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USACE / NAVFAC / AFCESA **UFGS-02458A (February 1998)**

Preparing Activity: USACE **Replacing without revision**
CEGS of same number and date

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 25 June 2004
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DIVISION 02 - SITE CONSTRUCTION

SECTION 02458A

PRESTRESSED CONCRETE PILING

02/98

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SECTION 02458A

PRESTRESSED CONCRETE PILING
02/98

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NOTE: This guide specification covers the requirements for prestressed concrete piles for fresh water and for marine use.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents**, including their organization designation and telephone number, is on the Internet.**

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR)**.**

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.
****

PART 1 GENERAL

1.1 REFERENCES

****
NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ACI INTERNATIONAL (ACI)

ACI 214R	(2002) Evaluation of Strength Test Results of Concrete
ACI 304R	(2000) Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 318/318R	(2002) Building Code Requirements for Structural Concrete and Commentary
ACI SP-66	(1994) ACI Detailing Manual

AMERICAN WELDING SOCIETY (AWS)

AWS D1.4	(1998) Structural Welding Code - Reinforcing Steel

ASTM INTERNATIONAL (ASTM)

ASTM A 416/A 416M	(2002) Steel Strand, Uncoated Seven-Wire for Prestressed Concrete
ASTM A 421	(1998a) Uncoated Stress-Relieved Steel Wire for Prestressed Concrete
ASTM A 615/A 615M	(2003a) Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM A 616/A 616M	(1996a) Rail-Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A 617/A 617M	(1996a) Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A 82	(2002) Steel Wire, Plain, for Concrete Reinforcement
ASTM C 109/C 109M	(2002) Compressive Strength of Hydraulic Cement Mortars (Using 2-in. [50-mm] Cube Specimens)
ASTM C 136	(2001) Sieve Analysis of Fine and Coarse Aggregates
ASTM C 143	(1998) Slump of Hydraulic Cement Concrete
ASTM C 150	(2002ae1) Portland Cement
ASTM C 172	(1999) Sampling Freshly Mixed Concrete
ASTM C 260	(2001) Air-Entraining Admixtures for Concrete
ASTM C 31/C 31M	(2003a) Making and Curing Concrete Test Specimens in the Field
ASTM C 33	(2003) Concrete Aggregates

ASTM C 39	(1993a) Compressive Strength of Cylindrical Concrete Specimens
ASTM C 494	(1992) Chemical Admixtures for Concrete
ASTM C 566	(1997) Total Evaporable Moisture Content of Aggregate by Drying
ASTM C 595	(2003) Blended Hydraulic Cements
ASTM C 595M	(1997) Blended Hydraulic Cements (Metric)
ASTM C 666	(2003) Resistance of Concrete to Rapid Freezing and Thawing
ASTM C 70	(1994; R 2001) Surface Moisture in Fine Aggregate
ASTM D 1143	(1981; R 1994e1) Piles Under Static Axial Compressive Load

PRECAST/PRESTRESSED CONCRETE INSTITUTE (PCI)

PCI JR-119	(1972) Grouting of Post-Tensioned Prestressed Concrete
PCI MNL-116	(1999) Quality Control for Plants and Production of Structural Precast Concrete Products
PCI MNL-120	(1999) Design Handbook - Precast and Prestressed Concrete
PCI STD-112	(1984) Standard Prestressed Concrete Piles Square, Octagonal and Cylinder

1.2 BASIS FOR BIDS AND PAYMENT

****

NOTE: This paragraph anticipates bids on a lump sum price for an entire project, including prestressed concrete piling, with directed changes in accordance with the CONTRACT CLAUSES or with the unit prices defined in the following subparagraphs. Where the basis for bidding is based on unit price, this paragraph should be deleted and the following paragraph used instead.

BASIS OF PAYMENT:

Unit Price: The Contracting Officer reserves the right to increase or decrease the length of piles to be furnished and installed by changing the foundation pile locations or elevations, requiring the installation of additional piles, or requiring omission of piles from the requirements shown and specified. Whether or not such changes are made, the Contractor will be paid at the contract unit price per linear meter foot (including control test

piles), multiplied by the total length of acceptable piles actually installed.

Full Compensation: Payment in accordance with the above paragraph, Unit Price, shall constitute full compensation for furnishing, delivering, handling, and/or installing (as applicable) all material, labor and equipment necessary to meet contract requirements applicable to the foundation piles. The Contractor will not be allowed payment for withdrawn, broken, or rejected piles or (except for control test piles) for any portion of a pile remaining above the cut-off point.

