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Author: D.S. "Sax" Saxena, P.E.
ASC geosciences, inc., Lakeland, Florida, USA

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TEAM APPROACH AND EFFECTIVELY PLANNED GROUND IMPROVEMENT METHOD PROVIDES AN ECONOMICAL SOLUTION - A CASE HISTORY

D.S. "Sax" Saxena, P.E., F. ASCE
Alamo/Saxena Consultants, Inc. (ASC)
5675 New Tampa Highway, Suites 1-3, Lakeland, Florida, USA

ABSTRACT

Construction of a 4-story reinforced concrete medical office building was planned in southeast Fort Myers, Florida, USA. An earlier geotechnical exploration performed by others recommended the use of stone column vibroreplacement ground improvement method under load bearing elements for an allowable bearing pressure of 240 kPa. A costly estimate for the ground improvement method led to other foundation alternatives. ASC was commissioned to provide value engineering services in the proper selection of an economical and satisfactory foundation system.

A geotechnical exploration program consisting of test borings and piezocone penetration tests (PCPT) revealed that almost two-thirds of the building area was underlain by a non-uniform layer of caprock between 2.1 to 3.4 m deep and that for the originally indicated column loads of 2,000 to 3,300 kN a positive foundation support consisting of piles (short or long) would be most economical.

Structural revisions were made thereby reducing the column loads to the range of 900 to 1,500 kN. This effort assured that a stone column vibroreplacement procedure would provide the most economical and satisfactory foundation alternate. The vibroreplacement method was used, and a total of 160 stone column points were installed for a total length of 730 m. Depth of installation ranged from 4.6 to 7.6 m below the ground surface. A total of 13 post-improvement PCPT probes indicated compliance with the relative density criterion of 70 percent which correlated to a design bearing pressure of 240 kPa. The project was completed in October 1991 and has since been occupied. This value engineered foundation solution resulted in substantial savings for the owner and provided an effective method for the development of this office building.

RÉSUMÉ

La construction d'une édifice de 4 étages de béton armé pour un bureau médical a été planifiée à Fort Myers sud-est en Floride dans les États-Unis. Une étude géotechnique antérieurement faite par d'autres a recommandé l'utilisation de méthode de vibroremplacement à colonnes de pierres pour fins d'amélioration du terrain sous des éléments de soutien pour une capacité portante admissible de 240 kPa. Un estimé coûteux pour la méthode d'amélioration du terrain a mené à d'autres alternatives de fondation. ASC était délégué pour fournier des services de valeur de génie pour la sélection convenable d'un système de fondation satisfaisant.

Un programme d'exploration géotechnique composé de forages et d'essais de pénétration au piézocône (PCPT) a démontré que presque deux tiers de l'aire de l'édifice était à la base de pierre de faîte sous-jacente d'une profondeur entre 2,1 m et 3,4 m et que, pour les charges de colonnes indiquées originales de 2 000 à 3 300 kN, un support de fondation positif composé de pieux (courts et longs) serait le plus économique.

Des révisions structurales on été faites de façon à ce que les charges des colonnes soient réduites à un ordre de 900 à 1 500 kN. Cet effort a assuré que la procédure de vibroremplacement à colonnes de pierres fournirait l'alternative fondation la plus économique et la plus satisfaisante. La méthode de vibroremplacement a été utilisée et 160 points de colonnes de pierres au total ont été installés sur une longueur totale de 730 m. La profondeur de l'installation variait de 4,6 m à 7,6 m sous la surface du sol. Au total, après l'amélioration, 13 sondes (PCPT) ont servi comme indicatif de conformité avec le critère de densité relative de 70 pour cent ce qui mettait en corrélation la capacité portante calculé de 240 kPa. Le projet a été complété en octobre, 1991 et a été occupé depuis cette date. Cette solution géniale de fondation a résulté en une épargne considérable pour le propriétaire et a aussi fourni une méthode de développement efficace pour cette édifice à bureaux.

