Performance of Wick Drains in Boston Blue Clay

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SYNOPSIS: The use of wick drains to accelerate the consolidation of soft clays is a cost effective alternative to the use of pile foundations. This paper presents a case history of using wick drains to accelerate the consolidation of a 5.7 acre area in Metropolitan Boston, Massachusetts, USA. Boston Blue Clay was encountered approximately 25 to 40 ft below existing grade with varied thickness and consistency. Wick drains were installed to a depth of 70 ft in a triangular pattern. Geotechnical instruments were installed to monitor the settlement of clay with time. As a result of the preconsolidation program, about $8 million was saved in construction cost.

INTRODUCTION

The Boston Harbor Project is an 11-year, $6.1 billion dollar program, directed by the Massachusetts Water Resources Authority in an effort to stem pollution and clean Boston Harbor. The design and construction of this project involves the execution of more than 61 Construction Contracts on an ambitious schedule. The construction site of the project is Deer Island, an island north-east of the Boston, Massachusetts, USA.

During geotechnical exploration, an area underlain by up to 50 ft of soft gray clay (Boston Blue Clay) was discovered (Figures 1 and 2). Undesirable settlement would occur if the proposed facilities were to be built on this area. Pile foundations, a possible solution to this problem, would be costly. As a result of a value engineering study, it was decided the clay would be preconsolidated to accelerate the settlement prior to construction of the facilities in this area. References cited are some of the available literature on the preconsolidation approaches to accelerate the settlement of soft soils.

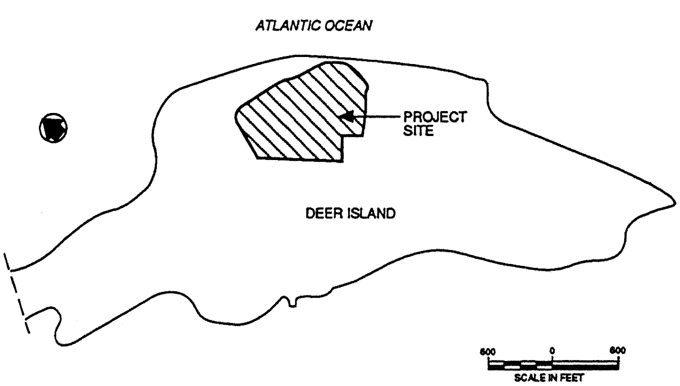

FIGURE 1. SITE LOCATION PLAN

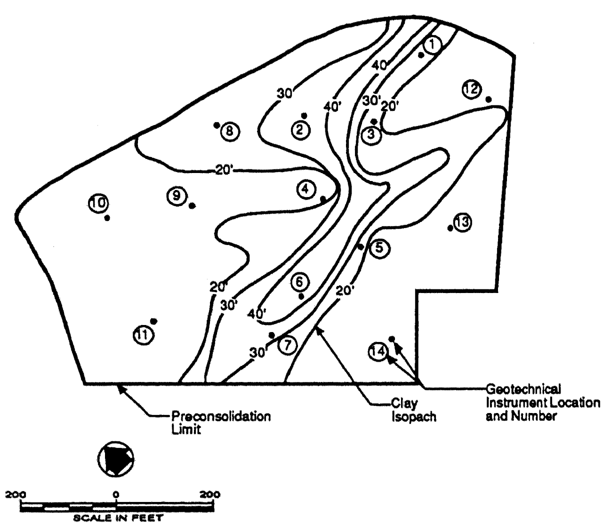

FIGURE 2. CLAY ISOPACH AND GEOTECHNICAL INSTRUMENT LOCATIONS

GENERAL GEOLOGY

Formerly, an island, Deer Island is now a peninsula due to the formation of a tombolo connecting it to the mainland at Winthrop. The surfacial geology of the island is dominated by the central and northern drumlins which were deposited during the last glaciation. Glacial deposits are hypothesized to have blanketed the bedrock surfaces. An interglacial marine clay, the Boston Blue Clay, is also found on the island mainly in areas of bedrock depressions. Minor amounts of peat and other organic deposits are found in the lowlands between the two drumlins and along the shore.

