Why Use Precast, Prestressed Concrete Piles?

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There is a widely held misconception that driven precast, prestressed concrete piles (PCPs) are principally for use in marine and river structures. As a result of this unfortunate misconception, PCPs are often prematurely eliminated from consideration during the preliminary design phase of other projects. The truth is, however, that PCPs are a high-performance, durable, and cost-effective solution that are typically a great choice for many deep foundation projects. Yes, they are certainly an excellent choice for marine and other in-water applications, but PCPs have many qualities that make them suitable for nearly all foundation types, including on-land structures.

Another misconception is that PCPs cannot be used in moderate- or high-seismic areas. However, PCPs can be easily designed and detailed to provide the ductility required by code or by agency specifications to resist seismic loads.

Precast concrete as a material provides many benefits for structural components. Furthermore, compared with piles made from other materials, PCPs gain the following additional advantages:

- *Adaptability:* From small-diameter piles on land to 200-ft-long single-piece marine piles in saltwater, PCPs have a wide range of sizes and cross-sectional shapes. PCPs can also be spliced for deeper depths.
- *Sustainability:* Local materials and labor, long service life, reusable formwork, and reduced amounts of concrete and material waste enhance

Precast, prestressed concrete piles are cast in steel forms in long-line casting beds under factory-controlled conditions. Pile dimensions and material properties are tightly controlled. Photo: Gulf Coast Pre-Stress Partners Ltd.

The main type of reinforcement in precast, prestressed concrete piles is high-strength prestressing strands. During casting, the strands are anchored against thick steel plates that facilitate precise placement of the individual strands. Photo: Roy L. Eriksson.

Once a precast concrete pile has been cast and removed from its form, it is fully prestressed and can be easily and safely lifted, handled, and transported to the jobsite. Note that at this stage, the entire pile can be fully inspected. Photo: Roy L. Eriksson.

the sustainability of PCPs. Sustainability can be further improved with high-performance concrete, which can significantly reduce the cross-sectional areas of components, resulting in less material being required.

- *Quality control:* The quality of PCPs is facilitated by nationally recognized quality-assurance and quality-control procedures. Also, the ability to visibly inspect finished PCPs before installation helps ensure high-quality outcomes.
- *Structural efficiency:* High-strength concrete and prestressing allow for smaller cross sections. PCPs have greater capacities than steel H-piles, which means fewer piles are needed and smaller footprints can be achieved. Longitudinal and confinement reinforcement run the full length of the PCP, providing high flexural strength and enhanced ductility from end to end. Due to cross-sectional symmetry, high lateral stiffness is provided in all directions in PCPs, unlike steel H-piles.
- *Long design life:* The use of high-performance concrete with low permeability, combined with permanent axial compressive stress that provides excellent crack control, results in low moisture intrusion, low corrosion, and excellent durability.
- *Accelerated construction:* PCPs are fabricated off site at a plant and prior to or concurrent with jobsite activities, which greatly accelerates construction schedules.
- *No drilling spoils:* PCPs are displacement piles, so the need to dispose of drilling spoils is eliminated. That gives PCPs a distinct advantage over drilled-in piles and shafts on sites that might have subsurface contamination.
- *Densification of surrounding soil:* As piles are driven into granular soils, the soil surrounding the piles is densified, which increases skin friction and end-bearing capacities. Solid PCPs displace larger volumes than thin-walled sections, such as steel H-shapes, which causes further densification.
- *Bearing capacity*: Testing to verify bearing capacity is often not needed with PCPs. Pile driving analyzer tools may be used to verify pile capacities. Pile-driving contractors say it best: "A driven pile is a tested pile."

Available precast, prestressed concrete pile shapes and sizes vary by region and by manufacturer, but the most common shapes in the United States are square, octagonal, or round (cylindrical) in cross section. Typical sizes range from 10-in.-square solid piles to 66-in.-diameter hollow cylinder piles.

