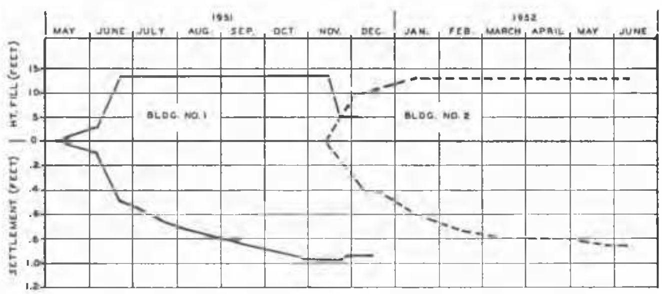


Fig. 3 Settlement and Fill Record for Building No. 1 and Building No. 2
Mesures de tassement et de remblayage en fonction du temps pour les bâtiments Nos 1 et 2

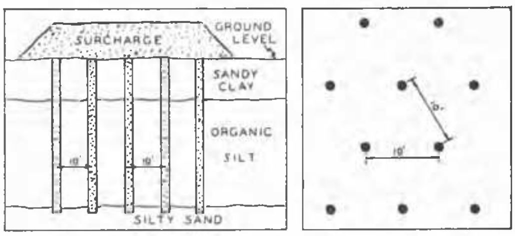


Fig. 4 Cross Section of Sand Drains and Surcharge Fill. Plan of Sand Drain Pattern
Coupe transversale des drains verticaux de sable et du remblai de surcharge. Disposition des drains en plan

at La Guardia Airport (*Kyle*, 1950). The pattern of the sand drain grouping was established in accordance with *Barron*'s most economical pattern of drain wells (*Barron*, 1947). Fig. 4 indicates this pattern. The height of fill was determined by computing a surcharge of double the proposed floor load. Since borings showed a sand drainage layer underlying the compressible organic silt, it was decided to drive the sand drains through the silt and approximately one foot further into the sand layer. Actual construction was performed as follows (Fig. 5):—

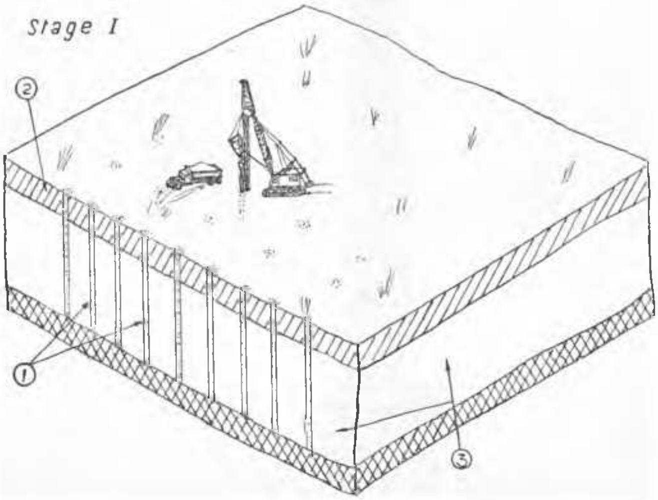
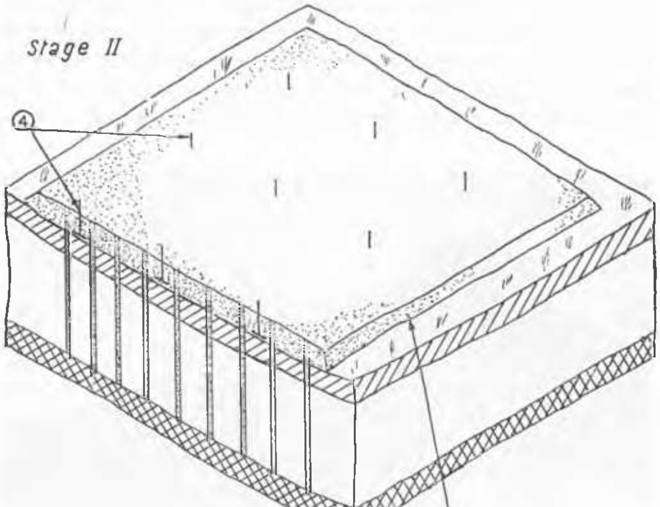
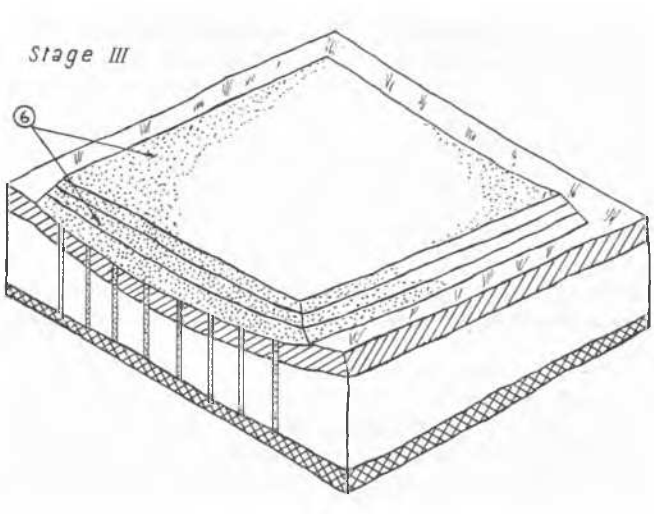


