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SYNOPSIS: This paper illustrates an exhaustive geotechnical effort to accompany the design and construction of the foundations of the SIMA Building of the United States Naval Shore Support Facility on Staten Island, New York.

INTRODUCTION

In early 1980's the Congress authorized several U.S. naval facilities to be stationed at strategic locations of the continent of the United States in support of the Surface Action Group (SAG) Vessels. One of these sites is now located in Staten Island, New York. (See Figure 1.) As a primary part of a new U.S. Navy shore support installation on Staten Island, a large maintenance and repair complex has been designed and constructed, eliminating the need for drydocking vessels of the Northeast Battleship Group when repairs are due. As a homeport for this Navy Group, the complex serves six major ships besides the Battleship USS Iowa--one of them is a cruiser, two frigates, and three destroyers. The site, along the waterfront, is approximately 40 acres in size.

It was in early 1985 that Sverdrup and Grad Associates, PC, were commissioned to design a host of buildings, large and small, with floor area varying from 1,000 sq ft to 200,000 sq ft, in various locations on this 40-acre land. The largest building, the Shore Intermediate Maintenance Activity (SIMA) with a floor area of 203,000 sq. ft, will be used as a sample in this paper.

SITE HISTORY

The site has a long, narrow configuration. The property extends for a distance of approximately 5,000 feet along the Stapleton waterfront and varies in width from approximately 200 feet at the southern end to 500 feet at the northern end. The ground surface elevation is about El. 10 MLW.

The existing bulkhead was a pile supported relieving platform constructed in the mid 1920's. The bulkhead extended along most of the length of the property. The Stapleton Piers were built by the City of New York in the 1920's, approximately 12 piers in total. Until World War II, a major portion of the upland area and several piers were used for storage and processing of foreign and domestic cargo. These activities were halted during the war when the U. S. Army used the piers as a port of embarkation. In the 1970's, the Stapleton piers became inactive and were demolished to prevent hazards to navigation. However, in isolated areas, the pilings have not been removed and are visible above the waterline.

The onshore area at one time contained a complex of industrial buildings and service facilities. But remnants of concrete pavement and hardstands as well as a rail siding still existed when the construction started. Besides, the remainder of the site was overgrown with weeds and littered with trash and other debris.

SUBSURFACE EXPLORATION

Several subsurface exploration programs had been conducted at the Stapleton site in the 1960's and again in 1984. However, in order to obtain site-specific subsurface information, a total of twenty four (24) borings were made in the SIMA footprint and three test pits were dug. Of these 21 borings, 6 were taken during the 35% design stage, and 15 were taken during the construction stage.

SUBSURFACE CONDITIONS

The soil stratification encountered from the existing grade can be described as follows.

The miscellaneous fill, with an average thickness of 20 to 25 feet, consists of cinders, boulders, bricks, garbage, wood and glass intermixed in a matrix of sand, silt and gravel.

The underlying soft sediments consist of organic silt and clays. The soil is compressible and occasionally contains shell fragments, peat or root fiber. In the project areas, the thickness of this stratum varies from 5 to 10 feet and is generally encountered between El. -5 and -20 MLW.

The granular soil is generally encountered at a depth of approximately 30 feet below existing ground surface. This stratum consists of: (1) an upper layer of gray medium dense to dense sand, (2) a layer of dense reddish brown silt, and (3) lower layer of dense to very dense gray or brown sand with trace silt and trace gravel. The dense sand stratum having a standard penetration resistance of 50 blows per foot or greater can be anticipated approximately 60 feet below the existing ground surface.

DESIGN OF BUILDING FOUNDATIONS

As mentioned previously, the miscellaneous fill contains heterogeneous and deleterious material, such as cinders, trash, wood, glass, boulders, construction debris, and old foundations, which include old pilings. Below this miscellaneous fill, a compressible organic clayey silt is often encountered. Therefore, all building structures were recommended to be pile supported.

The number of borings taken during the 35% design was considered to be adequate for the overall site deep foundation contract preparation. It was understood, however, that additional borings might be required during foundation construction. In selecting the foundation type, it was assumed that the buildings would be constructed in one large contract. Therefore, it was desirable to use only two types of piles, one for high capacity and the other for low capacity.