PCPs are an engineered product, made of precast, prestressed concrete. Concrete alone can resist very high compressive stresses, but relatively low tensile stresses. Typical reinforced concrete overcomes this by incorporating reinforcing bars to carry the tensile stress. Prestressed concrete takes this concept to a much higher level by replacing the typical Grade 60 (60-ksi yield strength) reinforcing bars with high-strength (270-ksi ultimate strength) prestressing strands. Before casting, each strand is tensioned to about 70% of its ultimate strength and then anchored at the ends of the stressing bed. Once the transverse reinforcement (ties or spiral) has been placed in the casting form and the concrete has been placed and cured, the prestressing strands are detensioned and the prestressing force transfers to the concrete pile. This precompresses the pile

A typical on-land pile-driving operation allows piles to be stockpiled on site for easy access. Precast, prestressed concrete piles are displacement piles that create no spoil at the site. Photo: Concrete Technology Corp.

Prestressed concrete piles are typically square, octagonal, or round (cylindrical). Availability of shapes and cross sections varies by geographical region. Photo: PCI.

with a uniform level of axial compression, which enables the pile to resist much higher levels of tension from applied loads whether they be from driving or in service.

Prestressing a concrete pile produces several benefits. Principal among them is the ability to mitigate cracking of the concrete. The integrity of the pile is preserved and protected during its entire service life, from stressing bed to handling and hauling, pile driving, incorporation into a structure, and in-service loading. With prestressing, corrosion is effectively mitigated, which greatly improves durability. An uncracked section also means the stiffness of the pile is maintained under flexural loading.

PCPs are typically fabricated using steel forms on long-line casting beds in permanent facilities with proven quality-control and quality-assurance procedures. Because the cross-sectional dimensions are defined by the form, the shape of the pile remains true and constant along the entire length of the pile form. The prestressing strands are anchored at each end of the bed against thick steel plates through which the strands pass. These plates are predrilled with a fixed hole pattern that defines the location of each strand. Therefore, concrete cover—the clear distance between the edge of a strand and the face of the pile—remains constant, as required by design code or specifications. As a result, corrosion resistance is not compromised by insufficient concrete cover, greatly enhancing pile durability.

Durability is also enhanced by virtue of the concrete being mixed in the precast concrete plant, which gives greater control over the concrete mixture proportions and consistency among batches. Admixtures of various types can easily be blended into the concrete mixture. Water-reducing admixtures can be added to improve concrete flowability and workability. Additives such as calcium nitrate inhibitor, which improves corrosion resistance, can also be added.

Continuous improvements to existing materials and the introduction of new materials have increased the performance of precast, prestressed concrete. New prestressing strand types include larger-diameter strand, higher-strength steel, stainless steel strand, and carbon-fiber-reinforced-polymer strand. Performance-enhancing additives include structural fiber that can be blended into the concrete mixture. Advances in the science of materials have resulted in a new class of concrete called ultra-high-performance concrete (UHPC), which is typically defined as having a compressive strength of at least 17 ksi, a defined flexural strength, and enhanced tensile strength. As a result, new pile shapes are being developed that start to approach the shape of steel H-piles.

So, why use precast, prestressed concrete piles for your next project? The real question is: *why not?*

Additional Resources

The following publications offer more detailed information about precast, prestressed concrete piles as well as design resources:

- White, C. D., R. W. Castrodale, and M. C. Nigels. 2004. *Precast Prestressed Concrete Piles*. BM-20-04 (*Bridge Design Manual* Chapter 20). Chicago, IL: Precast/Prestressed Concrete Institute (PCI).
- PCI Prestressed Concrete Piling Committee. 2019. "Recommended Practice for Design, Manufacture, and Installation of Prestressed Concrete Piling." *PCI Journal* 64 (4): 84–116. https://doi.org/10.15554/pcij64.4-05.
- Parkins, J., D. Eckenrode, and R. Eriksson. 2021. "Precast, Prestressed Concrete Piles." PCI webinar, December 14, 2021.

EDITOR'S NOTE

In addition to the resources noted in the article, other tools, webinars, and related articles can be accessed through the PCI website. Included are two new PCI eLearning modules—T624: Overview of PCI's Recommended Practice for Prestressed Concrete Piles *and T626:* Application of PCI's Recommended Practice to Building Piles*—which are now available at https://www.pci.org/HowPrecastBuilds/Component/Piles.aspx.*