Pin Piles

Donald A. Bruce

Introduction

The last decade has seen a significant growth in the use of Pin Piles[sm] in the United States. Generically, these piles may be classified as small diameter, bored, cast-in-place elements, and they owe their origins to developments by specialty contractors in Italy over 40 years ago. As a result of the kind of research and development activities described below, their safe working load range has been extended from 25-50 tons to up to 200 tons, while special test piles have yielded ultimate loads of around 600 tons in certain conditions.

Initially, these advances were made as a result of the careful execution and analysis of full scale field test programs, and such experiences have been widely published (References 1-8). However, within the last few years it has become apparent that extra dimensions of research efforts are necessary to explore and understand fundamental aspects of Pin Pile behavior, and especially those related to the performance of the component materials in resisting and transferring axial load. These programs are outlined below, but firstly, and in order to introduce the terminology, a brief review is made of construction techniques.

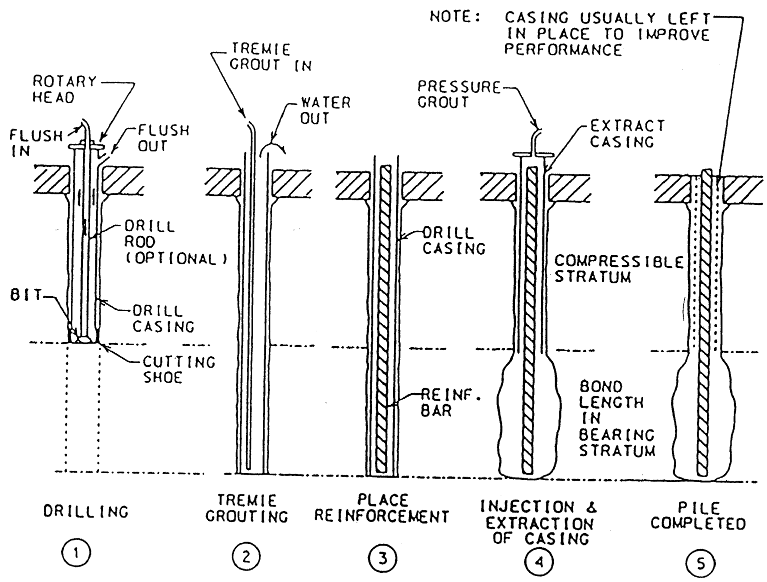

Figure 1. Stages in the construction of a typical Pin Pile in soil

Construction

Pin Piles are most commonly used to underpin existing structures settling, or liable to settle as a result of changes in loading or foundation conditions. Construction methods have therefore been developed to accommodate the gamut of ground and structure types, while causing the minimum of damage to either, or the environment. Also Pin Piles operate principally in side shear and so these techniques have been honed to enhance bond capacity at the gout/soil interface.

A common contemporary method of installing Pin Piles is shown in Figure 1. Older variants using compressed air to pressurize the grout, or a vibrated mandrel (displacement pile) are described by ASCE (Reference 9) but are rarely if ever used in developed countries. Likewise, the "expanded base" pile (Reference 10) and the Menard inflatable cylinder pile (Reference 11) are never seen nowadays.

The successive steps of relevance to the content of this article (and therefore excluding consideration of Connection to Structure and Corrosion Protection) are:

- Drilling: A drilling method is chosen to ensure the minimum practical disturbance or upheaval to the structure or the soil. Frequently a different system may be necessary to penetrate through any existing structure from that to be used in the soils below. For soil drilling, some type of duplex method (Reference 12) is common, although in certain conditions the use of a single casing is permissible. Water or foam flush (Reference 7) is typical: air flushing is typically disallowed. In certain soil conditions (e.g. clays) or where fluid spoils cannot be tolerated within the structure being underpinned for environmental reasons, a hollow stem auger can be used, although subsequent grout/soil bond capacity may be impacted adversely as a result of lateral decompression of the surrounding soil. This is a clear reminder that the critical design aspect of pile-soil bond capacity is highly sensitive to constructional method, and especially the drilling and grouting techniques.

