PILING IN ROCK – CONSTRUCTION ASPECTS

J.M. AMIR; President, Amir Geotechnical Engineering Ltd., Tel-Aviv, Israel

ABSTRACT

The paper describes piling in rock as developed in Israel in recent years. Drilling is done by a pneumatic percussion rig, with typical diameters of 300 to 600 mm and typical lengths of 2 to 20 m. The method is applicable to all kinds of rock, above and below ground water. It is shown that this piling method is superior to conventional spread footings with respect to construction time, manpower, concrete, steel and energy input. Sample specifications are provided for the benefit of practicing engineers.

INTRODUCTION

During the last decade, since suitable equipment appeared in Israel, it has become evident that piling in rock has the following advantages:

a. It is applicable to all kinds of soils and rocks, including weathered, jointed and Karstic rock.

b. It combines a high load-carrying capacity with relatively small settlements.

c. Construction time is extremely short, with daily outputs of 50 piles per rig quite common.

In view of the above considerations, piling is now the preferred foundation method in rocky terrain, even in sites with bedrock on the surface or at a shallow depth.

This paper describes the equipment used and the construction methods employed. A comparison is then made with conventional footings and suggested specifications presented.

EQUIPMENT

In early piling projects, use was made of conventional rotary rigs and coring buckets. Such equipment is still used in relatively soft rocks, like chalk or sandstone, or where only a thin layer of harder rock has to be overcome. The rotary equipment is relatively inexpensive, but its very low productivity makes it uneconomical in hard formations, where percussion equipment is much more efficient (Hartman, 1968).

The system now employed in Israel consists of the following elements:

a. A tractor-mounted drilling rig, sometimes retaining the dozer blade.

b. A suitable down-the-hole hammer.

c. A "button" - type drilling bit.

d. A compressor supplying energy to the hammer, with a typical output of 34 to 57 cu.m/min (1200 to 2000 cfm) at 700 to 1055 kPa (100 to 150 psi). The compressor is either mounted on the rig (Fig 1) or separate (Fig. 2). In the second case the two units are connected by an air hose which may be easily damaged, but the rig itself is compact and easy to maneuver in tight places.

CONSTRUCTION

Drilling

After the rig is positioned with respect to centricity and verticality, drilling is begun as a combination of percussion and rotation. No crowd is applied, as the heavy drill rod provides sufficient down pressure. From time to time, the drilling is stopped, and the heavy cuttings flushed out under air pressure. Soft layers, such as clay, may be penetrated by an auxiliary helical auger. Generally, up to 2 drill rod extensions may be added, giving a total depth of about 20 meters. Drilling is normally vertical, with rake angles of up to 1:3 possible.

Concreting

Upon completion of the hole, its upper part is protected by a steel collar about 500 mm long. The reinforcement cage is then inserted into the hole, and the concrete poured through the collar. The concrete, of 30 MPa minimum strength and a 100 mm slump, is compacted by a needle vibrator in order to eliminate voids and ensure good contact between the concrete and the surroounding rock.

Construction Under Water

The use of large quantities of air leaves the hole virtually dry when drilling is completed. Low rates of seepage are therefore of no concern if the pile is concreted immediately, as the water collected at the bottom can only effect end-bearing (Thorburn and Thorburn, 1977), which is anyhow not taken into account.

When larger quantities of water collect in the hole, the pile should be cast with a concrete pump, the hose being lowered to the bottom of the hole. The concrete displaces the water which floats on its surface and is duly disposed of together with any affected concrete.

If a water-bearing sandy layer is present above the rock, an initial preparatory stage is necessary. This consists of augering an oversized hole down to bedrock using bentonite slurry, and lowering a casing into the hole. Alternatively, the hole may be filled with lean concrete, which is later penetrated by the percussion rig.

