*Proceedings of the 21st ICSMGE, Vienna, Austria, 14 – 19 June 2026. Pistrol, Adam & Schweiger (eds.)*
*Published by: ÖGG, Austrian Society for Geomechanics, Salzburg, Austria, ISBN 978-3-9503898-4-5*
*https://doi.org/10.53243/ICSMGE2026-976*

# Leaving the temporary steel casing in place for replacement pile construction – Better or worse?

**Albert T. Yeung**
*Institute of Environmental Engineering, National Yang Ming Chiao Tung University, Hsinchu City 300, Taiwan, tyeung@nycu.edu.tw*

Andy Y.F. Leung
*Department of Civil & Environmental Engrg., The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong*

P.L. Ng
*Department of Civil Engineering, The University of Hong Kong, Pokfulam, Hong Kong*

Thirapong Pipatpongsa
*Department of Civil Engineering, National Yang Ming Chiao Tung University, Hsinchu City 300, Taiwan*

ABSTRACT: Temporary steel casing ("casing") is often used to excavate non-displacement or replacement piles. The casing prevents soil from caving into the excavated hole until it is filled with pile materials. Although the casing can increase the structural load-carrying capacity of the pile, it is often left in place unavoidably due to unforeseen ground obstructions because of the high cost of the casing. However, it may be left in place by design to overcome complex geologic conditions under extreme conditions. The impacts of leaving the casing in place vary depending on the casing installation and pile excavation method. In this paper, such impacts are discussed. When soil is excavated within the casing, leaving the casing in place may increase or decrease the pile's load-carrying capacity as the pile's side resistance changes, resulting from the interactions between the pile and soil at the interface. When soil is excavated below the casing tip, and the drill bit diameter is larger than the outer diameter of the casing to facilitate installation of the casing, leaving the casing in place decreases the pile's side resistance significantly due to the formation of a small gap between the casing and the surrounding soil. The gap is formed during pile excavation as the diameter of the bored hole is slightly larger than the outer diameter of the casing to accommodate the penetration of the casing into the ground. The results of two full-scale pile load tests on prebored socketed steel H-piles with casing left in place are presented. It is evident from the results that no side resistance has been developed in these two piles due to the formation of the gap between the casing and the surrounding soil. Moreover, the compressive load-carrying capacity of these piles may be limited by their buckling capacities, due to the absence of lateral support.

KEYWORDS: Replacement pile, non-displacement pile, temporary steel casing, pile construction, prebored socketed pile, large-diameter bored pile, minipile, casing-while-drilling method.

## 1 INTRODUCTION

Many commonly used non-displacement or replacement piles, such as large-diameter bored piles, prebored socketed steel H-piles, prebored socketed precast prestressed high-strength concrete piles, micropiles/minipiles, etc., are constructed by replacing the existing geologic materials with pile materials, including reinforced concrete cast *in-situ*, and precast prestressed concrete piles, steel H-piles, or reinforced steel bars embedded in cementitious grout. As the terms "micropile" and "minipiles" are used interchangeably (Sabatinia *et al*., 2005), the term "minipiles" is used throughout this paper. The design methodology, construction procedure, and load transfer mechanisms may vary with pile type. Typically, a hole is first excavated for insertion of pile materials afterward. Temporary steel casing ("casing") is often used during excavation to maintain the hole's stability, prevent ground loss, and provide a conduit for removing cuttings from the hole bottom to the ground surface. Since the casing is an expensive construction equipment, it is extracted during or shortly after the concreting or grouting operation, depending on the pile type, under normal circumstances. Moreover, the casing installation method depends on the pile type, the diameter of the pile, and the equipment used for pile excavation.

Foundation designers would generally not include the structural load-carrying capacity of the casing in the design, as the high cost of the casing makes it an uneconomical design option. However, the casing may be left in place by design to overcome complex and unstable geological conditions or to serve as concreting formwork for the pile to go through water. Otherwise, the casing is often left in place unavoidably due to unforeseen ground problems beyond the control of the foundation contractor. As a result, the foundation contractor incurs significant additional expenses by sacrificing the casing. It may also delay the contractor's foundation construction progress if the contractor needs to order additional casing. However, it remains a technical question whether the engineering performance of the pile so constructed is better or worse than that of the pile with the casing extracted as designed.

