Technical Paper

Title: Designed, Load-Tested, and Installed Piles for a High-Rise Building in Southwest Florida – A Case History

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DESIGNED, LOAD-TESTED, AND INSTALLED PILES FOR A HIGH-RISE BUILDING IN SOUTHWEST FLORIDA - A CASE HISTORY

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SYNOPSIS

This paper presents a case history of design, prediction, probe and production pile driving monitoring, loading test, and installation of piles for a 22-story condominium tower in southwest Florida, U.S.A. ASC was commissioned to provide value engineering services in the proper selection of an economical and satisfactory foundation system. For the site-specific subsoil conditions, various types of foundations were considered and following an evaluation of high structural loads, site-specific constraints, and the production timeframe mandated by the project owner, a prestressed concrete pile-supported system was selected as an economical and effective foundation approach.

The building foundations were designed for a compression capacity of 575 kN (65 tons) for the tower and 220 kN (25 tons) for the parking structure. The axial pile capacity and lengths were predicted using SPT91 software. The validation of these capacities was derived from driving 21 probe piles and performing static loading tests on selected probe piles (2 in compression and 1 in tension). The predicted pile capacities were evaluated with results from static loading tests on selected probe piles. This information was effectively utilized as part of an overall quality control program to install a total of over 920 prestressed concrete piles to lengths ranging from 11.5 to 16.5 m (37 to 54 ft) below existing ground elevation as part of the foundation support system.

INTRODUCTION

The Claridge Resort Complex is nestled between Pelican Bay and Park Shore providing a secure, gated beachfront community in northwest Naples, Florida, U.S.A. The building project consists of a 22-story tower with parking underneath and an adjoining parkade on the west side with a raised pool deck. The tower is of concrete and masonry construction with post-tensioned floor slabs. A project location map is shown in Figure 1 and the project building layout and boring location plan are illustrated in Figure 2.

An earlier preliminary geotechnical exploration was performed by another consultant in 1990. In 1992, ASC geosciences, inc. was retained to provide value engineering services including a complete geotechnical exploration, testing, and engineering evaluation as well as proper selection of an economical, effective, and satisfactory foundation support system. The construction phase for the project occurred between June 1992 and October 1993.

This paper presents a case history of the project detailing the engineering profile of subsoils at the project site. It also outlines the design considerations leading to the selection of prestressed concrete piles as the foundation element, and the loading test results of the installed piles.

SUBSURFACE CONDITIONS AND PROJECT DATA

Pre-construction project site features included a generally level topography with jurisdictional wetlands along the north property line. The location of all borings completed in 1990 and 1992 are indicated in Figure 2. Subsurface soil conditions observed from 11 Standard Penetration Test (SPT) borings to depths ranging from 8 to 30 m (25 to 100 ft) below the existing ground surface are illustrated in Figure 3.

The project site generally consisted of predominantly loose to very loose sands to silty sands to approximately 12 m (40 ft) with shallow deposits of compressible organic sandy silt and peat layers also present. These sand and silty sands are underlain by firm to hard limestone which is moderately well-cemented. However, some solutioning commonly referred to as weathering and karstic features were encountered in localized areas and confined in upper portions of the limestone formation. Structural design total loads for the tower area ranged from 3,900 to 7,150 kN (900 to 1650 kips). For the garage structure, column loads were estimated at 780 kN (180 kips). Furthermore, approximately 1.2 to 2.1 m (4.0 to 7.0 ft) of structural fill material was required to achieve the desired building grades.