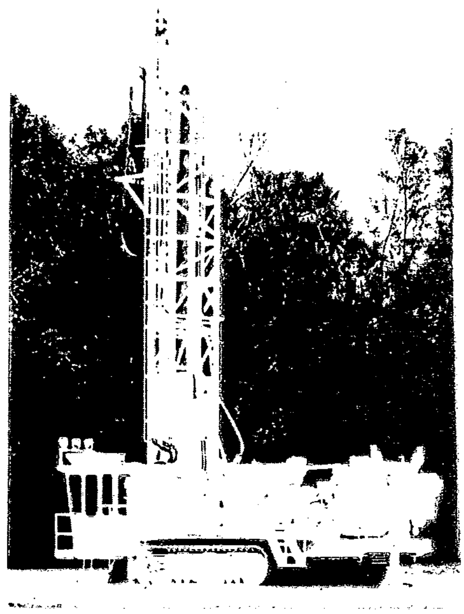

Fig. 1: Drilling Rig with Integrated Compressor

Corrosion Protection

If a corrosive soil layer (e.g. one containing excessive sulphates) is present above the rock, the pile is cast inside a polyethilene sleeve, 300 microns thick, which extends down to bedrock. Low water/cement ratios are recommended, and in extreme cases the use of sulphate-resistant cements may be justified.

Quality Assurance

The main methods for testing the integrity of piles are the sonic method, the gamma-ray scatter method and coring (Weltman, 1977). Apparently, none of the above is suitable for piles in rock which are generally short and of small diameter:

Numerous trials of the sonic method on piles in rock gave inconclusive results, because in short piles the initial wave is of such length that it masks any possible reflection. In longer piles, the wave energy is attenuated by the high sidewall friction, so that no reflected wave can be observed.

The gamma-ray scatter method necessitates the prior installation of 50 mm pipes inside the pile, but in a reinforced pile of 300 mm diameter this is almost an impossible porposition.

While coring such small diameter piles, there is a very substantial risk of the hole exiting the pile through the reinforcement cage, damaging the diamond bit in the process. In addition, coring can hardly be justified economically, as its cost may exceed that of the pile itself.

It may thus be concluded that, when piling in rock, effective supervision is indispensable.

COMPARISON WITH CONVENTIONAL FOUNDATIONS

The piling method was compared to conventional shallow footings with regard to construction time (which has a bearing on financing costs) and the outlay in labor, materials and energy. The comparison was made for a typical four-storey house, with 50 columns, each carrying a typical load of 500 MN. For the shallow footings, a depth of 1 m and an allowable bearing capacity of 500 kPa were assumed. The piles, on the otherhand, were assumed to be 2 m long and 300 mm in diameter.

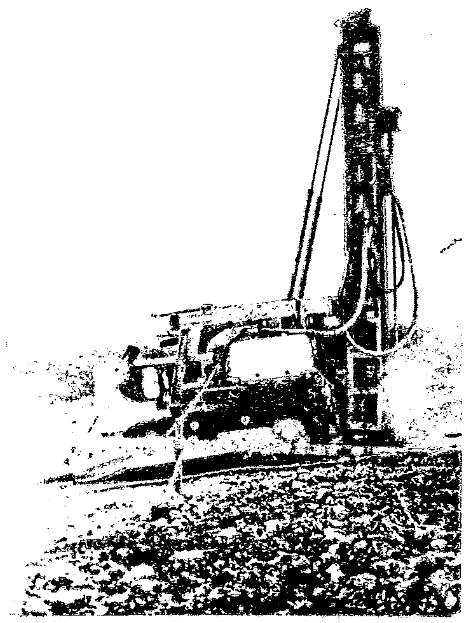

Fig. 2: Drilling Rig with Separate Compressor

The drilling rig considered is mounted on a D8 tractor, with air supplied by a 1200 cfm compressor. For the excavation of the shallow footings, two 150 cfm compressors with two breakers each were considered. The results of the comparison are presented in Fig. 3. The advantages of the piling solution, in all respects, are obvious.