(traduit par Jean L. Lemire pour le comité d'organisation)

INTRODUCTION

Metro Medical Plaza is a 4-story medical office building located in Fort Myers, southwest Florida, as illustrated in Figure 1. The office building is located directly across from the existing Gulf Coast Hospital. The full complex, as completed, included a reinforced concrete structure with a building footprint of approximately 41 by 23 m. Construction commenced in January 1991 and the building was released for occupancy in October 1991.

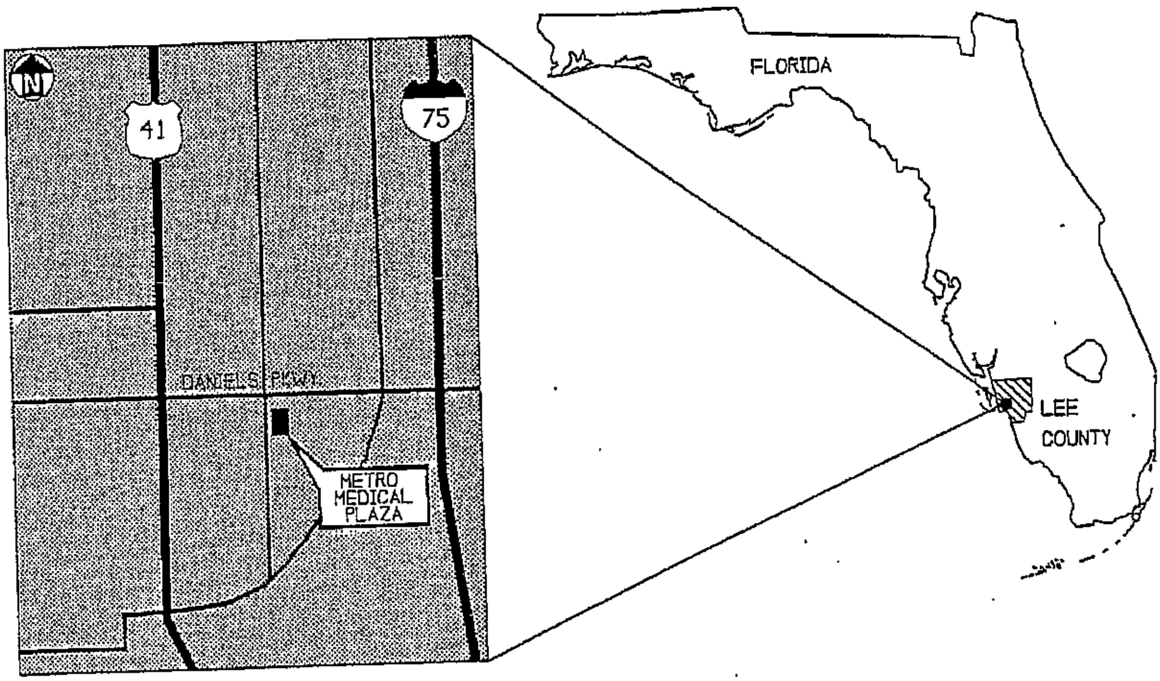

FIGURE 1. Project location map.

The purpose of the engineering services provided by my firm for the project included the following:

a. review the unanticipated escalation in the proposed foundation cost estimate;
b. utilize available subsurface soil and ground-water information from a geotechnical exploration performed by others;
c. perform a supplemental geotechnical exploration program; and,
d. assist the owner in the proper selection of an economical, effective, and satisfactory foundation system.

GEOTECHNICAL EXPLORATION PROGRAM

While existing geotechnical information was available and reviewed, a supplemental site investigation consisting of Standard Penetration Test (SPT) borings and piezocone penetration test (PCPT) soundings was undertaken as part of the overall value engineering services. A field exploration program plan indicating test locations is illustrated in Figure 2.