SUBSURFACE CONDITIONS

Subsurface soil conditions have been established based on local geology, site reconnaissance, and boring logs. A generalized subsurface profile of the site is shown in Figure 3. The major geologic units in order of their occurence below ground surface are as follows:

Fill: A layer of fill covered most of the site. The fill consists of sand and gravel in a silt and clay matrix apparently reworked glacial till. The fill thickness varies within the site and in some locations it was up to 40 ft thick. The consistency of the fill is hard to very hard. During wick drain installations, this layer was predrilled to facilitate installation of the drains.

Peat: Pockets of peat with varying thickness were encountered at some boring locations.

Sand: A layer of sand with varying thickness and consistency was encountered in the northwest portion of the site.

Clay: Clay could be divided into two units. The uppermost unit has been classified as a yellow gravelly or sandy clay. The yellow clay appears to be desiccated and has a consistency of hard to very hard. The lower unit is the gray clay (locally referred to as Boston Blue Clay) which underlies the yellow clay. The thickness of the gray clay is up to 50 ft and its consistency is soft to stiff. The consistency of the gray clay changes with its thickness; the thickest clay has soft to very soft consistency.

Glacial till: Underling the gray clay is glacial till. The glacial till consist of varying amounts of sand and gravel into a very hard matrix of silt and clay. Typically, the glacial till consists of about fifty percent fines passing no. 200 sieve.

Argillite: Cambridge Argillite bedrock underlies the glacial till.

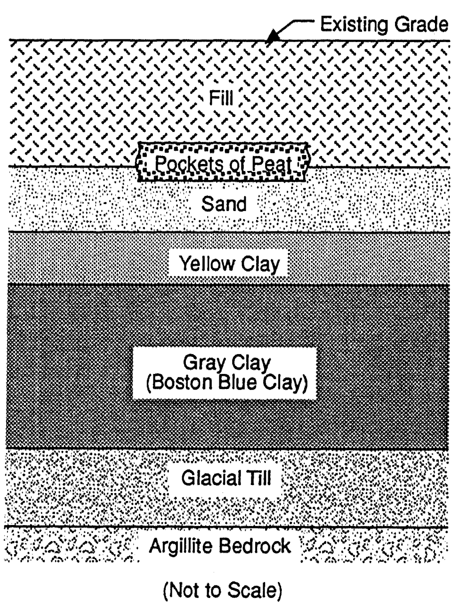

FIGURE 3. GENERALIZED SUBSURFACE PROFILE

PROPERTIES OF GRAY CLAY

The gray clay has been classified as CH and CL based on the laboratory testing. The clay properties that follow are prior to preconsolidation. The typical values for Atterberg limits are: liquid limit of about 50 percent and plastic limit of about 25 percent. The natural moisture content of the clay is about 35 percent. The undrained shear strength of the clay ranges between 500 and 1500 pounds per square foot. The typical coefficient of consolidation c_v of the clay is 50 square feet per year. The typical maximum past pressure is about 3 tons per square foot, and the compression index, c_c is about 0.25. The gray clay is slightly overconsolidated.

WICK DRAINS

A preconsolidation plan with wick drains was designed and constructed. Wick drains were installed in the areas where the gray clay thickness exceeded 25 ft Areas with less than 25 ft of clay were preloaded without wick drains. The wick drain spacing varied throughout the site and was selected based on the time available for preloading and the height of the preload. Triangular spacings of 5, 7, and 9 ft were utilized within the wick drain area.

The wick drains had a prefabricated corrugated PVC core that was wrapped in a non-woven geotextile fabric. Approximately 5,000 vertical wick drains were installed between May and August of 1990, prior to the relocation of Deer Island's central drumlin. The drains were installed from ground surface to clay bottom. A drainage blanket, 18 inches of sand with strips of horizontal prefabricated drains, was laid at ground surface. This blanket, sandwiched between the preload fill and the clay, allows the water forced by pressure from the clay, to drain freely.

PRELOAD SURCHARGE

Ideally a surcharge of uniform height is desirable to preconsolidate the clay, however due to the site restrictions such a surcharge could not be achieved because of such constraints as relocation of a prison and a haul road. Therefore, a non-uniform surcharge was adopted and fill heights in non-constrained areas were increased to compensate for other areas with insufficient fill heights. The surcharge consisted of 2 mounds of fill up to 75 ft in height. Placement of surcharge fill started in August 1990 and was completed in November 1990. Figure 4 shows the wick drain limit and surcharge fill contours.