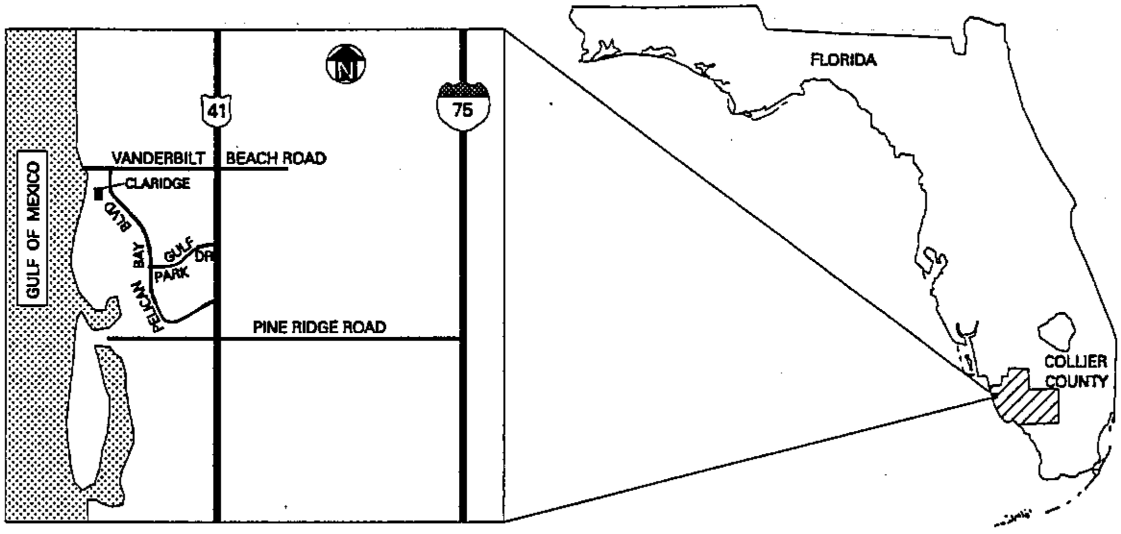

Figure 1. Project Location Map

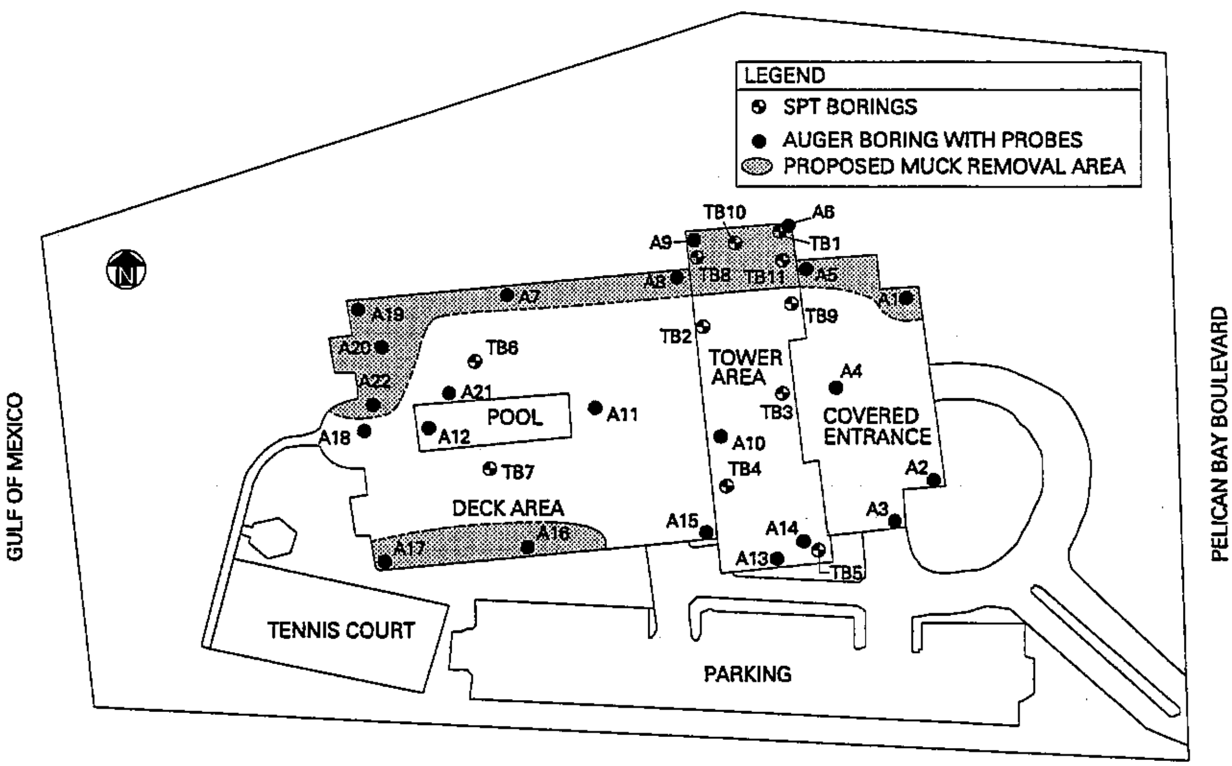

