CASE HISTORY OF A FIVE-STORY PRINTING PRESS FOUNDATION WITH ZERO MOVEMENT CRITERION

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ABSTRACT

This paper presents a case history of design and effective utilization of pile foundations for a 10,000 kN (1,100 ton), 5-story high printing press for a newspaper publishing facility on a site with difficult and challenging subsoil conditions. This dynamically loaded printing press foundation had a "zero movement" required by the designer. As part of the design finalization process, an extensive probe pile-driving program consisted of dynamically load testing a total of nineteen 13.8 m (45ft) 356 mm (14-in) square, PPC concrete piles to driven depths ranging from 7.6 to 12.2 m (25 to 40 ft) utilizing Pile Driving Analyzer (PDA). PDA-predicted ultimate pile capacity ranged from 736 to 2,186 kN (81 to 240 tons) at EOID and from 814 to 2,596 kN (90 to 286 tons) at BOR. Time elapsed between EOID and BOR ranged from 24 to 120 hours. Piles at this site exhibited set-up ranging from none to 36 percent. This information was effectively utilized as part of the overall quality control program to install a total of 250 PPC piles within the press foundation limits to embedded depths ranging from13 to 20 m (42 to 68 ft). The predicted pile capacities compared very well with the capacities from the CAPWAP analysis for probe piles. One year after the press went into production in 1997, the zero movement was confirmed.

RÉSUMÉ

Ce papier présente une histoire du cas de conception et utilisation efficace de fondations du tas pour un 10.000 [kN] (1,100 tonne), de la haute presse 5-story pour un service d'édition de journal sur un emplacement avec des états difficiles et provocants de sous-sol. La fondation de la presse d'imprimerie chargée de cette [dynamically] avait un "zéro mouvement" a exigé par le dessinateur. Comme partie du processus du [finalization] de la conception, une enquête étendue programme tas-impérieux a consisté d'essai de la charge du [dynamically] un total dix-neuf 13,8 m (45ft) 356 [mm] (14-in) carré, PPC concrétise tas à profondeurs commandées alignent de 7,6 utilise à 12,2 m (25 à 40 [ft]) le Tas Analyzer Impérieux (PDA). PDA-predicted capacité du tas ultime a aligné de 736 à 2.186 [kN] (81 à 240 tonnes) à EOID et de 814 à 2.596 [kN] (90 à 286 tonnes) à BOR. Time s'est écoulé entre EOID et BOR a aligné de 24 à 120 heures. Tas à cet emplacement ont exposé ensemble-en haut aligne d'aucun à 36 pour cent. Cette information a été utilisée efficacement comme partie de la qualité totale commande le programme installer un total entasse de 250 PPC limite dans la fondation de la presse aligne à profondeurs encadrées from13 à 20 m (42 à 68 [ft]). L'a prédit des capacités du tas a comparé très bien avec les capacités du CAPWAP analyse pour tas de l'enquête. Une année après la presse est allée dans production dans 1997, le zéro mouvement a été confirmé.

1 INTRODUCTION

The project is located in downtown Lakeland, Polk County, in west central Florida, USA. It consists of a 9,300 m^2 (100,000 ft^2) production building with 2 new high-speed printing presses and a 4,650 m^2 (50,000 ft^2) administrative building. In August 1995 ASC geosciences, inc. was retained to provide complete geotechnical exploration and engineering evaluation as well as proper selection of an economical, effective, and satisfactory foundation system. A project and building layout, as well as test boring location plan, are illustrated in Figure 1.

This paper presents a case history of design and effective utilization of pile foundation for a 10,000 kN (1,100 tons), 5-story high printing press for this newspaper publishing facility. The printing press foundation had a very stringent settlement criterion of zero movement coupled with dynamic loading conditions.