Substitute Pile: In the event the Contracting Officer directs the Contractor to install foundation piles of a size different from that specified, the difference in the supplier's market price as of the date of bid opening, between that originally specified and that specified in the change order shall be multiplied by the total number of linear meters feet of the substitute pile actually installed and accepted. Payment to the Contractor, in accordance with the preceding paragraph, will be adjusted upward or downward, as the case may be, by the foregoing amount.

Load Tests: The contract includes [_____] pile load tests. The Contracting Officer reserves the right to increase or decrease the number of load tests. Adjustments in the bid price will be made for such increase or decrease in the amount of bid for "Additional Pile Load Test" or "Omitted Pile Load Test."

****

1.2.1 Principal Sum

The contract price for piling shall be a principal sum based on TABLE 1 (including [_____] test piles) having a total aggregate length of [_____] linear meters feet and shall include [_____] -metric ton-ton load test and [_____] test pile withdrawals.

TABLE 1. PILE SCHEDULE FOR BIDDING

Location	Number	Size	Capacity	Length
[_____]	[_____]	[_____]	[_____]	[_____]

1.2.2 Variations in Pile Quantities

From the results of laboratory tests on soil samples and data obtained as a result of driving and loading the test piles specified herein, the Contracting Officer will determine and will list for the Contractor "calculated" pile tip elevations and the minimum driving resistance for all piles. The Contracting Officer reserves the right to increase or decrease the total length of piles to be furnished and installed by changing the pile locations or elevations, requiring the installation of additional piles, or directing the omission of piles from the requirements shown and specified. Should the total pile length installed vary from that specified as the basis for bidding because of added or omitted piles or variations in the pile lengths, the principal sum shall be adjusted [in accordance with the CONTRACT CLAUSES] [by the applicable contract unit price per linear meter foot for "Additional Pile Length" or "Omitted Pile Length" (by size)].

1.2.3 Variations in the Number of Pile Load Tests

The Contracting Officer reserves the right to increase or decrease the number of pile load tests from that specified for the basis of bidding. For changes in the number of load tests required, the principal sum price shall be adjusted [in accordance with the CONTRACT CLAUSES] [by the applicable contract unit price for "Each Additional Pile Load Test" or "Each Omitted Pile Load Test"].

1.2.4 Basis of Payment

The Contractor shall furnish, and the price shall include, all necessary equipment, tools, material, labor, and supervision required to: deliver, handle, install, and cut off the piles (including test piles); conduct the load tests; and meet the applicable contract requirements. Payment for piles will be on the basis of the lengths of the piles measured from cut off elevations to final tip elevations. No additional payment will be made for: withdrawn, damaged, rejected, or misplaced piles; any portion of a pile remaining above the cut off elevation; backdriving; cutting off piles; splicing; build-ups; or any cut off lengths of piles. Payment for load tests shall be made for each load test satisfactorily performed.

1.3 SUBMITTALS

****

NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A “G” following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a “G”. Only delete an existing “G” if the submittal item is not complex and can be reviewed through the Contractor’s Quality Control system. Only add a “G” if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.
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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Installation

Drawings including shop and erection details and details of collars, shoes, splices, build-ups and embedded or attached lifting devices, prior to commencing the work or ordering materials. Drawings shall indicate pick-up and support points for piles. Reinforcing steel details shall conform to ACI SP-66.

Pile Driving.

A complete and accurate record of all driven piles. The record shall include the pile number or identification, location, size, length, elevation of tip and top of pile, and the number of blows required for each foot of penetration throughout the entire length of the pile, and the number of blows per inch for the last 450 mm 18 inches of penetration. The record shall include the type and size of the hammer, the rate of operation, the type and dimensions of driving helmet, and the cap-block and pile cushion used. Any unusual occurrence during driving of the pile shall be recorded and immediately reported to the Contracting Officer. The Contractor shall notify the Contracting Officer 10 days prior to driving of [test] [and load test] piles.

SD-03 Product Data

Pile Driving Equipment.

Descriptions of all pile driving equipment to be employed in the work, prior to commencement of pile installations, including details of the pile hammer, power plant, lead, cushion material, cap block, and helmet.

SD-06 Test Reports

Field Tests and Inspections.

Load Test Reports: A complete report on the load test, including, but not limited to, a description of the pile driving equipment, driving records for both test piles and reaction piles, complete test data, analysis of test data, and recommended allowable design loads based on the load test results, within [7] [_____] days of completion of load test. The report shall be prepared by or under the direct supervision of a registered professional engineer experienced in pile load testing and load test analysis.