Figure 2. Boring Location Plan

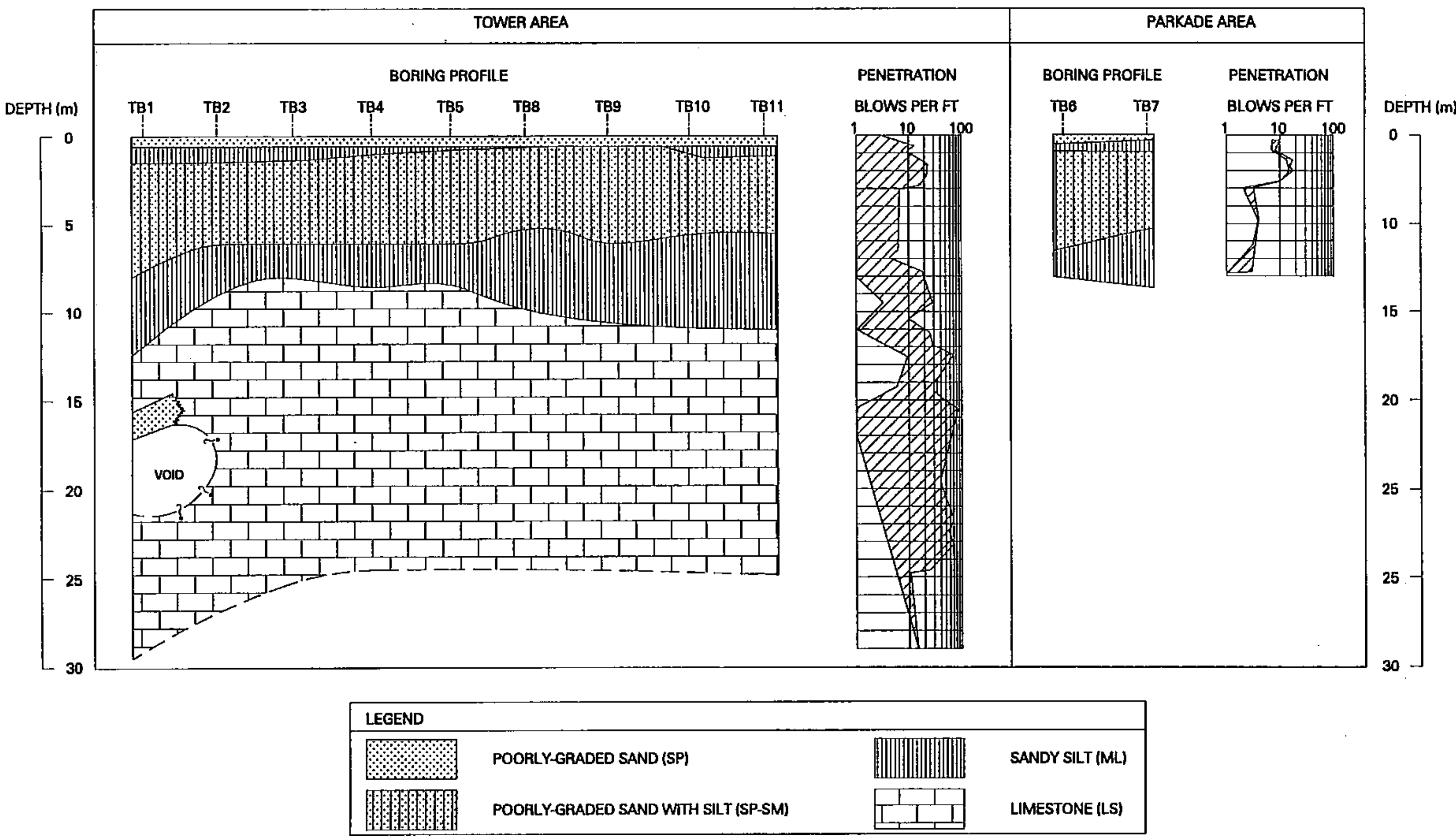

Figure 3. Summary of Subsurface Conditions.