The different casing installation methods are outlined in this paper. The impact of the installation method on the effects of not extracting the casing during or shortly after concreting or grouting is presented. Moreover, the results of two full-scale pile load tests on prebored socketed steel H-piles with casing left in place are presented.

## 2 EFFECTS OF THE CONSTRUCTION METHOD

The casing installation and pile excavation method vary depending on the pile type. The methods can be broadly classified into two types depending on the technique of soil excavation for the pile: (1) soil excavation within the casing; and (2) soil excavation below the casing tip. The casing installation and pile excavation method depend on the diameter of the pile. Generally, casing is installed before soil excavation within the casing for piles of diameters larger than 750 mm. Soil is excavated below the casing tip, and the casing is drawn or rotated into the ground simultaneously for piles of diameters of less than 750 mm using one of the available casing-while-drilling methods.

### 2.1 *Soil excavation within the temporary steel casing*

A large-diameter bored pile of diameter larger than 750 mm can be constructed by three different methods: (1) the dry method; (2) the casing method; and (3) the wet method (Reese & O'Neill, 1988). When the casing method is used, an oscillator or rotator is used to install the casing for pile excavation. The casing may be made in China, Japan, Germany, South Korea, etc. While the connection details vary from manufacturer to manufacturer, the casing is a steel cylinder of sufficient strength to withstand the lateral earth pressure and the porewater pressure in the ground, the downward and oscillating/rotating forces to penetrate the casing into the ground, and the upward and oscillating/rotating force to extract the casing. Sections of the casing can also be connected by welding or casing joints. A cutting shoe is typically installed at the casing tip to facilitate casing penetration. The casing is always installed before soil excavation begins. The torque generated by the oscillator or rotator must be adequate to overcome the friction between the casing and the surrounding soil. Telescopic casings may be used to reduce such friction when the piles are founded on rock at great depths. Soil is excavated within the casing. The casing is always advanced beyond the excavation level, and an adequate excess hydraulic head of water is maintained within the casing to minimize stress relief and disturbance effects at the bottom of the excavation. Cuttings are removed from the bottom of the bored hole by a grab, a bucket, or reverse circulation. Therefore, the casing is generally in good contact with the surrounding soil. However, the soil may still be weakened due to smearing by the oscillation or rotation of the casing when it penetrates the ground.

### 2.2 *Soil excavation below the casing tip*

When excavating the hole, the casing is installed simultaneously to avoid soil caving into the prebored hole to construct minipiles and prebored socketed piles. The technique is generally known as casing-while-drilling. However, the techniques used for minipiles and prebored socketed piles differ due to the significant differences in casing diameters.

#### 2.2.1 *Minipiles*

Minipiles generally have a diameter between 100 mm and 400 mm, with up to five high-yield steel bars installed in each pile. The most common diameters of minipiles used in Hong Kong are 219 mm, 273 mm, and 324 mm. Due to the relatively small diameter of the casing, it is generally rotated and pressurized to advance it into the ground while simultaneously drilling with a drill bit using a piling rig. Therefore, the casing is in good contact with the surrounding soil, similar to the casing conditions for a large-diameter bored pile. In some jurisdictions, such as Hong Kong, the casing must be permanent to enhance the steel bars' corrosion protection and the pile's lateral restraint (Buildings Department 2024).