Fig. 5 Sketches Showing Five Stages of Construction
Croquis illustrant cinq phases de la construction

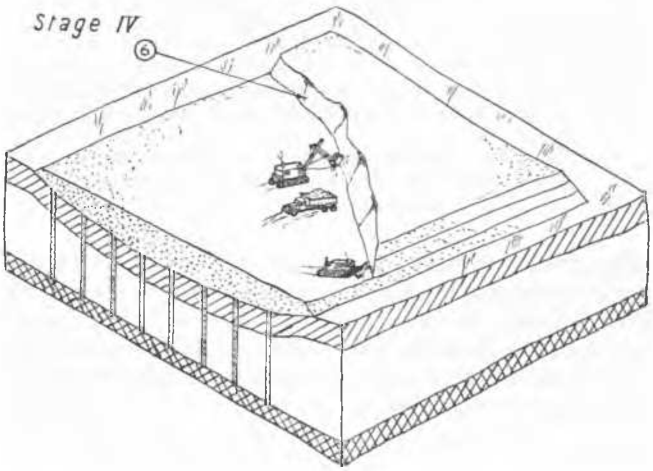
Stage 1 Vertical Sand Drains (1) are Driven by Means of a Mandrel through the Clay and Sand Strata (2), through the Soft Organic Silt (3) into the Firm Sand Strata. The Sand Drains (1) consist of 20″ Diameter Holes Filled with Porous Sand
Drains verticaux de sable (1) enfoncés à l'aide d'un mandrin à travers les couches d'argile et de sable (2), à travers le limon organique mou (3) dans les couches de sable ferme. Les drains verticaux de sable (1) consistent en forages de 20″ de diamètre remplis de sable perméable



Stage 2 Settlement Plates (4) and Piezometers are installed and a Porous Sand Fill Blanket (5) is placed on the Area to be occupied by the Building
Plaques-repères de tassement (4) et piezomètres sont mis en place et un tapis de sable imperméable (5) est placé sur l'aire qu'occupera le bâtiment



Stage 3 Additional Fill and Surcharge Load (6) is placed over the Porous Sand Blanket. This Causes Consolidation of the Organic Silt Layers as the Water is Gradually Squeezed Out of this Compressible Soil
Remblai additionnel de surcharge (6) mis en place par couches sur un tapis de sable perméable ce qui provoque la consolidation de la couche de limon organique en même temps que l'eau est graduellement exprimée hors de ce sol compressible



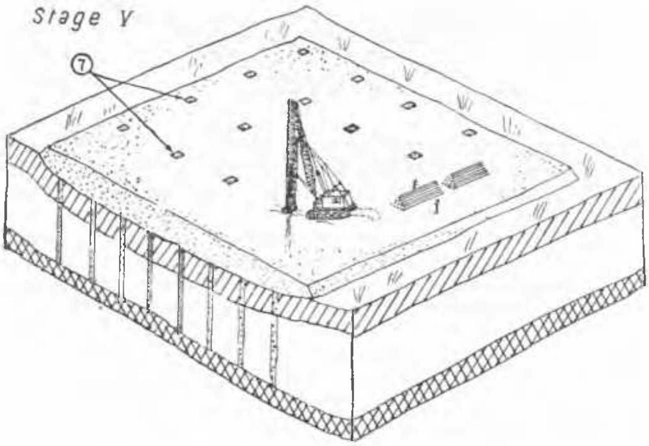
Stage 4 After Consolidation has Taken Place in the Soft Organic Silt, the Surcharge (6) is removed from the Building Area and placed on the next Building Site to be surcharged
Lorsque la consolidation du limon organique mou est obtenue la surcharge (6) est retirée de l'aire de construction et déposée sur l'aire du bâtiment adjacent

Stage 1

The first step in construction was the driving of sand drains (Fig. 6). Drains were installed by using modified pile driving equipment to push into the ground a hollow 20-inch diameter steel mandrel with a hinged plate at its bottom (Fig. 7). When the bottom of the mandrel reached into the sand layer underlying the organic silt, the driving was stopped. In many cases, the heavy mandrel actually slipped through the soft silt without requiring any blows from the hammer. The hollow mandrel was then filled with sand designed as a filter and having a very high permeability. Gradation of this sand drain fill was as follows:—

U.S. Standard Sieve Size	*Percentage Passing Sieve By Weight*
1 inch	100
½ inch	80–100
No. 8	40–100
No. 30	20–80
No. 50	0–20
No. 100	0–3

One hundred pounds per square inch of air pressure was applied inside the top of the mandrel and the mandrel was then slowly



Stage 5 Piles (7) to Support Heavy Column Loads are Driven and Site is Now Ready for Steel and Building Erection, and Paving of Floor
Les pieux supportant les charges des colonnes sont battus et l'emplacement est libre pour l'érection de la superstructure d'acier et le pavement du sol

withdrawn. The hinged plate was forced open allowing the vertical column of filter sand to remain in place in the ground. In some areas, the impermeable clay layer above the organic silt had so confined the water in the silt that it was actually under pressure and as soon as a sand drain had been driven water began to spurt out.