Several types of piling were considered during the design stage. Low capacity piling (25 tons plus 15 tons downdrag) and creosote-treated timber piles were selected for supporting utilities and for buildings which were lightly loaded. Cast-in-place steel pipe piles and pre-cast concrete piles were considered for higher capacity piling. The precast concrete pile, which is 16-inch square and yields a capacity of 80 tons (60 tons plus 20 tons downdrag), was recommended for inclusion in the contract document because they had been successfully used in large quantities for other parts of this Naval Station. However, immediately before bid issuance, cast-in-place steel pipe piles were included as an alternate, because they were competitive in cost at the time.

WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

In this project wave equation analysis was used for construction control, and the results were submitted by the Contractor for review prior to test pile driving. Basically the wave equation analyses in this project were for pile equipment selection, and for guiding test pile installation.

After extensive test pile driving and pile load testing, the driving criteria were established. Production pile driving soon followed.

ALTERNATE PILING

During the negotiation for the SIMA foundation work, a proprietary piling called Composite Pile with Tapered Pile Tip, or TPT, was introduced by the piling sub-contractor (Underpinning & Foundation Contractors, Inc.). In the view of the Contractor, the TPT piles would be founded in the upper layer of medium dense to dense sand, thus would be shorter than conventional piles. This piling contractor had just finished installing TPT piles in an adjoining area for utility support, although the installation quantity had been small. The SIMA building would require a total of about 900 TPT piles.

The TPT pile system is shown in Figure 2. A steel pipe mandrel is used to drive a precast concrete tip. The stem of the pile is a helically corrugated steel shell which is threaded into a mating socket cast into the concrete tip. The TPT sizes, capacities, and stems are shown in Figure 3. The tips used were J and H sizes of 29"x25"x42"(height) and 26"x23"x36", respectively. Pile stems were filled with concrete and reinforcement. By using the wave equation theories, the contractor's consultant has been able to predict very closely the appropriate hammer size, cushioning material, and driving resistance required to produce specific pile capacities with various combinations of tips and stems. The dynamic stresses have also been determined by wave equation analysis and this information has facilitated design of tip reinforcement.

The structural capacity of an enlarged base composite pile as a structural member is based on the diameter of the cast-in-place concrete stem. According to Reference Standard RS 10-3 of the Building Code of the City of New York, using working stress design, the allowable compressive stress for concrete is 0.25 f'c. With f'c = 6,000 psi and a 11-3/8-inch diameter cast-in-place concrete stem, the structural capacity would be 173 kips, which is greater than the required 160 kips.

The Building Code of the City of New York has a provision for calculating the bearing capacity of enlarged base piles, such as the TPT pile.

In view of the potential savings in construction cost, the Contractor was permitted to retain his geotechnical consultant to perform the subsurface investigation and soils testing necessary to properly design and install these pilings. The existence of the red-brown silt stratum had caused concern for the TPT pile design and installation. This silt stratum falls within the economic depth for TPT piles. The Contractor agreed to develop supporting subsurface information which would guarantee the performance of these TPT piles. The contractor also took an additional fifteen (15) test borings within the SIMA Building footprint. Three-inch-diameter undisturbed tube samples were recovered from the silt stratum encountered in the borings, and two consolidation tests were performed. These tests were designed to determine whether this silt stratum is of low compressibility. Two consolidation tests were performed. Strength tests of selected silt samples, and sieve analyses of the materials forming the bearing stratum, were also performed. These tests included an unload/reload cycle in order to eliminate the effects of sample disturbance and to define the recompression characteristics of this silt stratum.

The consolidation tests revealed that this silt stratum is over-consolidated. The recompression ratios were found to be small. Thus, the consolidation tests confirmed that the compressibility of this silt stratum is similar to that of sand. The rate of consolidation of this silt stratum, as determined from the results of the consolidation tests, is expected to be rapid; a 2-ft-thick layer is expected to consolidate fully in about one-half day, a 4-ft-thick layer in about one and one-half days, and an 8-ft-thick layer in about six days.