#### 2.2.2 *Prebored socketed piles*

The outer diameter of the casing for the prebored socketed pile is typically 610 mm or larger. The hole is prebored by a drill bit assembly, which draws the casing into the ground, immediately following the drill bit assembly. There are different designs of the drill bit assembly. However, it all contains three basic components: (1) the driver; (2) the reaming mechanism; and (3) the drill bit. For example, the ODEX drill bit assembly is designed to have a smaller diameter than the internal diameter of the casing. However, the end of the ODEX drill bit assembly is enlarged to engage a stiffening ring installed at the casing tip. During the preboring process, the drill bit assembly is put through the tip of the casing without rotation. After the reaming arms have gone through the casing tip, they are turned clockwise to extend them below the casing tip and above the drill bit to ream the pilot hole large enough for the casing to penetrate the prebored hole following the drill bit assembly. When the prebored hole is completed, the reaming arms are rotated counterclockwise so that they can be retracted into their original positions to remove the drill bit assembly through the casing. The diameter of the bored hole is thus always slightly larger than the outer diameter of the casing. Some compressed air would escape through the annular space between the prebored hole and the casing during the ODEX drilling operation. As a result, the compressed air may loosen the soil at the bottom of the prebored hole and disturb the soil along the length of the prebored hole. The preboring operation can create voids outside the casing in the subsurface. Ground loss can thus result from these uncontrolled voids during construction. The ground loss can adversely impact the foundations of nearby buildings. Past case histories of these adverse impacts are documented by Wong (2014). The drilling method has not been approved by the Buildings Department of the Government of the Hong Kong Special Administrative Region for use in private development projects since 2008.

The design of the drill bit assembly has been improved to alleviate these problems. One of the adopted designs is the concentric system, as shown in Figure 1. A sacrificial wing bit is installed on the tip of the casing to obtain a tighter fit of the casing into the bored hole. The design eliminates the necessity of an extendable and contractible reaming mechanism. However, the wing bit must be left at the bottom of the bored pile upon completion of the boring operation. The diameter of the bored hole is still slightly larger than the outer diameter of the casing.

Figure 1. Sacrificial wing bit system: wing bit on the left, the driver and drill bit on the right.

## 3 FULL-SCALE PILE LOAD TESTS

Two prebored socketed steel H-piles were constructed in a site reclaimed from the sea in the early 1990s to investigate the load-carrying mechanisms of these piles with the casing left in place. The site comprises fill, marine deposits, alluvium, decomposed granite, and granitic bedrock (Yeung & So, 2001). The piles were excavated using the concentric system as shown in Figure 1. The steel H-pile was inserted into the hole upon completion of the bored hole. The space between the casing and the steel H-piles was filled with cementitious grout. Details of the two piles are tabulated in Table 1.

As the two piles are working piles, they were not fully instrumented for the pile load tests. The loads applied to piles were limited to twice their design load-carrying capacities. Moreover, only the loads exerted on the piles and the settlements of the pile heads were measured during the tests.

Table 1. Construction details of the two test piles

| Pile designation | P14 | P06 |
|---|---|---|
| Steel pile type | Grade S450 J0 305×305×223 | Grade S450 J0 305×305×223 |
| Pile cutoff level (mPD)[1] | 4.1 | 3.53 |
| Pile founding level (mPD) | -78.44 | -77.09 |
| Pile length (m) | 82.54 | 80.62 |
| Casing outer dia. (mm) | 610 | 610 |
| Casing inner dia. (mm) | 585 | 585 |
| Casing thickness | 12.5 | 12.5 |
| Casing tip level (mPD) | -74.42 | -71.96 |
| Rock socket length (m) | 4.02 | 5.13 |
| Rock socket dia. (mm) | 550 | 550 |

[1] "mPD" means meters above the Principal Datum of Hong Kong, which is at approximately 1.3 m below the mean sea level.

## 4 ANALYSIS AND DISCUSSION

As the impacts of leaving the casing in place depend on the casing installation and pile excavation method for different pile types, these impacts are discussed separately.

### 4.1 *Large-diameter bored piles*

Using the principles of soil mechanics, the side resistance of a pile is related to the cohesion of the soil, the adhesion factor between the pile shaft and the soil, the horizontal effective stress acting on the pile shaft, the effective interface angle of friction between the pile and the soil, and the overconsolidation ratio of the soil. The side resistance of the pile, $Q_f$, with casing left in place, can be estimated using the same methods, such as the well-known α-method (total stress), β-method (effective stress), and λ-method (Vijayvergiya & Focht, 1972), as depicted in Equations (1), (2), and (3), respectively, with appropriate modifications of the empirical parameters in the equations as a function of pile material, surface conditions of the pile shaft, soil properties, construction methods, pile embedment depth, etc.

