# Precast/Prestressed Concrete Piling

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Prestressed concrete piles are:

- Economical
- Durable
- Maintenance Free
- Ecologically Safe
- Ductile
- High Capacity
PRESTRESSED CONCRETE PILING

SQUARE

SOLID OCTAGONAL

HOLLOW OCTAGONAL

HOLLOW CYLINDER
## PRESTRESSED CONCRETE PILING PROPERTIES

<table>
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<th>PILE SECTION</th>
<th>Outside Dimension (in.)</th>
<th>Inside Diameter (in.)</th>
<th>Perimeter (in.)</th>
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<th>A (in.²)</th>
<th>I (in.⁴)</th>
<th>r (in.)</th>
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<th>Allowable Axial Load (Laterally Supported) (4)</th>
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**CONTACT CONCRETE TECHNOLOGY CORPORATION FOR MAXIMUM LENGTHS, CURRENT AVAILABILITY, AND PRODUCTION RATES FOR ANY OF THE ABOVE SIZES.**

**NOTES:**
1. Pile weights are based on 158 pcf combined concrete/reinforcement unit weight.
2. Number of 4" diameter, 270 ksi, low relaxation, seven wire strands, jacked to 0.75 fpu = 202.5 ksi.
3. Effective precompression in the concrete after long term prestress losses.
4. P = A (0.33f'c - 0.27fpd) in accordance with References 1, 2, & 3. The values derived from this equation, and reflected in the table above, are for concentrically loaded short columns. References 2 & 3 recommend the use of this equation for values of 4/πr less than 60, where r'c is the effective unsupported length of the pile, and r is the radius of gyration. In cases where r'r'c is greater than 60, or when the piles are loaded under combinations of axial load and moment, the interaction diagrams of Appendix B should be used in design.
5. Concrete cover over reinforcement = 2 in.
6. Allowable axial loads shown apply for conditions where the pile strength controls. Lower values may be dictated by the soil conditions.
7. This table is intended as an aid to preliminary sizing and must be interpreted on the basis of sound engineering judgement.
8. For additional information on specific applications, please contact Concrete Technology Corporation, (206) 383-3545.

**REFERENCES:**
NOTES:

1. See page 3 for definitions of high and low prestress levels.
2. For cases 1 & 2, do not allow pile tip to bear on other piling stored in a lower layer.
3. For cases 3 & 4, tilt the pile in the air, do not allow the pile to touch the ground.
4. The minimum angle between the pile and the lifting strap is 60 degrees when the pile is in the horizontal position.
5. The contractor is cautioned that storing piling without regard for proper bunking will result in breakage due to "highcentering" or other unplanned, incorrect support points.
6. Dragging a prestressed concrete pile across the ground into the leads may overstress the pile by impacts greater than those assumed in the preparation of these guidelines.
7. These guidelines do not apply to piling of a different size than shown, or to piling produced by other fabricators.
8. Solid end plugs in hollow piles, and driving tips on solid or hollow piles, will decrease the maximum lengths shown in the tables.
9. Concrete strength during field handling is assumed to be 6000 psi.
10. Impact on the dead weight of the pile is assumed to be 50%.
11. Tensile stress in the pile during field handling is limited to $3\sqrt{f_c}$, or 232 psi.
### MAXIMUM FIELD HANDLING LENGTHS

#### HIGH Prestress Level (Note 1)

<table>
<thead>
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<th>PILE SECTION</th>
<th>Outside Dimension (in.)</th>
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</table>
AXIALLY LOADED COMPRESSION OR TENSION PILES

DUCTILE PILES LESS THAN 35' LONG FOR AREAS OF SEISMIC RISK

DUCTILE PILES OVER 35' LONG FOR AREAS OF SEISMIC RISK

NOTES:

1. Clear cover over spiral is 2 in.

2. The value of the spiral reinforcement index $\rho_s$ can be calculated in accordance with PCI Committee on Prestressed Concrete Piling, "Recommended Practice for Design, Manufacture and Installation of Prestressed Concrete Piling," PCI JOURNAL, V. 38, No. 2, March-April 1993, Section 2.5.2, pp. 27-30.

3. When the pile length exceeds 35 ft., the ductile region is the distance from the underside of the pile cap to the point of zero curvature (point of fixity) plus 3 x D/12, or 35 ft., whichever is greater.

4. In non-ductile regions, spiral splices can be achieved by lapping two full turns of spiral. In ductile regions, spiral may be spliced by lapping one full turn and bending the end of the spiral to a 135° seismic hook, by welding, or by the use of a mechanical connector which will develop 125% of the yield of the spiral.