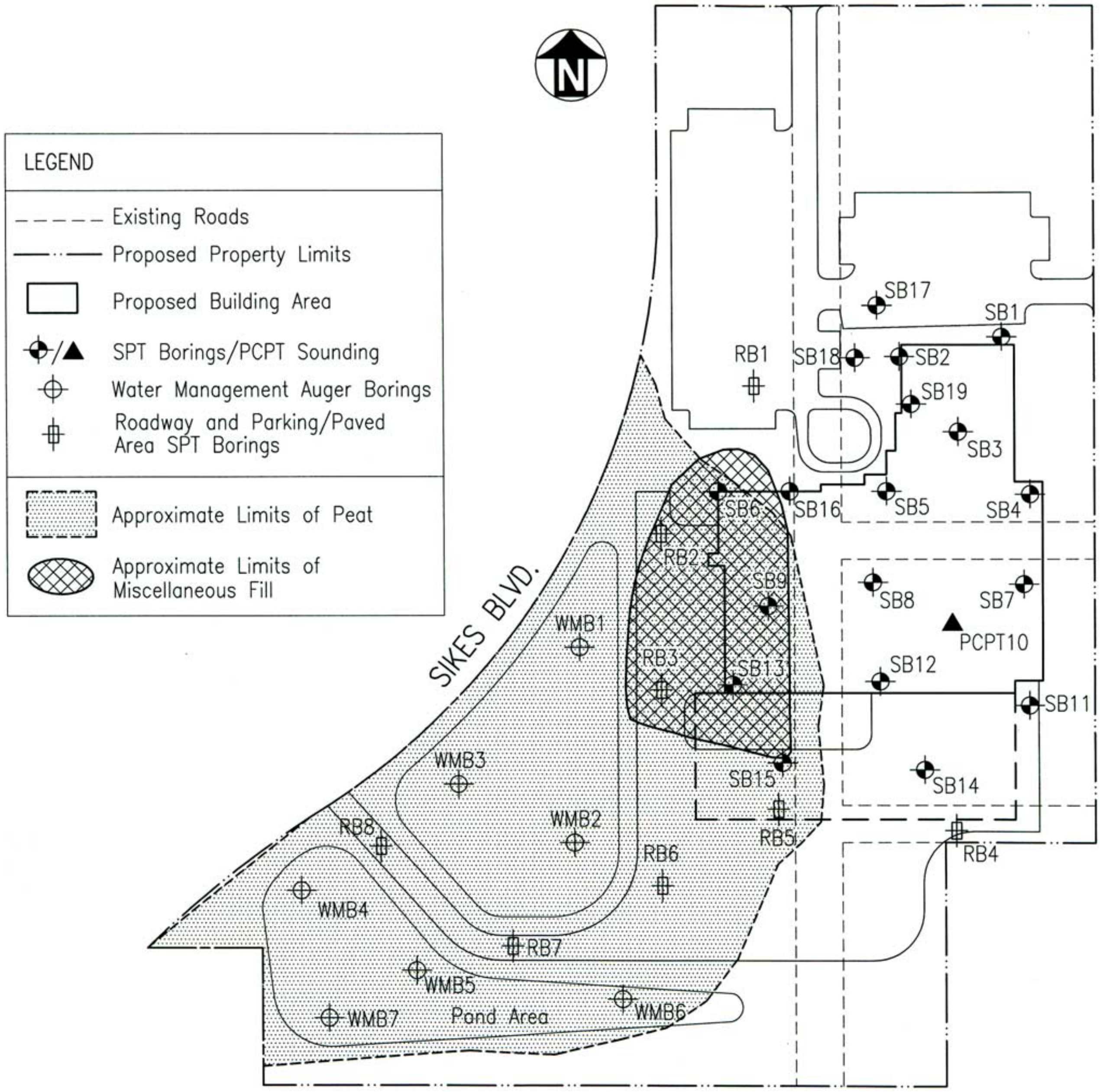

Figure 1: Project, Building Layout, and Test Boring Location Plan

2 SUBSURFACE CONDITIONS AND PROJECT DATA

Pre-construction site features included a sloping topography and presence of an existing 7,250 m^2 (78,000 ft^2) building complex on a 2.7 hec (6.7 ac) property. A portion of this existing structure was demolished and debris was removed from the site prior to commencement of construction for the administration building. A detailed geotechnical exploration program was undertaken for the entire project. However, for the high speed printing presses, four (4) Standard Penetration Test (SPT) Borings and a Piezocone Penetration Test Sounding (PCPT) were performed. A thick layer of miscellaneous fill was encountered primarily in structural borings located in the western portion of the Production Building area and in roadway borings in the loading/unloading area west of the Production Building area. In areas, a layer of relatively clean sand overlies the miscellaneous fill. The miscellaneous fill is generally underlain by a peat layer, which is believed to be a remnant of the old lake bottom or shoreline of nearby Lake Hunter, which once extended to some southwest portions of this project site.

In general, the project specific site stratigraphy consists of loose poorly graded sands to 1.0 m (3.0 ft) depth. These sands are underlain by local hardpan consisting of "N" Values ranging from 10 to 25 in the upper 4.5 m (15 ft) and between 16 to 25 from 4.5 to 12 m (15 to 40 ft) depth below ground surface. Firm to hard sandy elastic silts exist to the termination depth of 21.3 m (70 ft) over a major portion of the site. A detailed subsoil profile completed from 4 SPT borings and 1 PCPT sounding to depths ranging from 12 to 23 m (40 to 75 ft) was used and is illustrated in Figures 2 and 3.

