



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 9, Issue 10, October 2020

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.512



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Review on Comparative Study of Secant Pile Wall with Other Piling System

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ABSTRACT: Implementation of fast and cost-effective shoring systems has become very necessary to overcome the technical challenges such as variable soil and rock profile, high groundwater tables and limitations imposed by the built environment. Secant pile wall shoring systems allow the construction of overlapped piles in almost all subsurface conditions. Secant pile walls are usually used in hard ground, where it is not possible to install diaphragm walls, and in rocks, and it is technically possible to install secant pile walls in a extensive range of grounds. The isolation of vibrations from the surroundings is one of the important problems in the design of machine foundations. The use of open trenches, infilled trenches, single and multiple pile rows have been widely studied. This paper presents a numerical study to investigate various aspects of the behavior of secant pile wall. The studied aspects include the identification of earth pressure distributions exerted on secant pile wall.

KEYWORDS: Secant Piles, Continuous Flight Auger Method, Kelly Drilling Method

I. INTRODUCTION

Deep excavations in weak ground with a high ground water level provide significant challenges with regard to ground support and minimising ground water inflow. This is particularly important in urban environments where settlement resulting from ground loss or ground water draw down can result in damage to adjacent structures. The use of driven sheet piles or similar can result in unacceptable noise and vibration. The use of overlapping interlocking cast in-situ concrete piles to form a wall provided relatively quiet and vibration free method to install a wall that provided continuous support to the ground during excavation and reduced ground water inflows. These piles are known as secant piles.

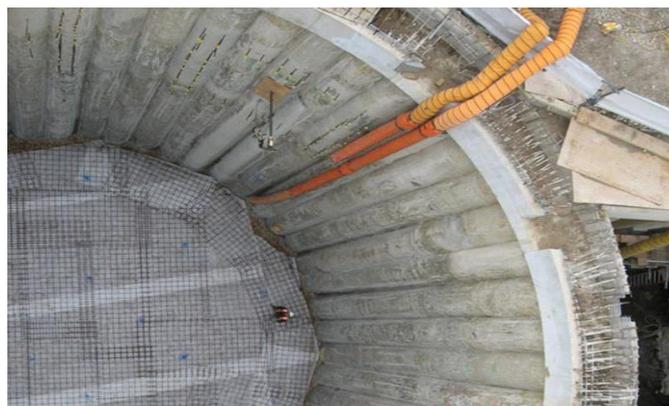


Fig 1 Secant piles

Secant piles are formed by constructing a series of overlapping concrete filled drill holes to form a continuous relatively watertight wall. Secant piles are constructed so that there is an intersection of one pile with another. The usual practice is to construct alternative piles along the line of the wall leaving a clear space of a little between the diameter of the required intermediate piles. The exact spacing is determined by the construction tolerances which can be achieved. These initially placed piles do not have to be constructed to the same depth as the intermediate piles which follow, depending on the way in which the wall has been designed and reinforced.

II. PRIMARY AND SECONDARY PILES

1. Primary piles

The low strength concrete or “female” piles have a number of functions but first and foremost it must needs to retain the ground and groundwater from passing between the reinforced concrete “male” piles. However, to achieve this and facilitate construction the mix requires the following properties:

1. Sufficient strength to support and distribute the earth pressures to the “male” piles. In reality these piles are spanning less than a pile diameter and the forces are distributed by arching with the material in compression. Depending upon the retained height and groundwater level strengths in the range of 1 – 2MPa are normally sufficient.
2. Low permeability to minimize the seepage of groundwater through either the piles or wall as a whole.
3. Low early strength gain to facilitate the boring of the “male” piles.
4. Suitably durable for the intended life of the material. The “female” pile is typically unreinforced and effectively temporary if a permanent lining wall is constructed on the inside face of the piles. For this reason durability is not normally a concern.
5. Fluid properties that is consistent with placement requirements during piling. The mix must be pumpable or of sufficient cohesion to enable placement.

2. Secondary piles

The reinforcement provided may be rebar cage. Rebar (short for reinforcing bar), also known as reinforcing steel, reinforcement steel is a steel bar or mesh of steel wires used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and hold the concrete in tension. Rebar's surface is often patterned to form a better bond with the concrete.