Material Test Reports: Copies of material test reports and mix proportioning studies, within 24 hours after completion of tests.

1.4 QUALIFICATIONS

The work shall be performed by a firm specializing in the specified foundation system and having experience in constructing and installing the specified foundation system under similar subsurface conditions.

1.5 SUBSURFACE DATA

Subsurface soil data logs are shown [on the drawings] [in the specifications]. The subsurface [investigation reports] [and] [samples of materials as taken from subsurface investigations] are available for examination at [_____].

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Admixtures

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NOTE: Air-entraining admixtures are less effective when used with low-slump, high-strength concrete. Furthermore, the need for air entrainment is reduced in high-strength concrete because of its high density and low porosity. The designer should carefully weigh the site conditions against the quality of the pile specified before making a decision on whether or not to call for air entrainment.

****

Admixtures, if used in the concrete mixtures, shall be used at no additional cost to the Government. Chemical admixtures shall conform to ASTM C 494. Air-entraining admixture shall conform to ASTM C 260. Admixtures containing chlorides shall not be used.

2.1.2 Aggregates

****

NOTE: Modify the requirements in ASTM C 33 as necessary to suit local conditions. For exposed piles in areas where reactive aggregates are found, provide for additional tests and certification to insure that reactive aggregates will not be used. While not wholly conclusive, petrographic examination (ASTM C 295), chemical test (ASTM C 289), provide valuable indicators. The mortar bar method (ASTM C 227), while more reliable, requires at least 6 months and preferably 1 year to yield results. Consider the use of low alkali cement in combination with aggregates which deleteriously react with the alkali in cement in areas where substitution of aggregate is not feasible. Service

records of concrete made with these materials along with tests should be used in evaluating these materials.

****

2.1.2.1 General Requirements

Aggregates shall conform to ASTM C 33, except as specified otherwise herein. Aggregates shall be free from any substance which may be deleteriously reactive with the alkalies in the cement in an amount sufficient to cause excessive expansion of the concrete.

2.1.2.2 Fine Aggregates

Fine aggregates from different sources of supply shall not be mixed or stored in the same stock pile, or used alternately in the same concrete mix or the same structure without approval. The fineness MODULUS of fine aggregate shall be not less than 2.40 or greater than 3.0. For piles that will be exposed to freezing and thawing, fine and coarse aggregate subjected to five cycles of the sodium sulfate soundness test shall show a loss not greater than 10 percent. If the selected aggregates fail the soundness test, the Contractor may use the aggregate source, provided concrete specimens made with the aggregates to be used for the piles shall have a durability factor of not less than 80 based on 300 cycles of freezing and thawing when tested in accordance with ASTM C 666.

2.1.3 Anchorage

Anchorage and end fittings for post-tension assemblies shall conform to ACI 318/318R.

2.1.4 Cement

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NOTE: For piles used in soil containing from 0.10 to 0.20 percent water soluble sulfate or used in fresh water containing sulfate from 150 to 2000 parts per million (ppm), the tricalcium aluminate content of the cement shall be limited to 8 percent. In soil or fresh water environments where the water soluble sulfate exceeds 0.20 percent or the sulfate solution contains from 2000 to 10,000 ppm, the tricalcium aluminate content shall be limited to 5 percent. For very severe sulfate exposure (more than 10,000 ppm in fresh water), Type V cement with a fly-ash mixture shall be used. For seawater exposure the tricalcium aluminate content shall be limited to [_____] percent. For piles in a seawater environment the tricalcium aluminate content in cement in ordinary cast concrete should be limited to 8 percent for "cold seawater" (temperature for long periods varies above and below 10 degrees C) and limited to 10 percent for "warm seawater." Warm seawater areas would include the Florida Coast, the Gulf Coast, the Southern California Coast, and Hawaii. For high-quality concrete produced by centrifugal casting using no-slump concrete and with low absorption factor, the tricalcium aluminate content is not critical.

****

Cement shall conform to ASTM C 150. Type IV cement shall not be used. [Cement shall contain less than [_____] percent tricalcium aluminate (C3A).] [Hydraulic cement ASTM C 595M ASTM C 595, Type [_____] is permitted.]

2.1.5 Grout

Grout materials used in prestressed piles shall conform to the requirements specified herein for concrete mixes. Grout for post-tensioned ducts and bonds shall conform to PCI JR-119. Admixtures, when required for grout, shall have no injurious effects on steel or concrete. Calcium chloride shall not be used.