FIELD INSTRUMENTATION

The geotechnical instrumentation consists of piezometers to monitor porewater pressure dissipation and settlement platforms, Borros anchors, and spiral-foot anchor to monitor settlement. Seven clusters of geotechnical instrumentation were installed within the wick drain area and seven clusters were installed in the preload area outside the wick drain area. Figure 2 shows the instrument locations. A combination of inclinometers and extensometers were installed prior to the preload fill removal to monitor lateral displacement of deep excavations and ground heave (rebound) of the preconsolidated clay.

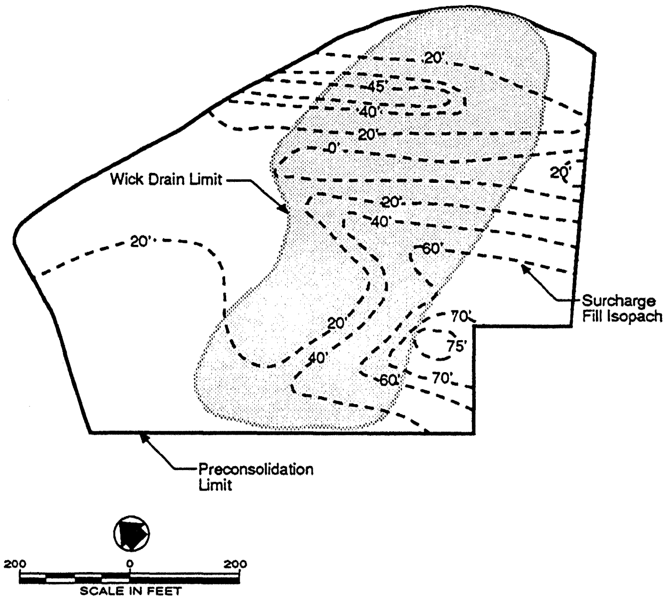

FIGURE 4. WICK DRAIN LIMIT AND SURCHARGE FILL ISOPACH

FIELD MONITORING

The geotechnical instruments were monitored bi-weekly. The geotechnical monitoring consisted of fill height elevation, groundwater elevation, and the settlement of the clay. These results were plotted in a semi-log form to evaluate the progress of preconsolidation and estimate the end of primary consolidation. Two typical plots of such monitoring are shown in Figures 5 and 6.