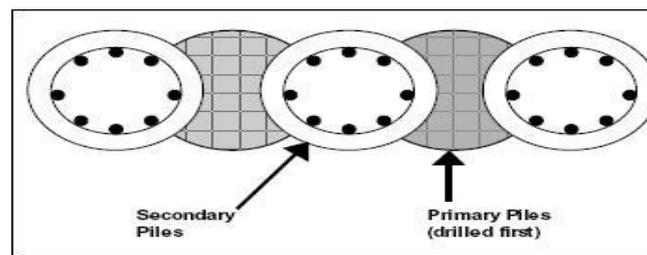


Fig 2 Plan of Secant Pile

III. CONSTRUCTION PROCEDURE

The construction process of secant piles is carried out as per the following steps:

1. Construction of guide wall
A guide wall is constructed to set out the position of the secant pile wall.
2. Installation of casing
The vibro-hammer drives a casing into the ground, leaving about 1 metre length of the casing protruding from the ground.
3. Augering of primary borehole
The auger, a drilling tool, cuts and removes the soil within the casing to form a primary borehole. The soil surrounding the borehole is supported by the casing. If the casing is not long enough to reach the required depth in the ground, bentonite slurry is used to support the soil below the casing.
4. Concreting of primary borehole
Concrete is poured into the borehole to form the primary bored pile.
5. Augering of secondary borehole
After the casings of the two primary bored piles are extracted by the vibro-hammer, the auger cuts and removes the soil in between the two primary bored piles to form a secondary borehole. The secondary borehole intersects with the adjacent primary bored piles.
6. Concreting of secondary borehole
Concrete is poured into the borehole to form the secondary bored pile.
7. Installation of steel cage
The crane lifts up the steel cage and places it within the secondary borehole.

8. Repetition of process

Above steps, except construction of guide wall are repeated till the entire length of the secant pile wall construction is complete.

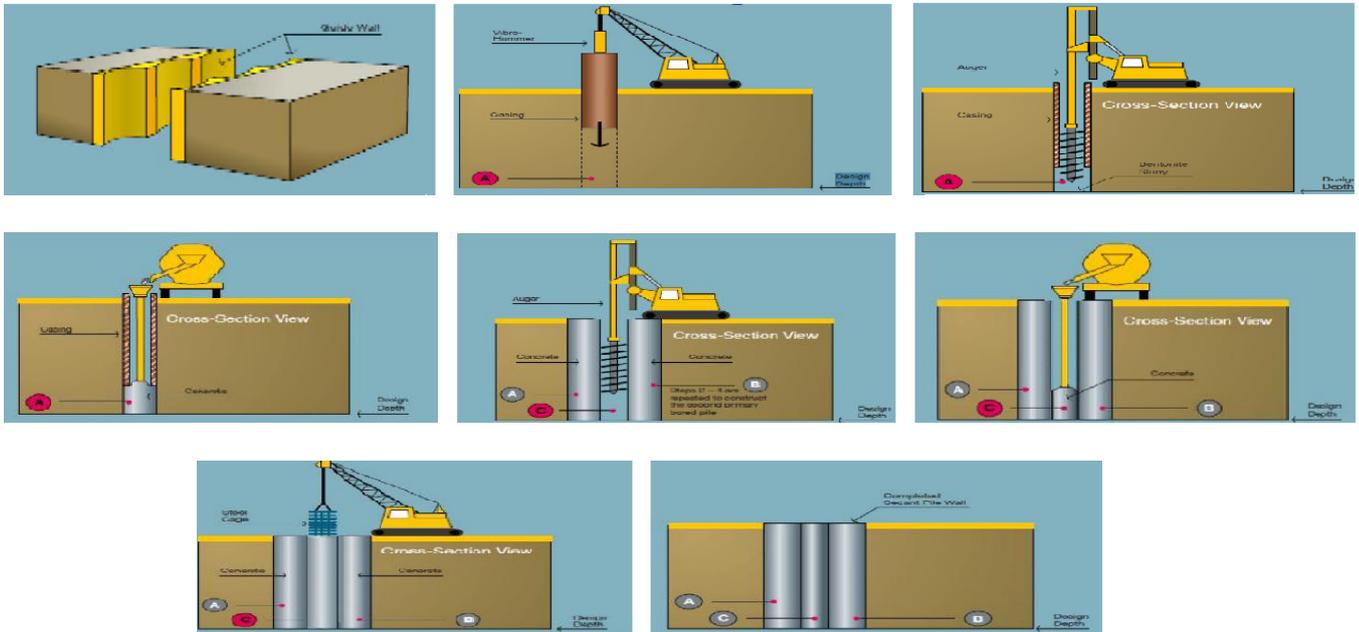


Fig 3. Construction Procedure

IV. DESIGN CONSIDERATIONS

The success of a secant pile system requires that the individual piles be structurally sound over their full length, and that adjacent piles be constructed to tolerances that maintain a reasonable overlap between the primary and secondary piles. Secant pile walls for excavation support are designed to function in one of two ways.