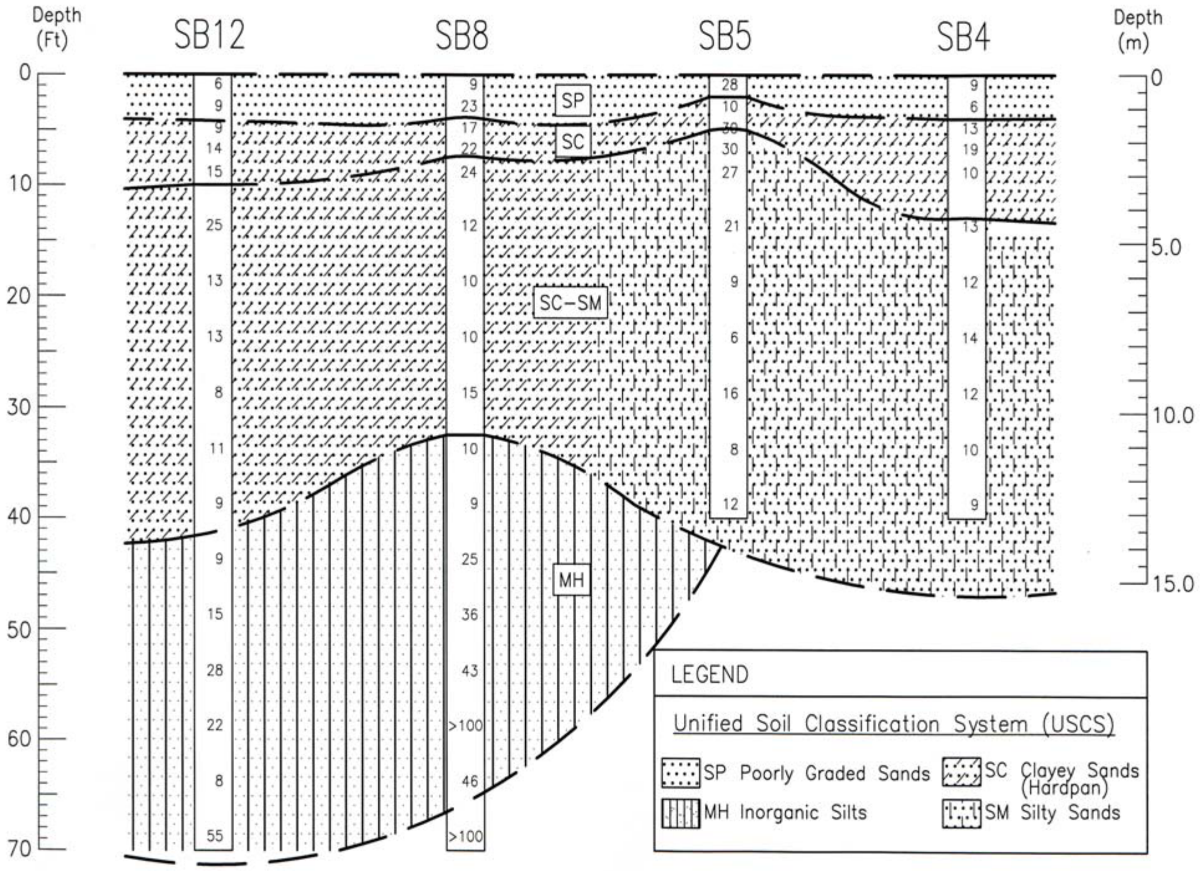

Figure 2: Press Site Subsurface Conditions Summary

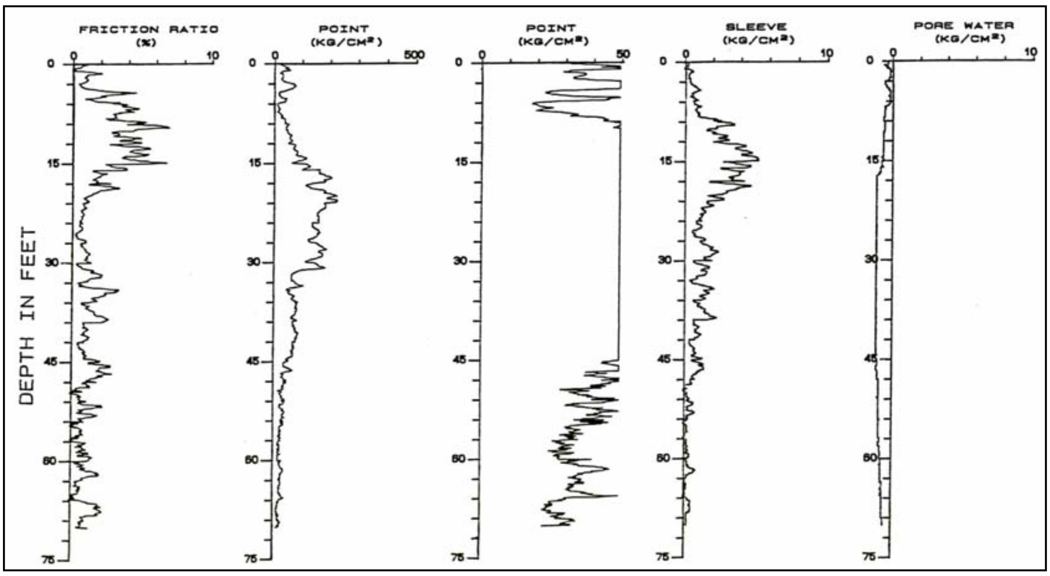

Figure 3: Piezocone Penetration Test Sounding (PCPT) Profile

3 FOUNDATION DESIGN AND ALTERNATES

The first step of the design process was to evaluate various foundation systems. Several foundation alternatives were considered for the proposed press structure including: (i) driven precast prestressed concrete (PPC) displacement piling; (ii) cast-in-place auger (ACIP) piles; and (iii) ground modification using vibro-replacement. In view of the owner's accelerated construction schedule, cost, and availability, a driven prestressed concrete piling system was finally selected for support of the vibratory press with the 5 story high mechanical equipment.

The allowable static capacities of piles were estimated using SPT94 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 and soil type. The design method used in SPT94 has been found to be reasonable for driven piles in cohesionless soils (McVay et al., 1989). Results indicated that prestressed concrete piles driven into silty to clayey sands and elastic silts to depths ranging from 9 to 12 m (30 to 40 ft), below the original ground surface, should provide a satisfactory and economical foundation alternative. The press foundation was designed for a pile capacity of 363 kN (40 tons).