$$Q_f = \alpha \bar{c}_u A_s \tag{1}$$

$$Q_f = \beta \bar{q}_o' A_s \tag{2}$$

$$Q_f = \lambda(\bar{q}_o' + 2\bar{c}_u) A_s \tag{3}$$

where $Q_f$ = side resistance of the pile; α = adhesion factor; $\beta = K_s \tan\delta$ = skin factor; λ = frictional capacity coefficient as a function of pile embedment depth; $\bar{c}_u$ = average undrained shear strength of clay along the shaft; $\bar{q}_o'$ = mean effective vertical stress between the ground surface and pile tip; $K_s$ = coefficient of lateral earth pressure; δ = soil-pile friction angle; and $A_s$ = total surface area of pile shaft embedded below ground surface.

As the casing is in good contact with the surrounding soil, the pile's side resistance behaves as a small-displacement steel pipe pile when the casing is left in place. However, the side resistance may be reduced as the friction coefficient between soil and steel is smaller than that between soil and concrete cast *in situ* (O'Neill, 1991). Moreover, the side resistance of the pile may be further reduced due to the existence of voids in the subsurface.

Due to improper casing management during extraction, more defects have occurred from using temporary casing than any other cause in large-diameter bored pile construction (O'Neill, 1991). The smearing effect occurs regardless of whether the casing is extracted. The smearing effect may be aggravated when the casing is extracted, as more oscillation or rotation of the casing occurs. Water from wet concrete migrates into the surrounding soil, causing further soil softening (Tomlinson & Woodward, 2015). Meyerhof and Murdock (1953) measured an increase of 4% in London Clay's water content for up to 76 mm from the concrete/soil interface. The lateral pressure of the wet concrete expands the pile circumference when the casing is extracted. The lateral earth pressure coefficient of the soil acting on the pile shaft is theoretically larger than the at-rest lateral earth pressure coefficient $K_o$. However, research results indicate that the lateral earth pressure coefficient of the soil acting on the reinforced concrete pile shaft is slightly smaller than $K_o$, probably due to stress relaxation and/or smearing during casing extraction. Moreover, water in the wet concrete may permeate the soil surface, resulting in smaller side resistance.

Skempton (1959) and Fleming *et al.* (2009) recommend appropriate α values for bored piles in clays. Recommendations for the β value for bored piles constructed in different geologic materials by different construction methods are given by Kraft & Lyons (1974), Meyerhof (1976), Stas & Kulhway (1984), Poulos (1988), and Fleming *et al.* (2009). These empirical parameters can also be correlated with results of *in-situ* tests such as SPT (Meyerhof, 1976; Decourt, 1982; Shioi & Fukui, 1982), CPT (Bustamante & Gianeselli, 1982), pressuremeter measurements (Frank, 1985; Baguelin *et al.*, 1986), etc. A good summary of these recommendations is given by Poulos (1989). The overall impacts of leaving the casing in place for a large-diameter bored pile or minipiles are tabulated in Table 2.

Table 2. Comparison of the impacts of leaving casing in place for large-diameter bored piles or minipiles

| Parameter | Casing left in place | Casing extracted |
|---|---|---|
| Smearing effect | Smaller | Larger |
| α value | Smaller | Larger |
| $K_s$ value | Larger | Smaller |
| δ value | Smaller | Larger |

The overall impact depends on the relative effect of each parameter.

### 4.2 *Minipiles*

The casing-while-drilling method is usually used to construct minipiles of less than 400 mm in diameter. A cutter shoe is installed at the casing tip, and the casing and the drill bit are rotated simultaneously to penetrate the ground. The casing-while-drilling method enables a tight fit between the casing and the surrounding soil. Therefore, the analyses of the impact of leaving the casing in place are similar to those for large-diameter bored piles, as elaborated earlier.

### 4.3 *Prebored socketed piles*

Regardless of the type of drill bit assembly used for excavating the pile, the diameter of the bored hole is always slightly larger than the outer diameter of the casing for the excavation of prebored socketed piles. A gap is thus formed, reducing the friction between the casing and the surrounding soil. Assuming the prebored socketed steel H-piles are fixed at the top of the rock sockets, i.e., no pile settlements occur within the rock sockets, the elastic shortenings of the composite piles without side resistance are calculated. The Young's moduli of the steel (for both the pile and casing) and grout are taken to be 205 GPa and 23 GPa, respectively. These calculated settlements are plotted against the measured pile head settlements as shown in Figure 2. It can be noticed from Figure 2 that they are in good agreement except that the calculated settlements are slightly larger than the measured settlements for Pile P06.