Fig 4. Compression Ring

The typical design approach develops the structural capacity of the wall in the vertical direction. The wall spans between its points of support (e.g., cross-lot bracing or tiebacks) as a vertical beam. For this type of wall system, the primary piles are unreinforced, and the secondary piles are reinforced with either a wide flange section or a rebar cage. The secondary piles are designed to have sufficient flexural and shear strength as beams in the vertical direction.

Secant pile walls can also be designed as ring compression structures. In this case, the piles are installed in a circular configuration and loads are resisted in circumferential compression. This type of structure is structurally-efficient because unreinforced concrete has significant compression capacity. Soil, groundwater and surcharge loads are resisted by thrust (compression) forces acting in the ring.

V. EVALUATION OF VERTICALITY

1. TOLERANCE CONTROL

Tolerance is the allowable maximum errors that can occur during the manufacturing or construction process, beyond these tolerances the piles may be rejected for use. Tolerance is evaluated in terms of both layout control and drilling verticality. Significant overall costs savings can be realized by using a guide trench and templates in order to ensure pile location is controlled at ground surface.

Verticality tolerances of 0.5% (1 in 200) or stricter are typically necessary for secant piling projects, compared with standard requirements of 1% to 1.5% (ACI 336.1) for drilled piers. Pile spacing is maximized for economy, and therefore successful secant piling projects require exceptional attention to drilling procedures, equipment, and quality control to ensure overlap is maintained. Drilling methods and equipment selection are integrally linked in the construction process.

2. INSTALLATION VERIFICATION

Until recently, there was no ready means of evaluating the verticality of a drill hole prior to it being exposed in an excavation. Therefore, it was necessary to make reasonably conservative assumptions about the verticality tolerance on which a design could be based. Downhole survey techniques that permit measurement of both the diameter and plumbness of a drill hole are now available.

Downhole surveys permit tighter installation tolerances to be used for design because the as-built pile locations can be confirmed prior to excavation. If the surveys indicate a potential problem, holes can be redrilled or other proactive corrective action can be taken at a specifically targeted location.

1. Sonicaliper

The Sonicaliper is a sonar device that provides a 360 degree profile of the drill hole at any depth. It can be used for surveying drilled shafts as well as slurry wall panels. The instrument is able to make measurements in a dry hole, under water, or even through polymer or bentonite slurry. Survey readings can be taken in a cased or uncased hole.

2. Inclinometer

The Inclination Measuring Instrument (inclinometer) manufactured by Bauer provides an alternate means of surveying cased drill holes. The instrument is similar to an inclinometer probe that is used for measuring lateral ground movements in a small diameter slotted casing, although at a much larger scale.

VI. DRILLING METHODS

1. Continuous Flight Auger Method (CFA)

Continuous Flight Auger (CFA) Piling is the quietest form of piling and is a fast and very economical technique. It is a cast in-situ process, very suited to soft ground where deep casings or use of drilling support fluids might otherwise be needed. CFA piling is a non-displacement piling system; hence the soil excavated from the pile is brought to the surface. CFA piles can be an attractive alternative to conventional bored piles (faster installation) and to drive piles (much less noise and vibration). The construction sequence can be seen in the animation image given, and consists of;

- (1) Drilling a full length auger with a hollow stem (temporarily plugged) into the soil using a constant penetration rate.
- (2) After reaching the design toe level, concrete is pumped through the hollow stem of the auger while the auger is extracted. It is important that the auger always remains embedded into the concrete (3) and that a positive concrete pressure is maintained throughout the placement of concrete. CFA piles have to be poured to platform level to facilitate reinforcement installation and avoid pile necking.
- (4) After completion of the concrete placement process the reinforcement cage plunged into the fluid concrete.