Table 1: Summary of Pile Set-up

Probe Pile No.	PDA Capacity at EOID "a" $^{(1)(3)}$ (kN)	PDA Capacity at BOR "b" $^{(2)(3)}$ (kN)	Time Elapsed Between EOID and BOR (hrs)	Increase [(b-a)/a] x 100 (%)
PP1	922.7	959.1	48	4
PP2	972.7	909.1	48	-7
PP3	822.7	900.0	48	9
PP4	736.4	1,004.5	24	36
PP5	909.1	918.2	24	1
PP6	790.9	877.3	48	11
PP7	2,186.4	2,595.5	48	19
PP8	909.1	959.1	24	6
PP9	763.6	813.6	48	7
PP10	945.5	1,481.8	24	57
PP11	950.0	922.7	24	-3
PP12	854.5	1,031.8	48	21
PP13	995.5	1,231.8	24	24
PP14	909.1	854.5	24	-6
PP15	854.5	995.5	48	16
PP16	764.0	777.0	48	2
PP17	409.0	514.0	120	25
PP18	1,014.0	1,040.0	120	3
PP19	936.0	1,059.0	120	13

Notes: (1) EOID = end of initial driving
(2) BOR = beginning of restrike
(3) 1 kN = 0.11 tons

4 PROBE PILE AND DYNAMIC LOAD TESTING (DLT)

In an effort to optimize penetration and capacity requirements for piles, a DLT program utilizing PDA instrumentation was recommended and performed.

4.1 Dynamic Load Testing

Nineteen 13.8 m (45 ft) long and 356 mm (14 in) square PPC probe piles were dynamically load tested during the probe pile driving and testing program within the printing press, as illustrated in Figure 5. Probe and production

piles were installed by a VULCAN 08 air steam hammer. This hammer was rated with maximum energy of 3,640 m-kg (26,500 ft-lb) and a ram weight of 36 kN (8,000 lbs). The purpose of the probe pile program was to evaluate the suitability of the contractor's pile driving equipment, determine and verify pile capacities, provide production pile lengths, and establish driving criteria for use during the production pile driving phase of the project. Plywood cusion 15 cm (6-inch) was used.

The PDA was utilized for this site to better evaluate and predict the increase in pile resistance with time (i.e., setup or freeze). This benefit was incorporated in the determination of production pile lengths.

All probe piles were instrumented over major portion of their lengths with the instrumentation at the top of the pile while all were instrumented during restrikes. A total of 19 piles were installed and tested. Restrike of all 19 probe piles was performed after 1 to 4 days. Probe piles were driven to depths ranging from 7.5 m (25 ft) to 12.2 m (40 ft). In view of the developer's desire to use these probe piles within the final structure, they were intentionally not driven to their entire length so as to leave adequate allowance for cut-off and PDA gage installation.

Dynamic load tests on probe piles confirmed that the subsoil conditions at the project site were fairly uniform, thus justifying he initial contention that the site was ideally suited for dynamic load testing utilizing a PDA. Because being relatively inexpensive and quick, many tests were performed to provide an interpretation of a larger portion of the site.

PDA-predicted ultimate pile capacity ranged from 736 to 2,186 kN (81 to 240 tons) at EOID and from 777 to 2,596 kN (85 to 286 tons) at BOR. Time elapsed between EOID and BOR ranged from 24 to 120 hours. The majority of the piles at this site exhibited set-up. The pile set-up is expressed as a ratio of pile capacity increase over initial pile capacity in percent. A summary of PDA results is shown in Table 1 with a bar graph illustrated in Figure 4.