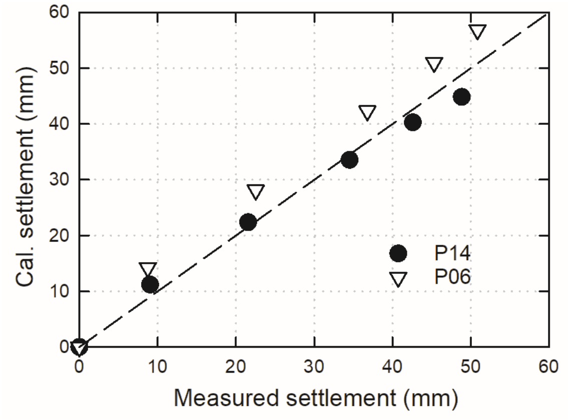

Figure 2. Comparison of calculated settlement and measured settlement at the pile head.

When the calculated settlements are larger than the measured settlements, some side resistances exist and act on the casing to reduce the measured settlements. When the measured settlements are greater than the calculated settlements, the elastic shortenings of the piles cannot account for all the measured settlements. Therefore, there must be pile settlements within the rock sockets.

## 5 CONCLUSIONS

These conclusions can be drawn from this study:

1. The impact of leaving a temporary steel casing in place for replacement pile construction depends on the casing installation and pile excavation method.
2. When the casing is installed before pile excavation, and the pile excavation is carried out inside the casing, such as in the construction of large-diameter bored piles, leaving the casing in place may increase or decrease the side resistance of the pile.
3. In constructing piles of diameters less than 400 mm, such as minipiles, the casing is rotated with a cutter at the casing tip to penetrate the ground. The casing is in intimate contact with the surrounding soil; leaving the casing in place may increase or decrease the side resistance of the pile. The situation is similar to that of large-diameter bored piles.
4. In constructing piles of diameters greater than 400 mm, such as prebored socketed piles, the drill bit assembly pulls the casing into the ground. Some form of reaming bit is installed below the casing tip to ream the bored hole slightly larger than the outer diameter of the casing, resulting in the formation of a gap between the casing and the surrounding soil. The side resistance of the pile is thus eliminated. The validity of the proposed phenomenon is verified by full-scale pile load results.

## 6 REFERENCES

Baguelin, F.J., Bustamante, M.G., and Frank, R.A. 1986. The pressuremeter for foundations: French experience. In S.P. Clemence (editor), *Use of in situ tests in geotechnical engineering*. GSP No. 6, New York, N.Y.: ASCE, pp. 31-46.

Buildings Department 2024. *Code of practice for foundations 2017 (2024 Edition)*. Hong Kong: Buildings Department, the Government of the Hong Kong Special Administrative Region.

Bustamante, M., and Gianeselli, L. 1982. Pile bearing capacity prediction by means of static penetrometer CPT. *Proc. ESOPT II*, Amsterdam, 2, pp. 493-500.

Chen, Y.J., Lin, S.S., Chang, H.W., and Marcos, M.C. 2011. Evaluation of side resistance capacity for drilled shafts. *J. Marine Sci. Technol.* 19, pp. 210-221.

Cheung, H.T., Yuen, S., and Li, V. 2012. Rock socketed precast prestressed spun concrete piles for foundation works in Hong Kong. In Li, V. (editor), *Bridging Research and Practice – the VLA Experience*, *Volume 2*, Hong Kong: Centre for Research and Professional Development, pp. 131-147.

Decourt, L. 1982. Prediction of the bearing capacity of piles based exclusively on N values of the SPT. *Proc. ESOPT II*, Amsterdam, 1, pp. 29-34.

Fleming, K., Weltman, A., Randolph, M., and Elson, K. 2009. *Piling engineering*. 3rd Edition. New York, N.Y.: Taylor & Francis.