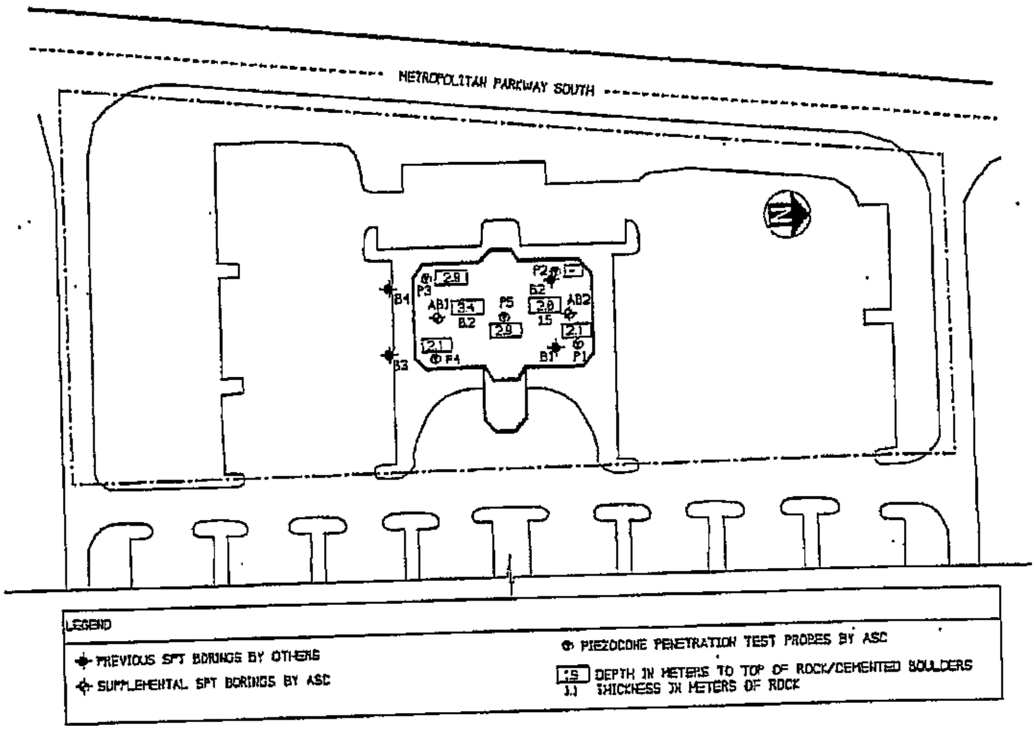

FIGURE 2. Field exploration program plan.

The supplemental site investigation provided information about the following site and foundation aspects:

a. confirmed the presence of a shallow caprock layer approximately 4.6 m below the existing ground surface;
b. allowed for an evaluation of the effect of the shallow caprock layer on the satisfactory installation and performance of a vibroreplacement site improvement technique; and,
c. clearly delineated the in-situ strength properties of materials underlying the shallow caprock layer in the 9.2 to 12.2 m zone in which medium-length piles could be effectively driven.

A general summary of data from the supplemental site investigation of SPT borings and PCPT soundings is illustrated in Figure 3. This investigation revealed that almost two-thirds of the building area was underlain by a non-uniform layer of caprock between 2.1 to 3.4 m deep and 0.2 to 1.5 m thick.