FOUNDATION DESIGN AND ALTERNATIVES

The first step of the design process was to evaluate various foundation systems and associated costs. Several foundation alternatives were considered for the proposed tower structure including: i) driven displacement piling; ii) cast in-place auger piles; and, iii) preloading the site and founding the structure on a mat foundation. For the parkade structure, foundation alternatives included support of shallow footings on vibro-compacted soils. In view of the owner's accelerated construction schedule and the mandated timeframe, a driven prestressed concrete piling system was finally selected for the tower and connected parkade structure. Piles were designed to penetrate into the limestone layer as end bearing or friction piles. In localized areas near test boring TB-1 the limestone stratum was considered unsuitable due to the presence of a soft zone and void.

The allowable capacity of piles were estimated using SPT91 software. This program, which was developed and used by the Florida Department of Transportation, estimates the axial capacity of a pile based on SPT "N" values. The design method used in SPT91 has been found to be very accurate for driven piles in cohesionless soils (ref 4).

Results indicated that prestressed concrete piles driven to depths ranging from 12 to 13 m (40 to 42 ft) below the original ground surface were the most economical foundation alternative. In many areas, the initial analyses indicated that the upper dense layer of limestone could act as a bearing layer for the piles. Piles lengths were then determined using SPT91 output based on the maximum axial load on a pile. Davisson's (ref 2) criterion was used to define the ultimate failure capacity of a pile. The allowable tensile capacity of the pile was defined as 70 % of the allowable skin friction.

PROBE PILE AND LOADING TEST PROGRAM

In an effort to optimize penetration and capacity requirements for piles, a loading test program was recommended and performed. A total of 21 probe piles were driven within the tower and the parkade area. A total of 3 loading tests (2 in compression and 1 in tension) were performed on probe piles. A pile layout plan and summary of loading test locations for the tower and parkade structure layouts are shown in Figures 4 and 5, respectively.

Following the geotechnical consultant's review of the pile layout plan and the specialty subcontractor's qualifications, details of pile driving specifications such as driving equipment and driving termination criterion were finalized for the probe pile program to proceed. The precast prestressed concrete pile installation operations were performed by Gulf Piling and Marine Construction of Naples, Florida. The pile driving termination criterion was established using 1-dimensional wave equation analysis. For the case of a pile toe embedded in weathered limestone a driving termination criterion of 5 blows per 25 mm (1 in.) for the final 120 cm (36 in.) was established for a 580 kN (65 tons) rating and 3 blows per 25 mm (1 in.) for the final 120 cm (36 in.) of penetration were established for a 224 kN (25 tons) rating. In 2 localized areas near probe piles TP3 and TP17, longer piles were required where weathered and solutioned limestone was encountered at a 12.2 m (40 ft) depth. ICE 520 and ICE 312 double-acting hammers with maximum rated energies of 4,200 m kg (30,000 ft lbs) and 2,520 m kg (18,000 ft lbs), respectively, were used for the tower and parkade structures.

The loading test program was conducted to verify the design capacities of the installed prestressed concrete piles. The procedures described in ASTM D 1143 (ref 1) for loading tests on piles were followed. Three loading tests were conducted on piles which were installed using the same criteria which were developed for the production piles. Figure 6 illustrates the load-movement curves attained for the loading tests of 356-mm (14-in.) square and 305-mm (12-in.) square piles. As established in ASTM D 1143, the piles were loaded to twice the design load. It is noted that the compression loading tests did not attain Davisson's failure criterion.

Following completion of the probe pile and loading test program, specific pile lengths and capacities were finalized after taking into consideration the excavated and prepared soil surface elevations of various areas within the building limits. Production pile lengths were determined based on minimum tip penetration requirements, results of static loading tests, and blowcount criteria for the pile toe located in sand or weathered limestone.

Pile Installation and Quality Control

Following the geotechnical consultant's review of the pile layout plan, details of pile driving specifications were finalized for the production pile program to proceed. Work commenced following completion of the prepared (i.e., excavated and graded) soil surface, and full-time monitoring and logging of the program was provided. Records of pile number, location, date of installation, length of pile, blows per foot, hammer energy, and unusual occurrences for each pile were kept. The approval for the pile driving termination was given upon review of pile driving records by an ASC engineering representative.