$D_{OS} = \text{Diameter of the prestressing strand (in.)}$
SPIRAL REINFORCEMENT
HOLLOW PILES

24" HOLLOW OCTAGONAL

HOLLOW CYLINDER

Note 1

D (in.)
JET PIPE DETAILS

JET PIPE

3" Steel nipple
3" Threaded steel coupling
3" Malleable iron 90° elbow
3" Steel to PVC adapter
3" Sched. 40 PVC pipe
3" Steel to PVC adapter
3" to 1½" Malleable iron reducer
1½" Steel nipple x 4" long

DRIVING TIPS

A

Rebar as required
Typ.

Bearing plate

HP Section as required
Hardened steel tip (optional)

SECTION 'A'

3½' Typ.
a = Length........................................... +6 in., -2 in.
b = Width or diameter .................................. ±3/8 in.
c = Sweep (variation from straight line parallel to centerline of pile) (considered to be a form tolerance) ........................................... ±1/8 in. per 10 ft.
d = Position of tendons.................................. ±1/4 in.
e = Wall thickness................................. -1/4 in., +1/2 in.
f = Position of handling devices............... ±6 in.
g = Position of steel driving tips.............. ±1/2 in.
h = Variation from specified end squareness or skew .............................................................................. ±1/4 in. per 12 in., ±1/2 in. max.
i = Local straightness any surface ................... .......................................................... ±1/4 in. per 10 ft.
j = Longitudinal spacing of spiral reinforce- ment ........................................................................... ±3/4 in.

PILE TO PILE CAP CONNECTIONS

Pour slot

Spiral Reinforcement

C.I.P. Concrete

Roughen surfaces to a 1/8" minimum amplitude

PILE EMBEDDED IN PRECAST PILE CAP

PILE EMBEDDED IN CAST-IN-PLACE PILE CAP

Mild steel reinforcement grouted into drilled or formed holes, (4) bars minimum

Same spiral reinforcement as req'd at the pile head

Length of formed or drilled hole to allow for potential cut-off and development length of rebar

PILE CUTOFF WITH STRANDS EXTENDED 2'-0" MINIMUM

PILE CUTOFF WITH LESS THAN 2'-0" EXTENDED STRAND
PILE TO PILE CAP CONNECTIONS

Mild steel reinforcement grouted into drilled or formed holes (minimum (4) bars and 1 3/8% area of pile cross section)

Same spiral reinforcement as req'd at the pile head

C.I.P. Concrete

Roughened surface

Expose spiral reinf. at the pile head and splice with new spiral in accordance with note 4 on sheet 6.

Note:
In hollow piles, rebar/spiral cage may be dropped into the circular void and concreted in a specified distance to facilitate pile buildups and connections.

BUILD-UP ON PILE DRIVEN BELOW CUTOFF

LIFTING LOOPS

270 ksi Strand

Patch recess with recommended material after cutting lifting loop

SOLID PILES

LARGE DIAMETER HOLLOW PILES

HOLLOW PILES

Lifting loops or other lifting devices are necessary for removing piles from the forms. These may also be used in the field, or they may be cut off and patched at CTC’s plant prior to shipping. It is generally not necessary to cut and patch lift loops when their final position is more than 10 feet below grade or mud line. Lift loop patches should be allowed to cure at least 24 hours prior to driving. Field patching of lift loops should follow CTC’s recommended procedure.
PILE SPLICES

Many different types of splices are available for joining piles in the field so that driving may continue. Some are proprietary, but many are not. Each type has advantages and disadvantages with regard to constructability and structural performance. The following references contain detailed information on specific pile splices:


Contact Concrete Technology Corporation (206) 383-3545 for further information on pile splices.
PART 1 - GENERAL

1.01 DESCRIPTION
   A. Work Included
      This section covers requirements for the manufacture, delivery, and installation of precast prestressed concrete piling as indicated on the plans and as specified herein.
   B. Related Work Specified Elsewhere
      (Optional section - to be supplied by specification writer, if needed.)

1.02 QUALITY ASSURANCE

   A. Driving
      It is the Contractor's responsibility to install in an undamaged condition all the piles to the tip elevations on the drawings or to refusal as defined by the Engineer. The Contractor shall select, subject to the approval of the Engineer, the hammer size and cushion type and thickness, and the frequency of replacement of cushions so that piles can be installed without damage. If piles are hollow (voided) or if they contain internal jet pipe, the Contractor shall submit, subject to the approval of the Engineer, the methods and procedures to be used during driving or jetting to ensure that the piles are not damaged by bursting forces from "water hammer" or jetting/driving operations.
   B. Manufacturer's Qualifications
      The precast concrete manufacturing plant shall be certified by the Precast/Prestressed Concrete Institute (PCI) Plant Certification Program. Manufacturer shall be certified at the time of bidding. Certification shall be in the following product groups and categories: C3 or C4. Written evidence may be required listing experience, plant facilities, quality control procedures, staff, and any other documentation needed to establish adequate qualifications for manufacture of the piles. A Manufacturer which meets these qualifications is: CONCRETE TECHNOLOGY CORPORATION, Tacoma, Washington.
C. Testing and Manufacturing Procedures
Fabrication and in-plant testing shall be in general compliance with the applicable provisions of PCI MNL-116, "Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products," latest edition.