Contemporary drilling rigs for such work are diesel hydraulically or electro-hydraulically powered, track mounted and extremely powerful for their compact size. Many have dimensions allowing them to pass through very narrow openings and operate in less than 3 m of headroom. Such rigs are highly maneuverable and capable of drilling at any angle through rock, soil, and obstructions. They can commence drilling

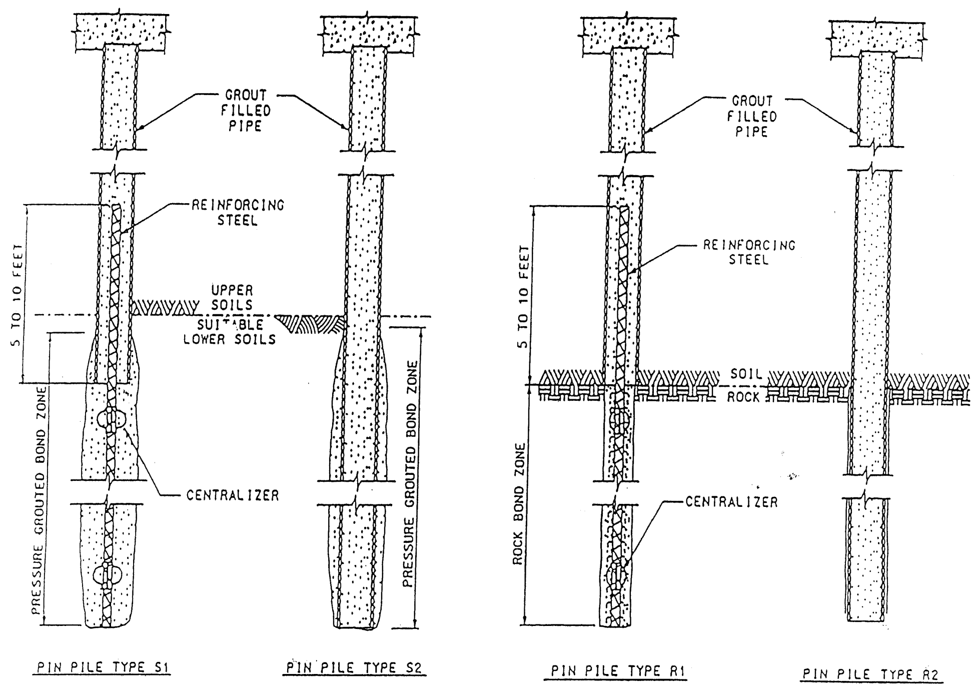

Figure 2. Pin Pile types in soil and rock (Reference 5)

within 30 cm of existing structures.

- Placing of Reinforcement, and Tremie Grouting: After the casing (or auger) has reached full depth, it is tremied full of grout. This grout is typically a neat cement mix prepared in a high speed colloidal mixer. The reinforcement, suitably centralized, is then placed. This may consist of a cage of reinforcing bars, a high strength bar (or group of bars) or a steel pipe, depending on the design requirements and the purpose of the pile.
- Pressure Grouting: The casing or auger is then withdrawn, while grout is continually injected through the drill head. This grout is pressurized (0.4-1 MPa) to enhance subsequent performance characteristics, with the maximum pressure reflecting:
  - the need to avoid soil hydrofracture or heave;
  - the nature of the drilling system (only relatively low pressures are possible in augers due to leakage at joints and around the flights);
  - the ability of the soil to form a "seal" around the casing during extraction; and
  - the "groutability" of the soil.

Pressure is maintained only over the bond zone length: the rest of the pile is filled with grout at gravity head.

In most countries, this drill casing is fully extracted (as the auger must always be) during this process. However, in the United States, it has been proven that by leaving the casing in place through the zones above the pressured zone, the Pin Pile performance is greatly enhanced, both vertically and laterally. This option also prevents wasteful travel of grout into these often permeable upper horizons while it also provides excellent corrosion protection to the interior of the pile in what is usually the most vulnerable zone. A useful subclassification of Nicholson Pin Pile types, based on the geology of the founding zone, and the internal composition (and the mode of action of the pile) is provided in Figure 2. (Reference 5):

Type S1 - A steel pipe is rotated into the soil using water to externally flush the cuttings up around the pipe annulus. A neat cement grout is tremied from the bottom of the hole to displace the water. The reinforcing element is then placed to the bottom of the hole. As the pipe is withdrawn over the length of the bond zone, additional grout is pumped under sufficient excess pressure to create the bond zone. The pipe is then seated into the grouted bond zone for 1.5-3.0 m. In granular soils, a certain amount of permeation and replacement of loosened soils takes place. In cohesive soils, some lateral displacement of localized improvement of the soil around the bond zone is accomplished with the pressure grouting. Postgrouting (see below) may be used later to further enhance soil/grout bond.