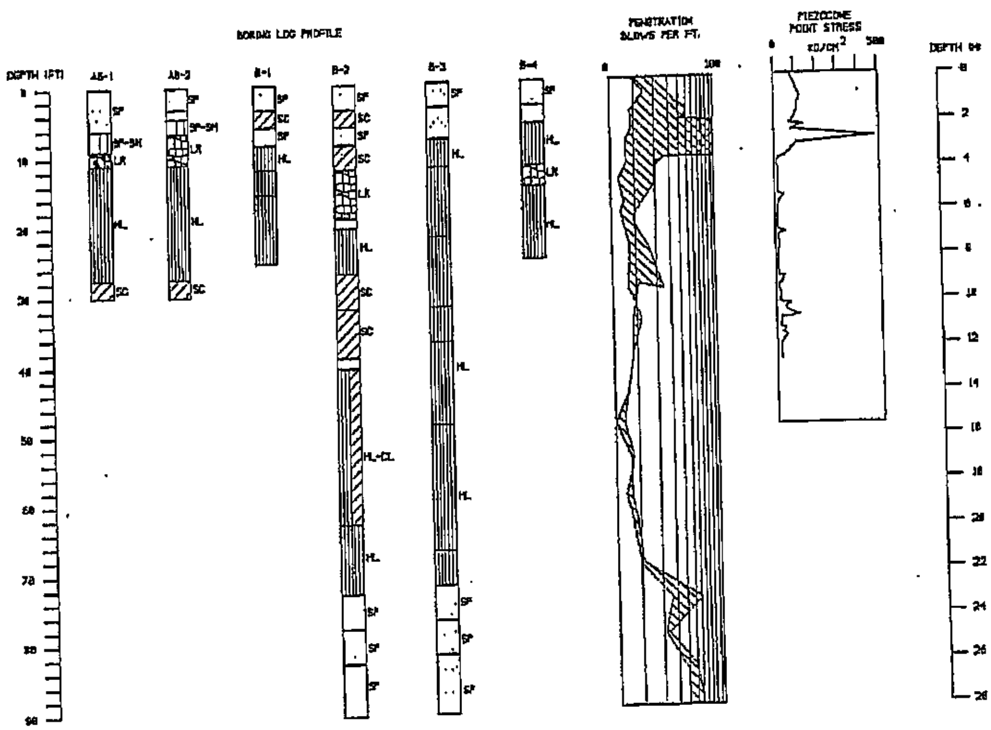

FIGURE 3. Summary profile of SPT boring and PCPT probe data.

DESIGN DETAILS

The design review process for this project consisted of an evaluation of generalized subsurface soil and ground-water conditions. It was concluded by other consultants that for the indicated column loads of 2,000 to 3,100 kN, driven piles (short or long) would provide an economical foundation approach even after allowing for predrilling in the upper 3 m. As a result of the evaluation by others, short and long piles driven to depths ranging from 10.7 to 24.5 m, respectively, were recommended. The structural arrangement with the original column loads and footing layout plan is illustrated in Figure 4.

The project developer requested a meeting with all project team members for a completed re-evaluation of the structural arrangement and resulting loadings schemes. Following a closely-coordinated team effort, structural alterations were proposed and accepted which, in turn, resulted in revised column loads in the range of 1,100 to 1,500 kN. The revised structural arrangement including the reduced loading scheme is illustrated in Figure 5. The revised footing sizes were substantially reduced from the original sizes and properly proportioned to provide effective soil-structure interaction. Additional optimization was achieved by incorporating the other consultant's recommended alternate of providing a continuous strip foundation layout rather than individual spread footings along the building perimeter.

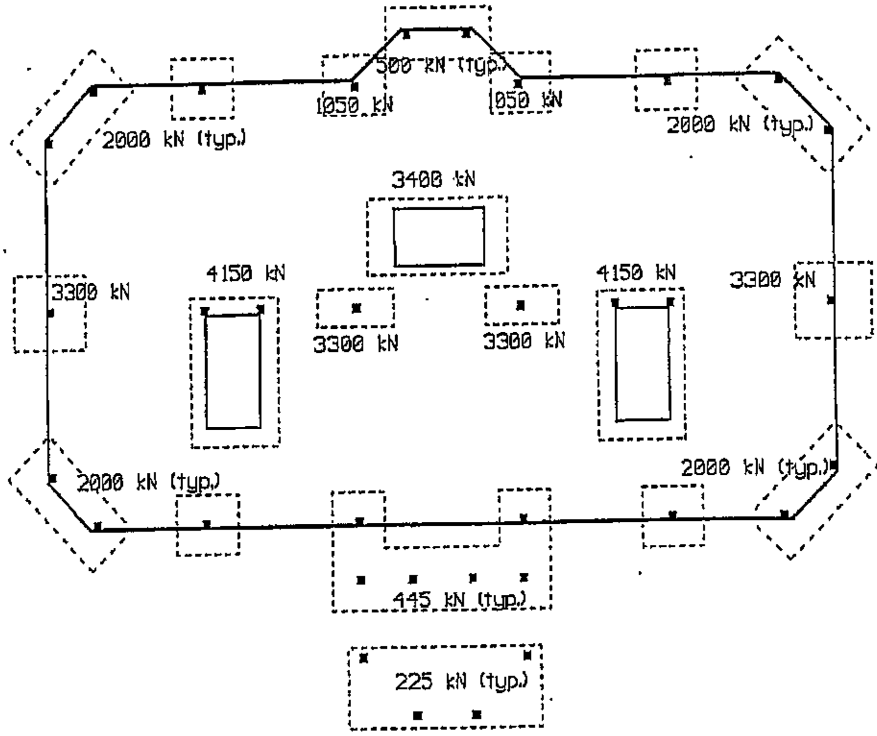

FIGURE 4. Structural and footing layout with original loads.