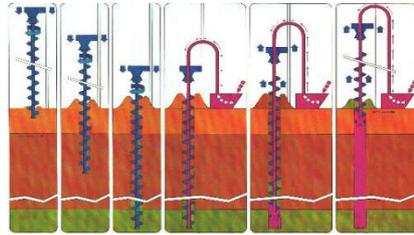


Fig 5. Schematic representation of drilling by CFA method



Fig 6. Kelly drilling

2. Kelly Drilling Method

A Kelly drive refers to a type of well drilling device on an oil or gas drilling rig that employs a section of pipe with a polygonal (three-, four-, six-, or eight-sided) or splined outer surface, which passes through the matching polygonal or splined Kelly (mating) bushing and rotary table. This bushing is rotated via the rotary table and thus the pipe and the attached drill string turn while the polygonal pipe is free to slide vertically in the bushing as the bit digs the well deeper. It is employed for secant piling.

Sectional heavy wall drill casing, advanced concurrently with the drill tool, performs the dual function of maintaining boring stability in cohesion less or unstable ground and stiffening the drill string in order to limit deviation at depth. Kelly drilling methods allow a range of soil and rock tooling to be employed within the casings such that different tools can be utilized to accommodate variations in ground type as the drill hole is advanced. Casing teeth configurations can be modified between or even within project sites to suit actual ground conditions.

VII. APPLICATIONS

Secant walls are utilized to transfer lateral, vertical or a combination of both loads through weak soil layers to a suitable bearing layer. They can be drilled in all types of configurations that can form an interlocking watertight wall, or provide for a structural overlapping wall. Secant walls are mainly used for foundation load transfer and earth retention systems. They are used in land-based structures, top-down tunnel, cofferdams and subway structures where the surface soil layers cannot provide the required load-bearing capacity. They are also used in marine-based structures and dams.

Secant piles are one of the most economical methods of creating an effective water control barriers for building structural walls, top-down tunnel and dams, when water tables and dewatering are major problems. Various drilling techniques are used to construct overlapping concrete cylinders through saturated soils, rock, extending well below the water seepage elevation. Sequenced drilling and concreting of the individual cylinders that make up the finished barrier allows the concrete to cure, ensuring a tight seal between the cylinders for complete water cutoff. Secant piles can be constructed to depths that exceed 150 plus feet, depending on the units Kelly bar/ auger length.

VIII. OTHER PILING SYSTEMS

1.SOLDIER PILE AND WOOD LAGGING

Soldier pile and wood lagging is a widely used and effective earth retention system. Soldier piles are drilled or driven at regular intervals along the perimeter of the excavation. Once the excavation starts, wood lagging is installed to maintain the excavated face. Soldier pile walls can cantilever or be laterally braced to suit the specific needs of the project.

2.SHEET PILE

When the retained soil cannot be dewatered, a sheet pile earth retention system is an effective solution. Sheet piles are steel sections in a wide variety of cross sectional shapes – all with the ability to interlock with one another forming a continuous, watertight wall. The sheets are driven or vibrated into the ground. Cantilever walls are typical, but the sheet piles can be laterally braced to suit the specific needs of the work site. Being manufactured from steel, they offer a high strength material with excellent quality control

3. TANGENT PILE WALL

Tangent pile walls are a variation of secant pile walls and soldier pile walls. However, tangent pile walls are constructed with no overlap and ideally one pile touches the other. Tangent pile walls are not as commonly used as contiguous pile walls. The axial distance between the piles is exactly equal to their diameter, so there is no free space between them. Tangent pile walls have a higher bearing capacity than contiguous walls and the positioning of anchors is easier because it is not necessary to use wales

IX. CONCLUSION

High groundwater levels combined with variable soil and rock profiles present challenges to the design and construction of deep excavation support systems. Increasingly, secant piling techniques are the preferred technical solution for shoring and foundation in these cases. Recent developments in drilling equipment, tooling and procedures allow cost-effective construction of deep, overlapped pile systems to tight tolerances in extremely difficult ground conditions.

Recent project experiences has proven that appropriate drilling equipment and methods can achieve installation tolerances that allow secant pile shoring systems to be used in geotechnical conditions and for excavation depths previously considered to be infeasible. Compared with other piling system, secant pile method is capable of providing greater wall stiffness and earth shoring. Secant pile wall act as water tight-cut off wall and can be installed in difficult ground.

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