Type S2 - pile is installed in the same fashion as the S1 pile except that:

- the centralized reinforcing element is not needed;

- the steel pipe is installed to the full length of the bond zone after pressure grouting is completed; and
- post-grouting is not typically used in this type of installation.

Type R1 - The Type R1 pile uses the same technique for advancing the steel casing as Type S1, except that the depth of penetration is limited to the top of rock. Once the pipe is seated into the rock, a smaller diameter drill string is advanced through its center to drill the rock bond zone of diameter slightly less that the inside diameter of the pipe. Neat cement grout is then tremied from the bottom, and a reinforcing element is placed in the rock bond zone to complete the pipe installation. A minimum transfer length is required for the reinforcing to develop inside the pipe (typically 5 to 10 feet).

Type R2 - The Type R2 pile differs from the R1 pile in that it uses a full length steel pipe. Centralized reinforcement is optional. In order to advance through both the overburden and the rock, a permanent drill bit is used on the end of the casing with a diameter somewhat greater than that of the casing. There are grout ports in the bit, and once the hole is advanced to the desired depth, grout is tremied from the bottom, and additional grout is pumped to ensure full grouting of the rock bond zone. This grout may not flow completely to the surface in some conditions. However, once the level inside the pile has stabilized, the final grout level on the outside of the pile can be verified.

Postgrouting (Optional)

By injecting discrete volumes of cement grout into the bond zone after the initial, or primary, grout has set, a significantly improved load bearing performance can be provided. The cement grouts are injected through a separate grouting tube (i.e., sleeved pipe or tube a manchette as in the Gewi pile system of Herbst, (Reference 13) or through the steel reinforcement itself (Tubfix and Ropress piles). In the latter case, the double packer is introduced into the steel core pipe (Reference 11), and the grout is ejected through the rubber sleeved ports at regular intervals). Postgrouting greatly improves the grout/soil bond, but in addition it may increase the nominal pile cross section, particularly in weaker soil layers or near ground level where natural in-situ horizontal stresses are small. Postgrout pumping pressures of over 4 MPa are not uncommon.

Mascardi (Reference 11) also noted that in cases of repeated postgrouting, an effective pile diameter in the range of 0.4-1.0 m inches can be achieved. Postgrouting tends to be most effective in ground where displacements can be imparted relatively quickly, such as sands and gravels, residual soils, shales, and some weaker sedimentary and low grade metamorphic formations. Jones and Turner (Reference 14) also noted a favorable response in stiff clay. Few service records of good behavior in very soft non consolidated clay or soft peat have been recorded to date, although recent tests conducted under the auspices of Caltrans in the Bay Mud of San Francisco have yielded encouraging results. (Reference 15).

Recent Research and Development Results

A major laboratory test program was recently executed by the University of Pittsburgh and Nicholson Construction Company (Reference 16). The test was in three phases:

- Phase 1, where single grout filled steel casings, simulating the upper (free) section of a typical high capacity Pin Pile, were compressed to failure to establish their composite strength and elasticity.
- Phase 2, as Phase 1 but including connected sections with threaded ends, and
- Phase 3, where similar tests were conducted on internally reinforced grout columns simulating the lower (bonded) section.

These data were used to benefit a succession of major field projects (References 7, 15, and 17) culminating in the most recent, at Vanderberg AFB, California. On this project, compressive loads of almost 600 tons were sustained on pin piles installed in sand with total deflections of the order of 2 inches.

The results from the laboratory and field tests have given engineers the ability to analyze load transfer mechanisms in pin piles, and so form a very strong predictive ability in terms of deflection and ultimate load holding capacity. This ability is approaching that currently enjoyed by specialist in the prestressed ground anchor business.

The author and Dr. Juran of the Polytech University of Brooklyn are currently co-authors of an FHWA sponsored study into the State of Practice of Micropiles. Data have been collected from specialists worldwide, but especially from French colleagues who have their own parallel national program, called Forever.

Given the intensity of research effort, and the ever growing national market for pin piles, it would seem that the popularity and demand for this technology will continue to expand for many years.

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Dr. Donald A. Bruce, C.Eng., Vice President/Director of Business Development & Technology, Nicholson Construction Company, P.O. Box 98, Bridgeville, PA 15017 Tel:(412)221-4500 Fax:(412)221-3127