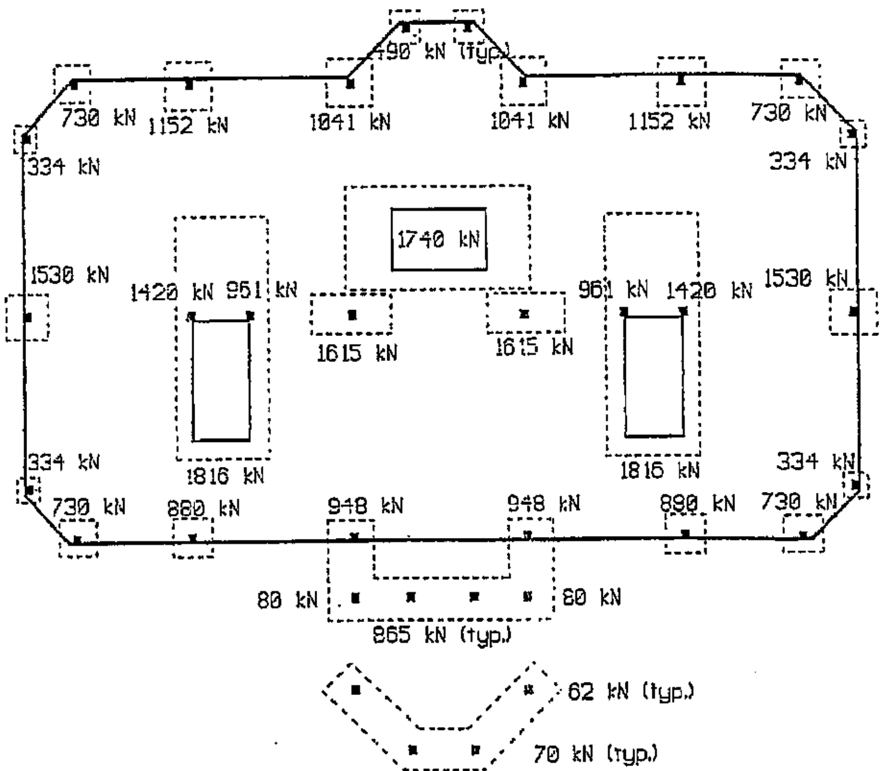

FIGURE 5. Structural and footing layout with final, revised loads.

GROUND IMPROVEMENT

Upon completion of my firm's review of the ground improvement layout plan, densification within the building footprint was achieved by the vibroreplacement method which was performed by GKN Hayward Baker, a specialty contractor from nearby Tampa, Florida. A total of 160 stone column points were installed for a total length of 730 m, with the depth of installation ranging from 4.6 to 7.6 m below the prepared and graded surface. Following completion of stone column installation, and a pore pressure dissipation period of 72 hours, the improved area was evaluated by post-improvement PCPT soundings. Data from these soundings were evaluated to check for compliance with the relative density criterion of 70 percent (Saxena 1987a, 1987b) which correlated to a design bearing pressure of 240 kPa. Some of the typical post-improvement PCPT profiles incorporating the 70 percent relative density criterion are illustrated in Figure 6.