Frank, R. 1985. Recent developments in the prediction of pile behaviour from pressuremeter results. *Proc. Symp. from Theory to Practice on Deep Foundations*, Porto Alegre, 1, pp. 69-99.

Jeldes, I.A., and Brown, D.A. 2022. Casing issues during construction of drilled shafts in glacially overconsolidated soils. In Lemnitzer, A., & Stuedlein, A.W. (editors), *Geo-Congress 2022: Deep foundations, earth retention, and underground construction*. GSP No. 332, Reston, Virginia: ASCE, pp. 292-298.

Kraft, L.M., and Lyons, C.G. 1974. State-of-the-art: ultimate axial capacity of grouted piles. *Proc. 6th Annual Offshore Technology Conference*, Houston, Paper OTC 2081, pp. 487-503.

Meyerhof, G.G. 1976. Bearing capacity and settlement of pile foundations. *J. Geotech. Engrg.*, ASCE, 102(GT3), pp. 195-228.

Meyerhof, G.G., and Murdock, L.J. 1953. An investigation of the bearing capacity of some bored and driven piles in London Clay. *Géotechnique*, 3(7), pp. 267-282.

Murthy, V.N.S. 2003. *Geotechnical engineering: Principles and practices of soil mechanics and foundation engineering*. New York, N.Y.: Marcel Dekker.

O'Neill, M.W. 1991. Construction practices and defects in drilled shafts. *Soils, geology, and foundations*. Transportation Research Record 1331, Washington, D.C.: Transportation Research Board, National Research Council, pp. 6-14.

O'Neill, M.W. 2001. Side resistance in piles and drilled shafts. *J. Geotech. Geoenvir. Engrg.*, ASCE, 127(1), pp. 3-16.

Poulos, H.G. 1988. The mechanics of calcareous sediments. Jaeger Memorial Lecture, *Proc. 5th Australia-New Zealand Conference on Geomechanics*, Sydney, pp. 8-41.

Poulos, H.G. 1989. Pile behavior – theory and application, *Géotechnique*, 39(3), pp. 365-415.

Rajapskse, R. 2016. *Geotechnical engineering calculations and rules of thumb*. 2nd Edition. Amsterdam: Elsevier.

Reese, L.C., and O'Neill, M.W. 1988. *Drilled shafts: Construction procedures and design methods.* Report FHWA-HI-88-042. Washington, D.C.: FHWA, U.S. Department of Transportation.

Sabatinia, P.J., Tanyua, B., Armourb, T., Groneckb, P., and Keeleyb, J. 2005. *Micropile design and construction (Reference manual for NHI course 132078)*. Report No. FHWA-NHI-05-039, Washington, D.C.: National Highway Institute, Federal Highway Administration, U.S. Department of Transportation.

Shioi, Y., and Fukui, J. 1982. Application of N-value to design of foundations in Japan. *Proc. ESOPT2*, Amsterdam, 1, pp. 159-164.

Skempton, A.W. 1959. Cast-in-situ bored piles in London clay. *Géotechnique*, 9(4), pp. 153-173.

Stas, C.V., and Kulhawy, F.H. 1984. *Critical evaluation of design methods for foundations under axial uplift and compression loading*. EPRI Report No. EL-3771, Ithaca, N.Y.: Cornell University,

Tomlinson, M., and Woodward, J. 2015. *Pile design and construction practice*. 6th Edition. Boca Raton, Florida: CRC Press.

Vijayvergiya, V.N., and Focht, J.A. 1972. A new way to predict the capacity of piles in clay. *Proc. 4th Offshore Technology Conference, Houston*, 2, pp. 865-874.

Wong, C.M. 2014. Overview of development and challenges in foundation design and construction in Hong Kong. *Challenges and Recent Advances in Geotechnics for Foundation Engineering*, Proc., the HKIE Geotechnical Div. Annual Seminar 2014, Hong Kong, pp. 27-52.

Yeung, A.T., and So, S.T.C. 2001. Geotechnical engineering properties of Hong Kong marine clays. *Proc., 3rd International Conference on Soft Soil Engineering*, Hong Kong, pp. 695-700.