The shop drawings were made in conformance with the Navy manuals. The Contractor provided the contours of the top of the bearing stratum. Several test piles were driven, and five (5) compression and two (2) tension tests were conducted, prior to production pile driving. At the conclusion of pile load test program, driving criteria were provided to the Contractor. However, the following supplementary procedures for TPT pile driving were also agreed upon by the Contractor. A typical TPT pile driving is shown in Picture 1.

1. Layout stakes to be placed at the centerline of each pile by a licensed surveyor.

2. Drive witness stakes 5 feet in either direction from pile stake.

3. Scribe lines in soil outlining bottom dimension of enlarged concrete tip.

4. Set enlarged concrete base over pile stake within scribed lines.

5. Once the pile tip is placed on grade, check its proper location in relation to the offset stakes.

6. Drive pile tip into ground to within 6 inches of ground surface.

7. Check location of pile tip from witness stakes. If pile is more than 2 inches from correct location, pull and reset pile tip.

8. Insert shell stem into socket in pile tip and drive pile.

9. The P.E. Inspectors record all driving data. Inspectors consider the possibility of dilatancy and call for additional blows after a ten minute interval on a professional judgment basis.

10. After completion of pile driving, measure and record deviation from design location on driving record.

11. For multiple pile groups, offset subsequent piles in the group to compensate for movement of previously driven piles in the group in order for the centroid of the group to be as close as possible to the design centroid.

12. Submit as-built pile locations prepared by a licensed surveyor on a periodic basis.

13. Cap and backfill around the pile to the cut off elevation with sand or other suitable material where voids exist. Place backfill prior to capping the pile. Block up pile shells in place to avoid shifting during the driving of adjacent piles.

14. During the driving operation, observe carefully the mandrel and shell for water or mud to insure that the shell not being damaged.

15. Remove from shell any mud or water prior to pouring concrete. P.E. Inspectors visually inspect the pile once driven.

16. No piles to be driven within 25 feet of another pile where the concrete has not hardened for at least seven (7) days.

17. Perform all pile placement, driving, concreting and testing under the direct supervision of P.E. Inspectors.

CONCLUSIONS

The following conclusions were reached based on observations during the construction of this project:

1. It is beneficial to allow alternate piling to be considered during the bidding/ negotiation stage, because considerable construction cost savings may be realized.

2. Test borings taken during production pile installation period to verify design assumptions and to modify pile driving criteria established by test pile are proven to be worthwhile for this project. The project delay and the cost of taking test borings are insignificant as compared to the significant savings in the construction cost.

3. Wave Equation Analysis can be used effectively to assist in pile driving equipment selection and in establishing dynamic pile driving criteria.

4. TPT piles can be effectively used where site conditions are suitable, thus substantial cost savings have been realized at the SIMA Building.

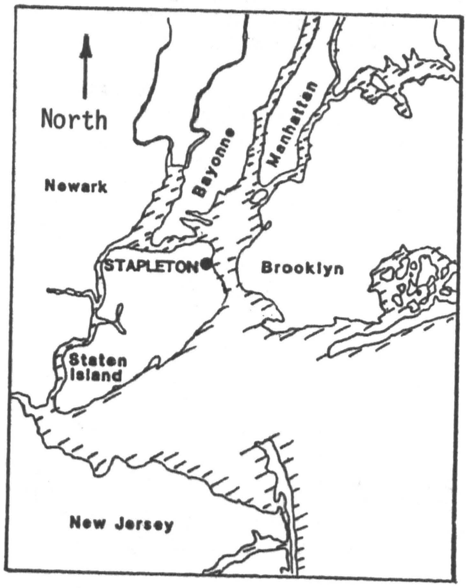
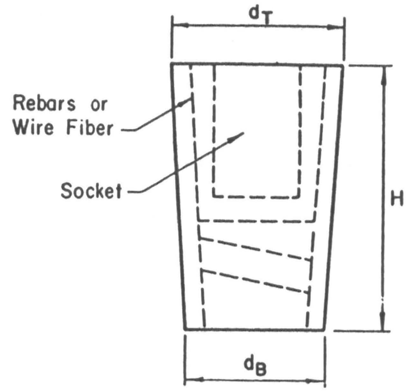