D. In-Plant Inspection
In-plant inspection of materials and finished products shall be under the supervision of the Manufacturer's Quality Assurance Manager and shall comply with the provisions of PCI MNL-116 and the Manufacturer's documented quality assurance program.

1.03 CODES AND STANDARDS
In addition to all applicable codes, the following codes and standards shall apply, except as may be modified herein:
C. ACI 214, "Recommended Practice for Evaluation of Strength Test Results of Concrete," latest edition.

1.04 SUBMITTALS
A. Pile order lists, details of equipment and methods proposed for handling and driving piles, and the sequence of construction. Driving of piles shall not commence until the Engineer's review of proposed equipment is complete and an authorization to proceed is given.
B. Manufacturer qualifications, as specified in 1.02-B.
C. Shop drawings showing the number and size of prestressing strands, prestress force, reinforcing, mark numbers, pick point locations, and all other details necessary for manufacturing and handling the prestressed concrete piles. Casting of piles shall not commence until shop drawings are approved by the Engineer.
1.05 PRODUCT DELIVERY, STORAGE AND HANDLING
Piles shall be lifted and supported during manufacturing, storage, transportation and driving operations only at the lifting and supporting locations shown on the shop drawings. All lifting devices shall have a minimum safety factor of three. If stacked in multiple layers during storage and shipment, suitable bunks shall be used between each pile at the support locations, with lifting devices accessible and undamaged.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Portland Cement: ASTM C 150, “Standard Specification for Portland Cement.” Types I, II, or III cement may be used, provided the C₃A content does not exceed 8 percent.
C. Water: Clean, potable and free from injurious amounts of oils, acids, alkalis, organic materials, or other substances that may be deleterious to concrete or steel.
H. Corrugated Metal Duct: Galvanized, corrugated steel interlocked duct, mortar tight, and free from grease, paint, or other substances which could interfere with proper bond of concrete or grout.
I. Jet Pipes: As shown on the drawings or as detailed by the pile manufacturer. Details and material shall be shown on the shop drawings and approved by the Engineer.
2.02 CONCRETE MIXES
Mix designs shall be developed by the pile Manufacturer using the materials as specified herein. The designs shall comply with the requirements of ACI 318 and shall have been prepared in accordance with ACI 211.1, for the concrete strengths shown on the contract drawings. The mix designs shall be based on materials previously evaluated by the pile Manufacturer using established methods of statistical quality control that conform to ACI 214.

2.03 FORMWORK
Provide exterior forms of steel on concrete founded casting beds. Side forms for square piles may have minimum draft adequate for stripping. Interior forms shall be of steel and either the fixed-collapsible or moving-mandrel type capable of maintaining specified dimensional tolerances. Forms must be cleaned and oiled prior to placement of reinforcing.

2.04 PLACEMENT OF REINFORCING
Place prestressing strands symmetrically in the piles and jack simultaneously to specified force. Space spiral wire to specified pitch and tie adequately to maintain position during placement of concrete.

2.05 PLACEMENT OF CONCRETE
Place concrete continuously and consolidate with high frequency vibration. Strike-off unformed surfaces and apply good float finish.

2.06 CURING
Cover forms with moisture-retaining cover and apply heat in uniform manner. Embed thermocouples in piles and connect through central computer to electrically heated test cylinders for constant monitoring of curing temperatures and to insure that test cylinders and piles are heated equally.

2.07 STRIPPING AND HANDLING
When a test cylinder made from the concrete pour for the piles involved reaches the minimum release strength specified, detension strands gradually and simultaneously so as to maintain internal stresses uniform across the pile cross sections. Burn strands flush with ends of piles. Handle and transport piles as described in paragraph 1.05 above. Do not drive piles until they have reached both their required 28 day strength and a minimum age of 10 days.
2.08 FINISHES
Piles with minor imperfections which do not impair the structural integrity of the pile, such as small surface holes caused by air bubbles, color variations, form joint marks, and minor chips and spalls will be accepted as is. Marina guide piles shall be sacked to five feet below extreme low water. Piles with defects such as honeycomb which could reduce the structural capacity of the pile will be accepted only if repaired to the Engineer’s satisfaction.