Stage 2

When drain installation was completed, settlement plates and open type *Casagrande* piezometers were installed. A two foot drainage blanket was then placed over the entire building area. Daily readings of settlement plates and piezometers were started. Specifications for this contract gave the Port Authority the right to determine the rate of placing the surcharge fill. This rate was determined by careful analyses of settlement plate and piezometer readings and ranged from two to four feet of fill per week. Fill was only placed when the pore pressure readings had fallen enough to assure that the underlying stratum was not under such a high pressure that it was unstable.

Stage 3

Placing of fill continued in layers until the full amount of the required surcharge had been completed (Fig. 8). Once the surcharge fill placement was completed, settlement plate and piezometer readings were put on a weekly basis.

Stage 4

After consolidation had taken place to 90 per cent of the theoretical value, the surcharge was removed and placed at the site of the next building. Experience with sand drains at La Guardia and Newark Airports led Port Authority engineers to believe that with a 10-foot spacing it would take approximately six months from the time sand drains were driven until the necessary consolidation had taken place. With this in mind and with the factors supplied by settlement and piezometer data from the surcharged building site, installation of sand drains was begun on the second building approximately five months after the start of the first. When drains were completed

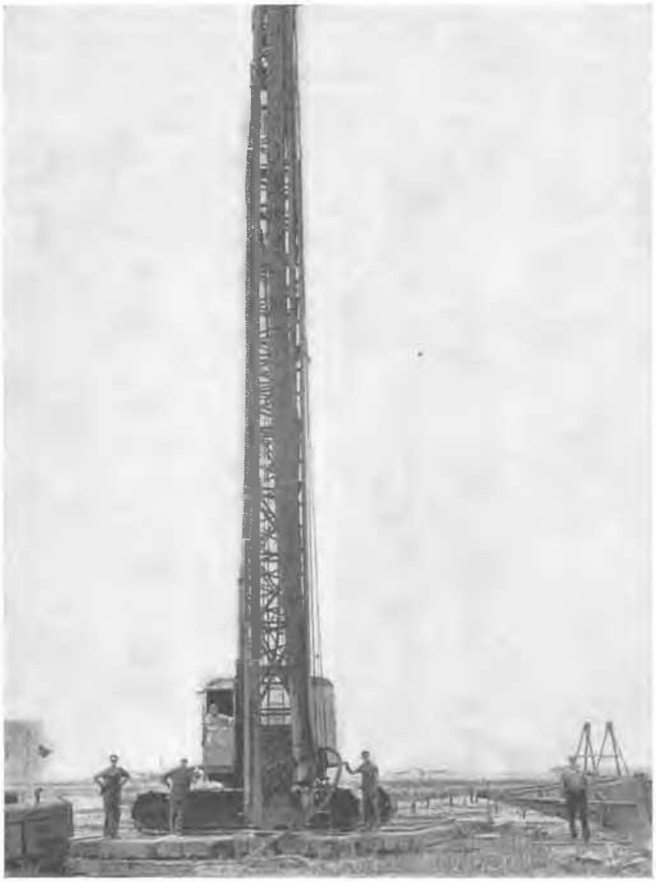


Fig. 6 Modified Pile Driving Rig for Installing Sand Drains
Sonnette de pilotagę modifiée en vue du battage des drains verticaux de sable

Fig. 7 Hollow Steel Mandrel with Hinged Plate at Bottom
Mandrin creux d'acier avec plaque à gonds au fond

Fig. 8 Aerial view of Surcharge Fill on Building No. 1 at Port Newark
Remblai de surcharge du bâtiment No 1 à Port Newark, vue à vol d'oiseau

for the second building and the two-foot blanket placed, surcharge fill was removed from the first building and placed on the second.

Stage 5

As soon as the surcharge had been moved from a building site, the pile foundations for the column supports were begun.

An interesting foundation pile driving technique was also used on this job. As described before, there exists a layer of sand below the compressible organic silt but above the silty clay. Rather than driving an ordinary wood friction pile that would punch through this sand layer and disturb the fairly stiff silty clay, the timber piles were driven butt-end down first. By this method the piles fetched up in the top of the sand layer and acted as bearing piles and this effected a saving of 45 feet of piling per column foundation.

Conclusion

Experience at Port Newark has proved that under certain soil conditions and building construction schedules, it is economically feasible to use vertical sand drains to stabilize poor soil under buildings so that heavy floor loads can be supported with a minimum of settlement. Spacing of sand drains and height of surcharge fill are determined by the physical characteristics of the soil and the time allowed for construction.

References

Barron, R. A. (1947): Consolidation of Fine-Grained Soils by Drain Wells. Proceedings of American Society of Civil Engineers, June, vol. 73, p. 811.

Kyle, J. M. (1950): Settlement Correction at La Guardia Field. Proceedings of American Society of Civil Engineers, November, vol. 76, Separate No. 43.