Fig. 1. Site Location Plan



TPT PILE TIP SIZES

CAPACITY RANGE (TONS)	TPT DESIGNATION	Dt (IN)	Db (IN)	H (IN)	STEM MATERIAL
60-240	E	41	35	60	12" TO 22" DIA SHELL/PIPE
60-240	D	38	32	60	12" TO 22" DIA SHELL/PIPE
60-240	C	35	29	60	10" TO 22" DIA SHELL/PIPE
60-240	B	32	26	60	10" TO 19" DIA SHELL/PIPE
60-240	A	29	23	60	10" TO 16" DIA SHELL/PIPE
60-240	J	29	25	42	10" TO 16" DIA SHELL/PIPE
60-240	Jw	29	26	36	10" TO 16" DIA SHELL/PIPE
60-180	H	26	23	36	10" TO 16" DIA SHELL/PIPE
30-150	W	24	20	36	10" TO 16" DIA SHELL/PIPE
20-80	V	24	18	30	10" TO 12" DIA SHELL/PIPE
20-80	T	20	16	30	8" TO 12" DIA SHELL/PIPE
20-80	U	18	14	30	8" TO 10" DIA SHELL/PIPE
20-50	X	19	15	30	8" DIA, PIPE OR WOOD
25-50	Y	17	13	30	8" DIA PIPE OR WOOD

Fig. 3. TPT Sizes, Capacities, and Stems

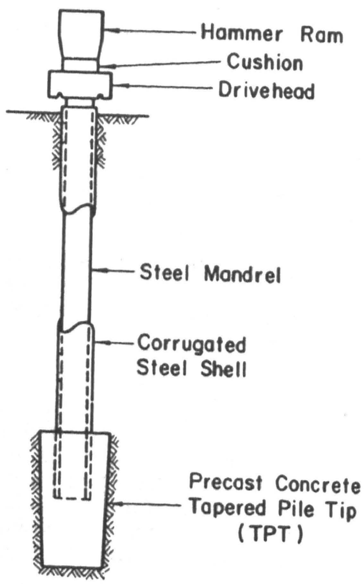
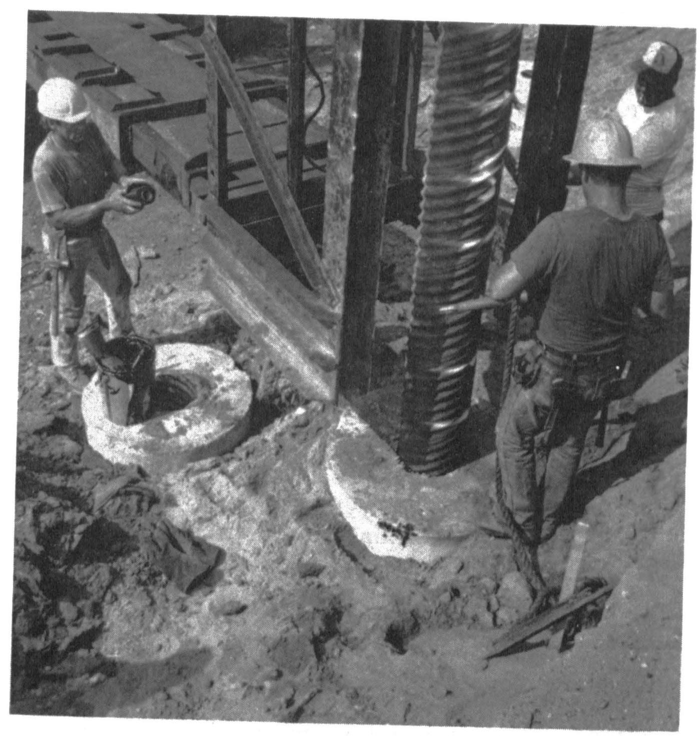


Fig. 2. TPT System



Picture 1. Driving TPT Pile (Typical)