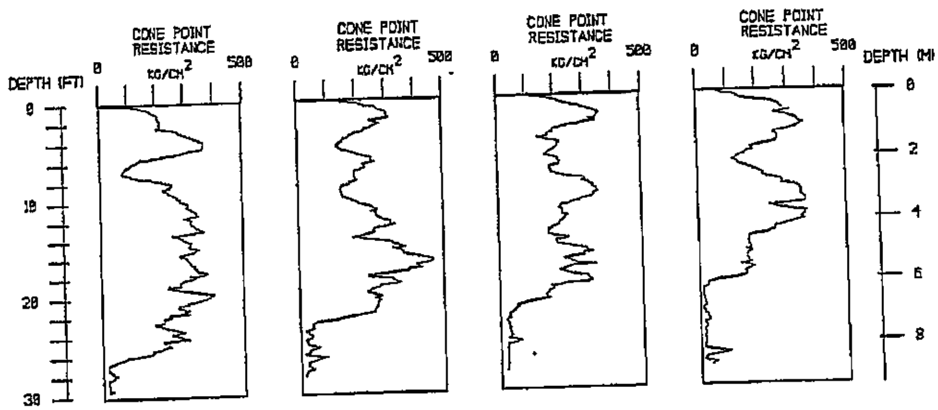

FIGURE 6. Typical post-vibroreplacement piezocone penetration test profiles.

VIBRATION MONITORING

Additional services provided for the project included a vibration monitoring program to monitor any effects from the vibroreplacement method on highly sensitive microscopic equipment at the nearby Gulf Coast Hospital. A seismograph equipped with an airborne sonic device was stationed at the nearby hospital to monitor peak particle velocity. Monitoring ensured that all vibroreplacement operations were performed well below the established threshold criterion of 5 cm/sec.

CONCLUSIONS

This value engineered foundation solution resulted in substantial savings for the owner and provided an effective method for the development of this office building. A comparison of the various foundation alternatives together with associated costs are summarized in Table 1.

TABLE 1. Foundation alternatives and cost comparison summary.

ITEM	TOTAL NO. OF STONE COLUMNS OR PILES	BREAKDOWN BY DEPTH/LENGTH	TOTAL FOOTAGE & UNIT COST $	STONE COLUMN OR PILE COST $	MOB/DEMOB ESTIMATED $	TOTAL COST $
VIBROREPLACEMENT (STONE COLUMN)						
PLAN (as originally proposed)	134	59 @ 7.7 m 70 @ 6.0 m 5 @ 4.5 m	899 m @ $39.40	35,340.00	2,500.00	37,840.00
PLAN (as revised)	132	51 @ 7.7 m 66 @ 6.0 m 15 @ 4.5 m	857 m @ $39.40	33,765.00	2,500.00	36,265.00
CONTINUOUS FOOTING (alternate)	123	51 @ 7.7 m 72 @ 4.5 m	717 m @ $39.40	28,250.00	2,500.00	30,750.00
PILE FOUNDATION ALTERNATE (SHORT PILES)						
PLAN (originally proposed)	190	10.7 m	2,023 m @ $39.40	80,100.00	2,500.00	82,600.00
CONTINUOUS FOOTING (alternate)	150	10.7 m	1,605 m @ $39.40	63,230.00	2,500.00	65,730.00
PILE FOUNDATION ALTERNATE (LONG PILES)						
PLAN (originally proposed)	70	22.8 m	1,603 m @ $42.60	68,280.00	2,500.00	70,780.00
CONTINUOUS FOOTING (alternate)	55	22.8 m	1,260 m @ $42.60	53,675.00	2,500.00	56,175.00

NOTES:

1. Continuous footing alternative includes support of all columns along a continuous strip footing (perimeter and interior) designed as a beam (with top and bottom reinforcement) on elastic foundation.
2. For short piles consider concrete taper or steel monotube piles (fluted section) - 10.7 m long rated for 178 kN.
3. For long piles consider concrete taper piles - 35 cm square and 22.8 m long rated for 534 kN.
4. All numbers are estimated.

ACKNOWLEDGEMENTS

The opportunity to perform the services discussed in this paper provided an interesting exercise in the planning and execution of this type of project. The information herein is from a project which the author and his firm, Alamo/Saxena Consultants, Inc. (ASC), were involved as the geotechnical engineering consultant. ASC expresses it appreciation to the other project team members: Medical Facilities Development, Inc., the developer; C.A. Oakes Construction Company, the contractor; Stephen Whitehouse Engineers, Inc., the structural engineer; and, GKN Hayward Baker, the specialty subcontractor, all from Tampa, Florida. The data assimilation and technical assistance of Anu Saxena, Jeanne Berg, and Swamy Kumar are also acknowledged.

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