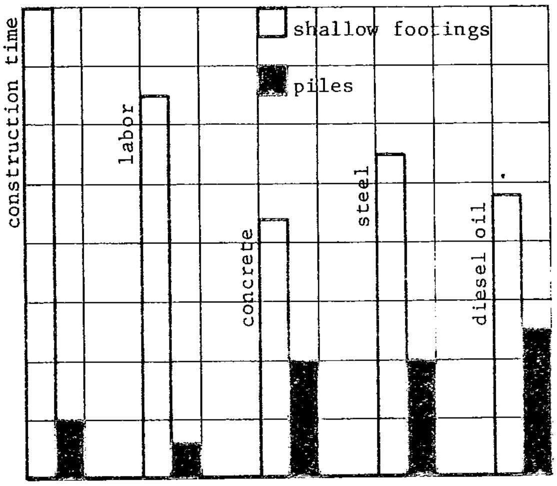

Fig. 3: Economical Comparison - Piles vs. Spread Footings

SAMPLE TECHNICAL SPECIFICATIONS

a. Tolerances: The deviation of any pile from the point indicated in the drawings shall not exceed 10% of the pile diameter in any direction. The maximum permitted deviation of the hole from the vertical will be 2%. The pile diameter shall not be less than the specified amount. Any hole not conforming to the above requirements shall be filled with concrete of the same quality used for the piles, and re-drilled at an age of not less than 7 days at the expense of The Contractor. A finished pile not conforming to the permissible tolerances shall be replaced by two piles and a pile cap, according to the requirement of the Engineer and at The Contractor's expense.

b. Casing: In unstable saturated layers The Contractor shall first drill with a rotary rig down to rock, using suitable bentonite slurry. The diameter of the hole shall exceed the pile diameter by at least 150 mm. After reaching rock, The Contractor shall introduce into the hole a temporary steel casing, with a diameter exceeding the pile diameter by at least 100 mm. The casing shall be of uniform cross-section, free from any visible distortion and clean from any internal projections or hardened concrete.

In piles where casing is unnecessary, The Contractor shall place an approved steel collar, not less than 500 mm long, to protect the hole until concreting is completed.

c. Drilling: The hole shall be formed by a pneumatic percussion drill, with a bit diameter not smaller than the required pile diameter. The hole shall penetrate into sound rock as shown in the drawings, with cavities, clay pockets and rock layers of less than 500 mm not taken into account.

d. Cleaning: Before lowering the reinforcement, The Contractor shall clean the hole for inspection using compressed air, submersible pumps and/or any other approved method.

e. Reinforcement: The reinforcement shall conform to the drawings and to the applicable Standards. The steel shall be clean and free from any loose rust at the time it is lowered into the hole. The helical reinforcement shall fit closely around the longitudinal bars, and be bound to them by approved wire, the ends of which shall be turned into the interior of the pile. The cover of all reinforcement shall be not less than 40 mm, and shall be ensured by the use of approved plastic spacers. The reinforcement cage shall be lowered into position with due care to avoid any distortion of the cage and scraping of the walls.

f. Concrete: The concrete shall conform to the requirements of the applicable Standard for a compressive strength of 30 MPa, with a slump of 100 mm, and shall contain not less than 350 Kgs of Portland cement per cu.m. The maximum aggregate size shall be 20 mm.

g. Concreting: The concrete shall be placed using an approved pump, with the discharge hose reaching the bottom of the pile. The concrete shall be pumped in one continuous operation, and the hose shall not be withdrawn until completion of concreting. As soon as the hole is filled with concrete, The Contractor shall compact the concrete using an approved internal vibrator. Each pile shall be cast as soon as possible after completion and cleaning of the hole, and in any case on the same day.

In dry, stable, holes and with prior approval by The Engineer, concrete may be poured by free fall instead of pumping.

h. Test-Cubes: Four test cubes shall be made from each 10 cu.m. or part thereof poured in each day's work. The cubes shall be made, cured and tested in accordance with the applicable Standard. One cube shall be tested at an age of 7 days and the other three - at 28 days. The Contractor shall submit to the Engineer certified copies of all test results.

i. Extraction of casing: Temporary casings, where used, shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted. No casing shall be raised unless it is full of concrete.

CONCLUSIONS

Piling using pneumatic percussion drills is a viable foundation method in all kinds of rock, above and below ground water level. In typical conditions, the construction of piles is much faster than that of conventional shallow foundations, and they consume much less labour, concrete, steel and energy.

As piles in rock may be subject to high stresses, effective supervision to assure adherence to the specifications is mandatory.

REFERENCES

1. Hartman, H.L.: "Principles of Drilling", Ch. 6.1 in Surface Mining, E.P. Pfleider, Ed., AIMMPE. New York, 1968

2. Thorburn, S. & Thorburn, J.Q.: "Review of Problems Associated with the Construction of Cast in Place Concrete Piles", DoE-CIRIA, London 1977 (pp. 24-25)

3. Weltman, A.J.: "Integrity Testing of Piles: A Review" DoE-CIRIA, London 1977

ACKNOWLEDGEMENT

The author is indebted to Mr. I. Magali, who started piling in rock in Israel, for reading the manuscript and offering his valuable comment.