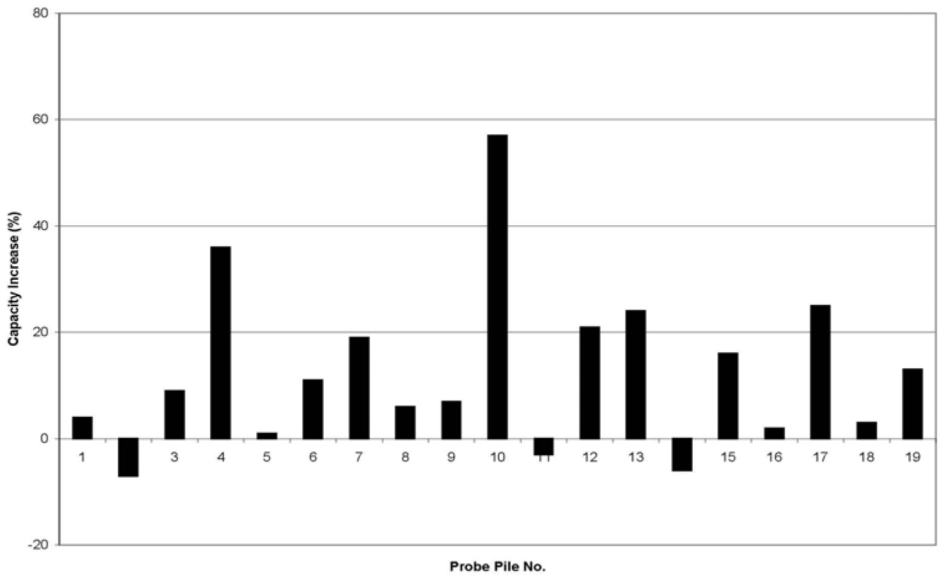

Figure 4: Bar Graph of Pile Capacity Increase

4.2 Results of CAPWAP Analyses

Dynamic data obtained in the field was further analyzed according to CAse Pile Wave Analysis Program (CAPWAP) for a more comprehensive understanding the soil and pile behavior during pile driving. CAPWAP analyses were performed on a total of 18 blows collected during initial and restrikes of probe piles. These analyses provided a better evaluation of total ultimate pile capacity. It is a signal-matching process where a measured signal is matched with a simulated signal. This step provides a refinement of the pile capacity estimated in the field during driving. Additionally, CAPWAP provided a distribution of soil resistance along the embedded piled depth. The distribution of resistance along the pile depth enabled an estimate of resistance at other depths above the pile tip. (This type of information is difficult to obtain using conventional static-load test unless expensive instrumentation such as telltales are installed in the test prior to driving.) Results from the CAPWAP analyses including static pile capacity, soil resistance distribution along pile shaft and under toe, soil damping and quake (maximum elastic deformation) values, and forces along pile length at ultimate resistance are presented in Table 2. Energy transfer ratio for the probe piles and the hammer ranged from 50 to 80 percent.

Table 2: Summary of CAPWAP Results

Probe Pile No.	Embedment Depth (ft)	Blow Count (bpf)	PDA Capacity (tons)	CAPWAP CAPACITY (tons)			Quake (Q) and Damping (J)			
				Side Friction	End Bearing	Total	Q_s	Q_t	J_s	J_t
PP1	26	24	105.5	36.2	71.0	107.2	.060	.610	.102	.078
PP2	27	20	100.0	48.0	61.1	93.1	.115	.230	.141	.094
PP4	35	24	110.5	62.6	57.9	120.5	.085	.520	.289	.033
PP5	27	24	101.0	39.0	55.2	94.2	.040	.775	.130	.045
PP6	33	17	96.5	56.7	38.3	95.0	.040	.730	.239	.028
PP8	25	26	105.5	42.6	39.5	82.1	.075	.320	.094	.274
PP9	25	15	89.5	30.7	49.1	75.8	.050	.910	.165	.104
PP10	32	24	163.0	55.4	63.9	119.3	.042	.281	.297	.284
PP11	31	24	101.5	46.5	47.7	94.2	.055	.556	.272	.080
PP12	32	24	113.5	53.4	36.9	90.3	.090	.460	.241	.324
PP13	30	24	135.5	43.6	52.5	96.1	.060	.525	.317	.422
PP14	35	17	94.0	59.4	33.3	92.8	.055	.772	.127	.040
PP15	29	26	109.5	47.1	57.1	104.2	.130	.410	.254	.066
PP16	31	13	85.5	35.5	41.3	76.8	.040	.700	.111	.034
PP17	37	15	57.0	46.8	18.0	64.8	.080	.235	.112	.052
PP18	39	36	114.5	66.5	46.0	112.5	.045	.380	.293	.114
PP19	38	25	116.5	56.2	48.6	104.8	.040	.445	.437	.030