2.09 PATCHING OF LIFT LOOPS
Prior to driving piles in a marine or fresh water location, cut off and patch embedded lifting loops at elevations higher than 10 feet below the mudline using materials and methods as recommended by the Manufacturer.

2.10 MANUFACTURING TOLERANCES
A. Length ................................................................. +6 in., -2 in.
B. Width or diameter ............................................. ±3/8 in.
C. Sweep (variation from straight line parallel to centerline of pile) (considered to be a form tolerance) .............. ±1/8 in. per 10 ft.
D. Position of tendons ............................................. ±1/4 in.
E. Wall thickness .................................................. -1/4 in., +1/2 in.
F. Position of handling devices ................................ ±6 in.
G. Position of steel driving tips ................................ ±1/2 in.
H. Variation from specified end squareness or skew ................. ±1/4 in. per 12 in., ±1/2 in. max.
I. Local straightness any surface ...................... ±1/4 in. per 10 ft.
J. Longitudinal spacing of spiral reinforcement ............. ±3/4 in.

PART 3 - EXECUTION

For recommendations and precautions for preventing damage to piles during driving, please refer to Chapter 5 - Installation of Prestressed Concrete Piles in the PCI Committee Report entitled “Recommended Practice for Design, Manufacture and Installation of Prestressed Concrete Piling,” PCI JOURNAL, V. 38, No. 2, March-April 1993, pp 36-41.

*********************************************************************************************

MANUFACTURERS OF PRESTRESSED CONCRETE ● TACOMA, WASHINGTON
PILE INTERACTION DIAGRAMS

The following pages contain interaction diagrams for use in the design of prestressed concrete piles. These are to be used only in conjunction with the design procedure and examples outlined in the references below:


These interaction diagrams are not to be used in conjunction with other column design procedures, such as moment magnification or P-delta analyses.

As noted in Reference 2 above, these diagrams are generally applicable to concentrically loaded piles with \( \ell / r \) greater than 60, or to piles loaded under combinations of axial load and moment. The variable \( \ell \) represents the effective unsupported length of the pile, and corresponds with the variable \( h' \) in the references above, while \( r \) is the radius of gyration.

Contact Concrete Technology Corporation with questions on the proper use of these diagrams, (206) 383-3545.
10" SOLID SQUARE PILE, 4-STRANDS

\[ f'_C = 6 \text{ ksi} \]

\[ f'_C = 7 \text{ ksi} \]

\[ f'_C = 8 \text{ ksi} \]
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10" SOLID SQUARE PILE, 5-STRANDS

\[ f'_C = 6 \text{ ksi} \]

\[ f'_C = 7 \text{ ksi} \]

\[ f'_C = 8 \text{ ksi} \]
12" SOLID SQUARE PILE, 4-STRANDS

\[ f'_C = 6 \text{ ksi} \]

\[ f'_C = 7 \text{ ksi} \]

\[ f'_C = 8 \text{ ksi} \]
14" SOLID SQUARE PILE, 6-STRANDS

\( f'_c = 6 \text{ ksi} \)

\( f'_c = 7 \text{ ksi} \)

\( f'_c = 8 \text{ ksi} \)
16" SOLID SQUARE PILE, 7-STRANDS

\[ f'_C = 6 \text{ ksi} \]

\[ f'_C = 7 \text{ ksi} \]

\[ f'_C = 8 \text{ ksi} \]
20" SOLID OCTAGONAL PILE, 9-STRANDS

$f_C = 6$ ksi

$f_C = 7$ ksi

$f_C = 8$ ksi
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20" SOLID OCTAGONAL PILE, 16-STRANDS

\[ f'_{C} = 6 \text{ ksi} \]

\[ f'_{C} = 7 \text{ ksi} \]

\[ f'_{C} = 8 \text{ ksi} \]
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24" SOLID OCTAGONAL PILE, 22-STRANDS

$f'_c = 6$ ksi

$f'_c = 7$ ksi

$f'_c = 8$ ksi
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24/15" HOLLOW OCTAGONAL PILE, 8-STRANDS

\( f_c' = 6 \text{ ksi} \)  \( f_c' = 7 \text{ ksi} \)

\[ \text{AXIAL LOAD } \phi P_n \text{ (kips)} \]

\[ \text{BENDING MOMENT } \phi M_n \text{ (ft.k}) \]

\( f_c' = 8 \text{ ksi} \)

\[ \text{AXIAL LOAD } \phi P_n \text{ (kips)} \]

\[ \text{BENDING MOMENT } \phi M_n \text{ (ft.k}) \]

MANUFACTURERS OF PRESTRESSED CONCRETE • TACOMA, WASHINGTON
36/26" HOLLOW CYLINDRICAL PILE, 13-STRANDS

$f_c = 6$ ksi

$f_c = 7$ ksi

$f_c = 8$ ksi