A total of 920 piles were installed during probe and production pile installation phases. For the tower area, the 356 mm (14 in.) square piles were delivered to the site in the lengths of 14.5 m (47 ft) and were driven to depths ranging from 11.6 to 16.5 (37 to 54 ft). The driving termination criterion was achieved in most of the piles. In cases where the driving termination criterion was not met, the piles were spliced and driven to the desired driving termination criterion at depths ranging from 17.6 to 22 m (58 to 72 ft). Similarly, for the parkade area, the 305 mm (12 in.) square piles were delivered to the site in lengths of 14.5 m (47 ft) and were driven to depths ranging from 11.6 to 14.5 m (37 to 47 ft). Where the driving termination criterion was not met, the piles were spliced and driven to the desired driving termination criterion at depths ranging from 18.9 to 23.5 m (62 to 77 ft).

Based upon ASC's continuous and satisfactory monitoring of the pile installation programs (e.g., logging the blowcount, periodic checking of hammer energy, and keeping track of pile embedment) the prestressed concrete pile foundation system, as installed, was approved and accepted for the buildings. The Claridge Resort building complex project was completed in October 1993. The building was released for occupancy after completion of the project and to date all the structures have performed well.

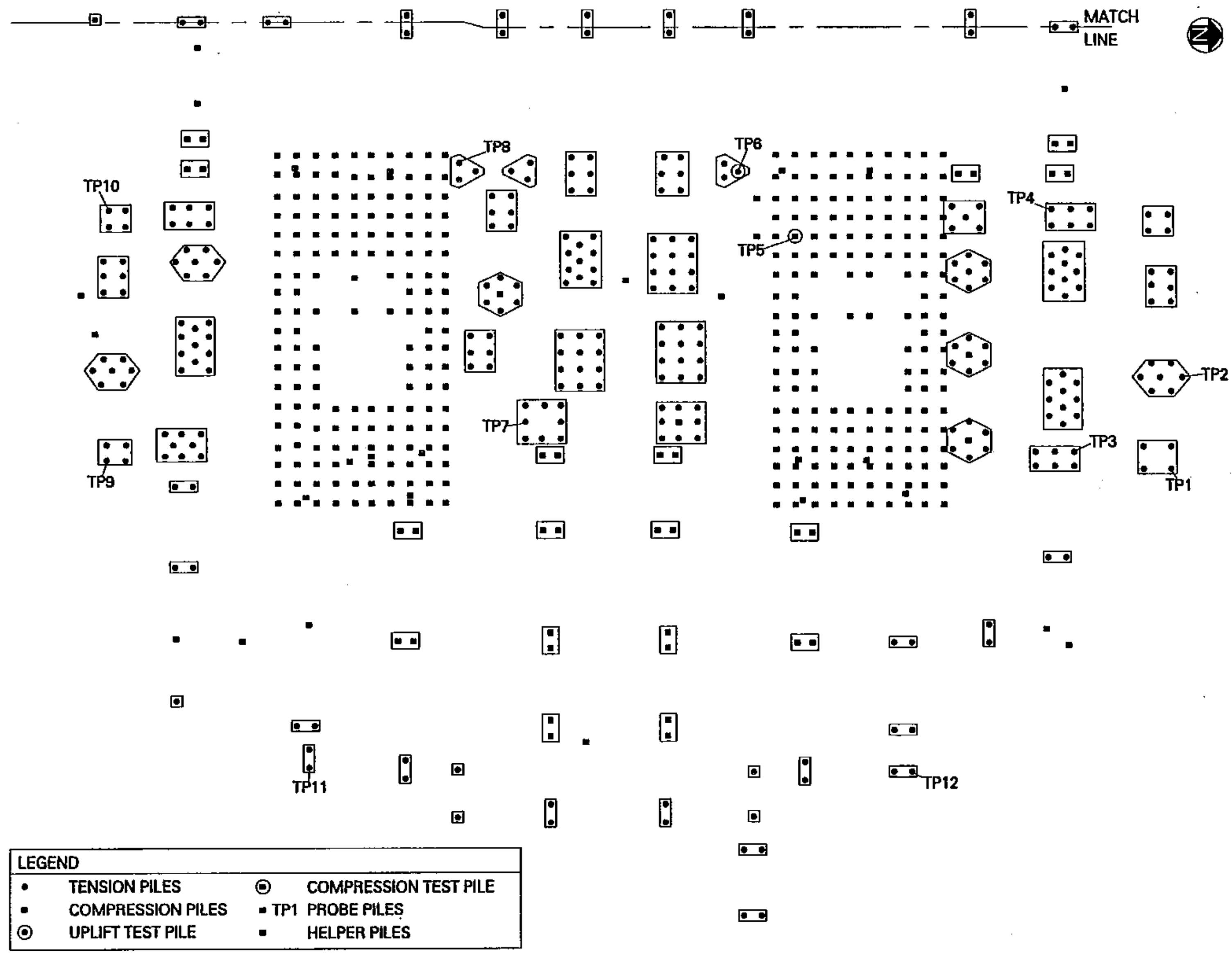

Figure 4. Pile Layout Plan and Loading Test Locations, Tower Area

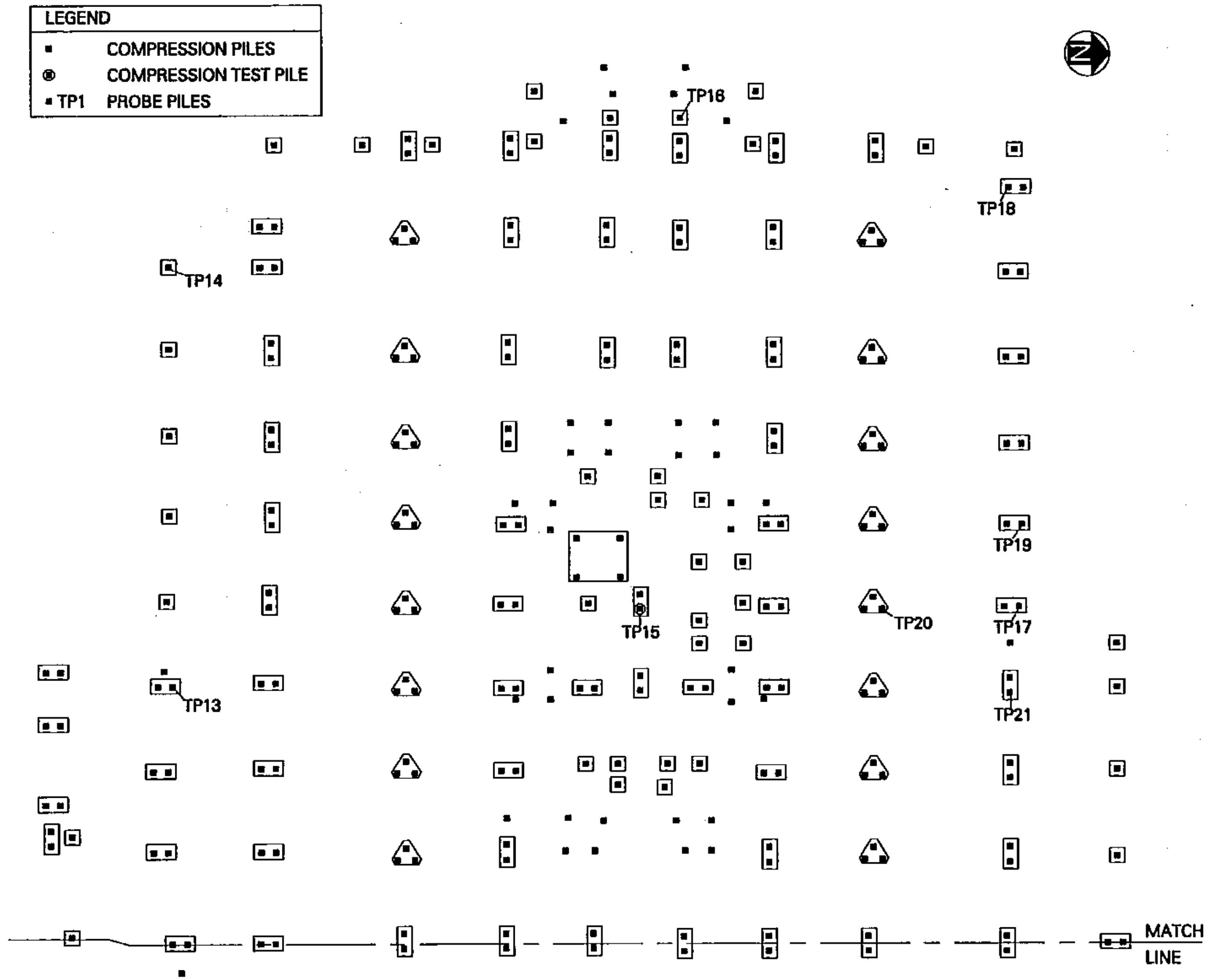

Figure 5. Pile Layout Plan and Loading Test Locations, Parkade Area

CONCLUSIONS

The authors believe that the use of properly installed and effectively monitored and tested prestressed concrete piles are economical as compared to other deep foundation systems and that quality control forms a key element of the overall approval and acceptance process.

1) It is important to have an accurate and reliable method of calculating axial pile capacity. Although several methods exist for designing axially loaded piles, every design method should be verified for applicability to a specific site prior to use. The SPT91 software was selected for this project due to its applicability to foundations in Florida soils.

2) The cost of the selected pile foundation was generally less than that of other deep foundations such as auger-cast piles and concrete drilled shafts. The speed of foundation installation was helpful in completion of the project ahead of schedule and resulted in a bonus for the contractor. In this case, a cost savings of 20 percent was realized for the owner by using prestressed piles versus other deep foundation alternatives.