4.3 Production Pile Lengths

Following completion of the probe pile and DLT program specific pile lengths and capacity were finalized after taking into consideration the excavated and prepared surface elevations of carious areas within the press limits. PDA assisted DLT program resulted in a fully optimized pile layout plan utilizing 2 different pile lengths to achieve allowable capacities of 363 kN (40 tons).

5 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. These recommendations included:

- a minimum initial driving or restrike criteria of 25 blows per foot for the 363 kN (40 tons) allowable compression capacity. This was revised to 16 bpf for production piles along column line 7 based upon supplemental dynamic load tests performed on 4 production piles;

- retapping of a randomly selected pile (1 in 10) to verify pile capacity after freeze for the piles which met the previously established criteria;

- retapping of all the piles which did not meet the initial criteria; and,

- a minimum embedment depth of 7.6 m (25 ft).

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 pf pile driving records by an engineering representative of the geotechnical consultant.

A total of 306 PPC piles were installed during the probe and production pile installation phase. For the press area, 356 mm (14-in) square piles were delivered to the site in the lengths of 9.1 to 10 m (30 to 35 ft) and were driven to depths ranging from 7.0 to 9.5 m (25 to 32 ft). As many as 35 percent of the piles were retapped since they did not meet the EOID criteria. All of the retapped piles met the blow count criteria. A foundation layout and pile delineation plan is illustrated in Figure 5.

The project specification mandated the pile heave control and monitoring. Piles which heaved more than 6.35 mm

(0.25 in.) were considered for further evaluation. Although most of the piles on this project heaved, evaluation performed on few selected and representative piles, indicated that heave was not detrimental to the pile capacity.