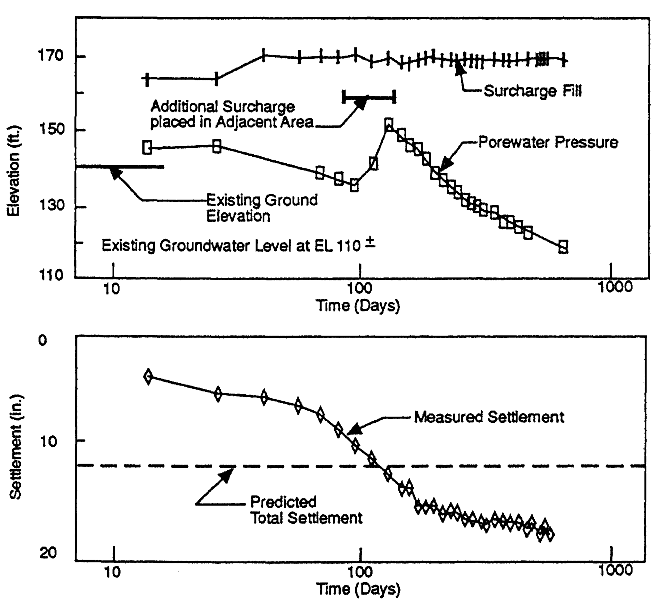

FIGURE 5. SETTLEMENT AND PIEZOMETER MEASUREMENTS FOR INSTRUMENT LOCATION 2

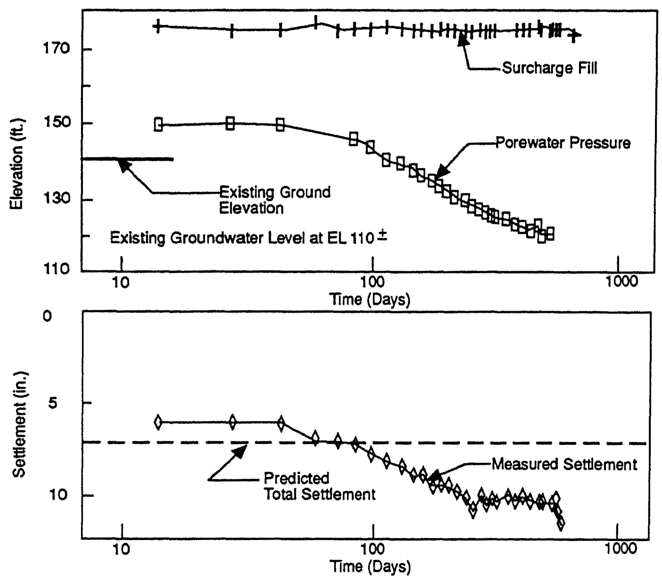

FIGURE 6. SETTLEMENT AND PIEZOMETER MEASUREMENTS FOR INSTRUMENT LOCATION 3

POST CONSTRUCTION EVALUATION

Seven test borings were drilled at the end of preconsolidation program. Undisturbed tube samples were collected from the gray clay layer to evaluate the preconsolidation program. The boreholes were drilled adjacent to the borings drilled prior to preconsolidation. Figure 7 shows the standard penetration resistance of two of the boreholes before and after preconsolidation. The unconfined compressive tests revealed that the undrained shear strength of the clay ranged from 2200 to 2600 pounds per square foot; substantial strengthening compared to strengths prior to preloading. The maximum past pressure was about 6 tons per square foot which again is a substantial improvement compared to 3 tons per square foot prior to preloading.

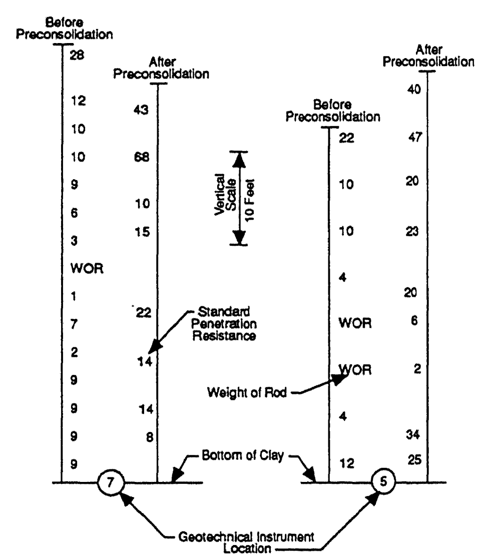

FIGURE 7. STANDARD PENETRATION RESISTANCE BEFORE AND AFTER PRECONSOLIDATION

CONCLUSIONS

The geotechnical instrumentation, post construction test borings and laboratory testing indicate that the clay has reached the end of primary consolidation. Data is still being collected from the inclinometer and extensometers to evaluate the rate of rebound of the clay. Excavation work is underway on the site. For one set of structures, engineers designed a mat foundation; on a second set of structures, a combination of mat and pile supported foundations have been designed. The preconsolidation program has saved an estimated $8 million in pile foundation costs. The cost of the preconsolidation program was about $1.5 million.

ACKNOWLEDGEMENTS

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REFERENCES

Charles R.D. (1988), "Performance of Prefabricated Drains in Soft Soils", Proc. Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, St. Louis, MO, Paper No. 5.36.

Davie, J.R. and Lewis, M.R. (1988), "Accelerated Consolidation of Soft Clays Using Wick Drains", Proc. Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, St. Louis, MO, Paper No. 5.29.

Institution of Civil Engineers (1982), Vertical Drains, Thomas Telford LTD.

Long, R.P., Hover, W.H. (1984), "Performance of Sand Drains in a Tidal Marsh", Proc. First International Conference on Case Histories in Geotechnical Engineering, May 6-11, St. Louis, MO, Vol. III, pp. 1235-1244.