3) Optimization of pile penetration depths based on probe pile and loading test program was achieved in this case.

ACKNOWLEDGEMENTS

The information herein is from project which the authors and their firm, ASC geosciences, inc., were involved as the geotechnical and value engineering consultant.

ASC expresses its appreciation to the other project team members: Mr. Kevin Manning of McCoy Development Company, the owner; C&A Engineers, the structural engineer; and Gulf Piling and Marine Construction, the piling contractor, all from south and southwest Florida.

The case history information from this project provided a useful database for reference on future projects of this type in this area of southwest Florida. The authors also wish to thank Swamy Kumar for preparation of diagrams presented in this paper.

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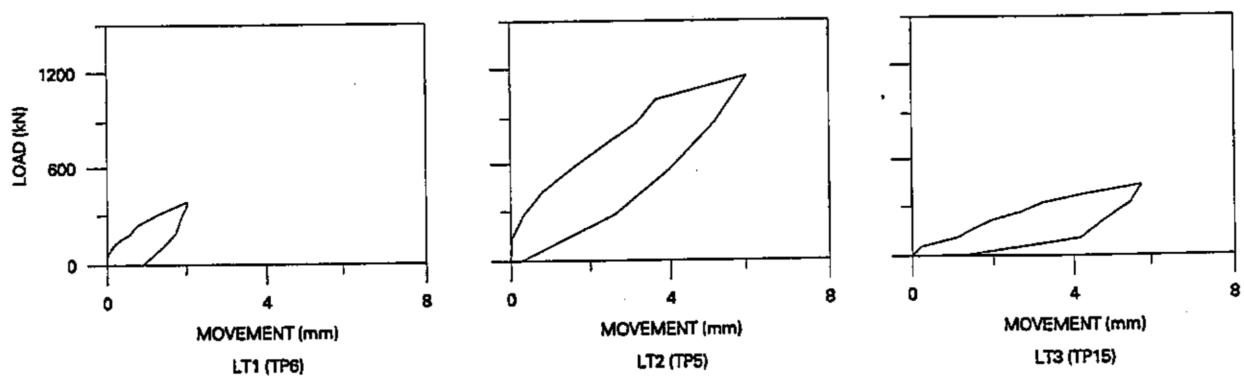

LOADING TEST NO.	PILE		CAPACITY [2]	
	WIDTH (mm) [1]	LENGTH (m) [1]	PREDICTED (kN) [1]	DAVISSON (kN) [1]
LT1 (TP6)	356 [3]	12.5	390 [4]	--- [5]
LT2 (TP5)	356 [3]	12.3	1,155	--- [5]
LT3 (TP15)	305	13.1	445	--- [5]

NOTES:
(1) 1 mm = 0.04 in.; 1 m = 3.28 ft; 1 kN = 0.11 tons
(2) all capacities are ultimate failure capacities
(3) tapered piles
(4) uplift failure capacity
(5) not attained

Figure 6. Summary of Static Loading Test Results