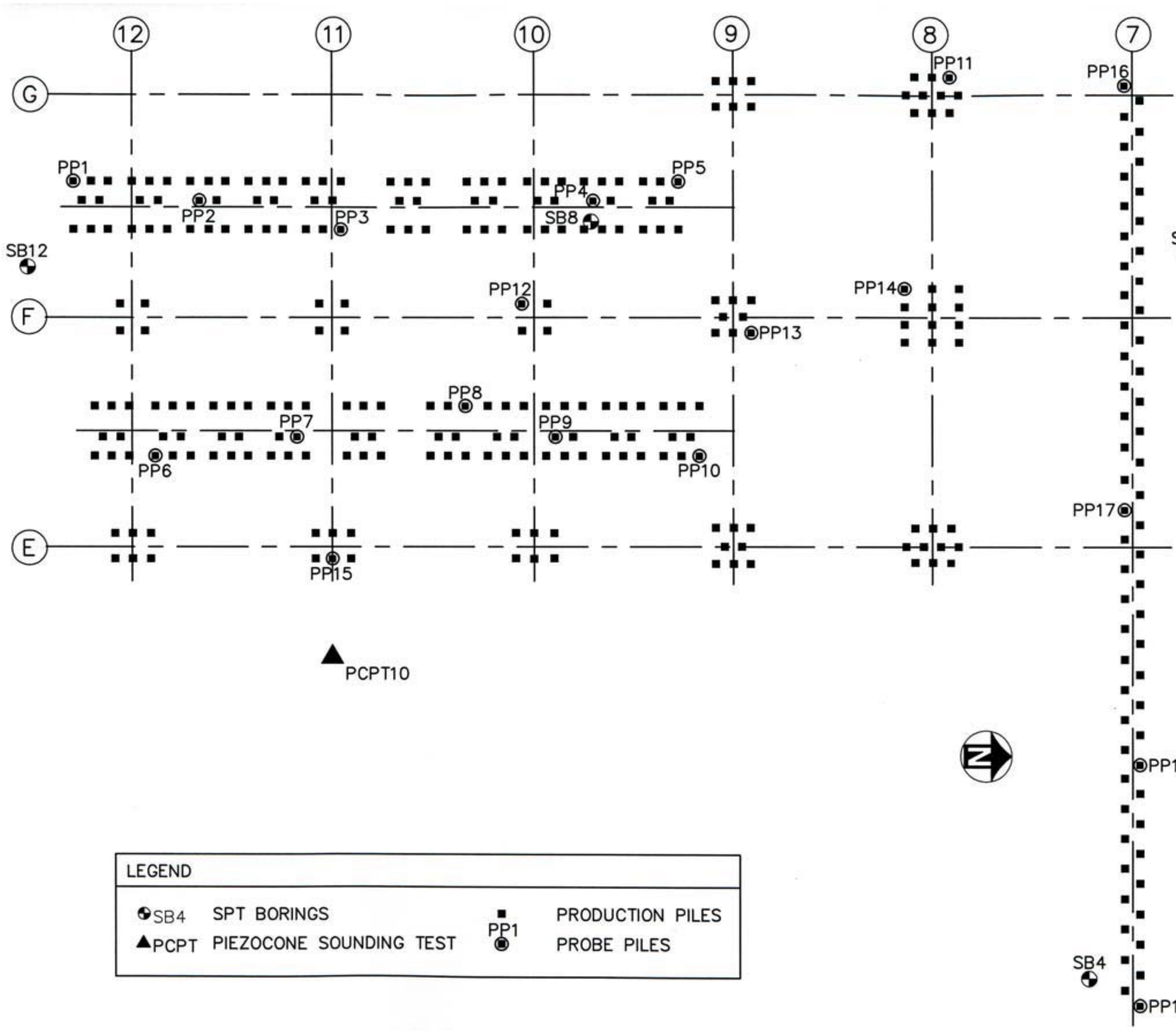

Figure 5: Foundation Layout and Pile Delineation Plan

During the pile installation phase, continuous vibration monitoring operations were also performed by utilizing Safeguard Seismic Unit 1000D. This was done to measure the vibrations resulting from the production pile driving operations on the project site and to evaluate the possible effects of vibrations on the structures within 30m (100 ft) of the construction. Continuous recording of the peak particle velocity (PPV) was recorded on a paper tape in units of inches per seconds (ips). Most of the readings recorded at the instrument station were well below the threshold value of 5.0 cmps (2.0 ips), where minor perceptible damage to building structures could occur. This was a part of the overall quality control program.

6 CONCLUSIONS

Following completion of all the services and close coordination between various project team members it was determined that:

- optimization of the pile penetration depths and capacities was based on PDA assisted pile driving program. It was achieved by effectively utilizing PDA during the probe pile driving and restriking phase;
- phenomenon of pile capacity increase with time (set-up or freeze increase) can be effective in establishing pile length and driving criteria;

- acceptance of the pile foundation system; and,

- longer piles generally exhibit higher set-up than shorter length piles with threshold embedment depth 9.0 m (25 ft) or greater. This trend can be attributed to the fact that pile set-up is predominantly derived from skin friction rather than end-bearing and longer piles have greater surface area than shorter piles of the same diameter (Saxena, et al., 1998).

Upon satisfactory monitoring of the pile installation program (e.g., logging the blowcount, periodic checking of hammer energy, and keeping track of pile embedment) the PPC pile foundation system, as installed, was approved and accepted for the press foundation. The project was completed in mid 1997. One year after the 5-story Goss Colorliner presses went into production, zero movement was confirmed from survey data.

7 ACKNOWLEGEMENT

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