2.1.6 Prestressing Steel

Prestressing steel shall be seven-wire stress-relieved strand conforming to ASTM A 416/A 416M or stress-relieved wire conforming to ASTM A 421, Type WA. The minimum ultimate strength shall be 172 MPa. 250,000 psi. Prestressing steel shall be free from grease, oil, wax, paint, soil, dirt, loose rust, kinks, bends, or other defects.

2.1.7 Reinforcing Steel

Non-prestressed reinforcing steel shall conform to [ASTM A 615/A 615M] [ASTM A 616/A 616M] [ASTM A 617/A 617M], Grade [_____]. Welding of reinforcing steel shall be in accordance with AWS D1.4.

2.1.8 Ties and Spirals

Steel for ties and spirals shall conform to ASTM A 82.

2.1.9 Water

Water for mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalies, salts, organic materials, or other substances that may be deleterious to concrete or steel. Mortar cubes made with nonpotable mixing water shall have 7-day and 28-day strengths equal to at least 90 percent of the strengths of similar specimens made with potable water.

2.2 MANUFACTURED UNITS - GENERAL REQUIREMENTS

Concrete piles shall be designed and fabricated by a precast concrete manufacturer certified under the PCI Plant Certification Program.

2.2.1 Pretensioned Piles

Pretensioned piles may be solid or hollow and shall be cast as monolithic units of homogenous high-strength concrete from head to tip and stressed with high-tensile cold-drawn stress-relieved steel strands.

2.2.2 Post-Tensioned Piles

Post-tensioned piles shall be hollow and cast in sections or as monolithic units stressed with high-tensile cold-drawn stress-relieved wire or strand. Design criteria shall be in accordance with PCI MNL-120.

2.2.3 Seawater Exposure

****
NOTE: Delete paragraph pertaining to seawater exposure along with referenced documents when not applicable to the project. Delete requirement for air entrainment for pile strengths 48 MPa (7000 psi) and greater.
****

For piles to be exposed to seawater, the concrete mix design and the concrete materials should be selected, placed, and cured in a manner that ensures production of extremely dense concrete free of shrinkage cracks and honeycomb with a minimum degree of permeability. The maximum permissible water-cement ratio (by weight) shall be 0.40 or 17 liters 4.5 gallons of water per sack of cement. The cement shall be air entrained with a minimum of 4.5 percent and a maximum of 6 percent air entrainment, accomplished by use of an additive at the mixer and approved by the Contracting Officer.

2.2.4 Conveying

Concrete shall be conveyed from the mixer to the forms as rapidly as practicable by methods that will not cause segregation or loss of ingredients in accordance with ACI 304R. It shall be deposited as nearly as practicable in its final position in the forms. At any point in conveying, the free vertical drop of the concrete shall not exceed 1 meter. 3 feet. Chuting will be permitted only where the concrete is deposited into a hopper before it is placed in the forms. Conveying equipment shall be cleaned thoroughly before each run. Concrete shall be deposited as soon as practicable after the forms and the reinforcement have been inspected. Concrete that has segregated in conveying shall be removed.

2.2.5 Protection From Freezing

For hollow piles exposed to freezing, drain holes shall be provided through the pile wall at approximately the ground water elevation and the pile filled with free-draining material. For hollow piles standing in open water, a concrete plug shall be placed from the lowest freeze depth to a minimum of 300 mm 1 foot above the maximum high water level and drain holes through the pile wall shall be provided just above the surface of the concrete plug.

2.3 FABRICATION OF PRETENSIONED PILES

2.3.1 Workmanship

****
NOTE: Pile pick-ups points should be shown on the project drawings, and should be considered in the design. Insert ultimate compressive strength.
****

Workmanship shall conform to PCI MNL-116. Pile pick-up points shall be [located where indicated] [the responsibility of the Contractor]. Unless special lifting devices are attached for pick-up, pick-up points shall be plainly marked on all piles after removal of the forms, and all lifting shall be done at these points. Piles shall be lifted by a suitable bridge or sling attached to the pick-up points. Piling shall not be driven until the concrete attains a compressive strength of not less than [_____] MPa psi as indicated by breaking test cylinders.

2.3.2 Forms

Forms shall be of metal, shall be well braced and stiffened against deformation, and shall be accurately constructed and watertight. Forms shall permit movement of the pile without damage during release of the prestressing force. Bottom of the form shall be within 6 mm 1/4 inch of a true plane in a length of 15 meters. 50 feet.Inside forms or void tubes may be of treated fiberboard, plywood, or other material and/or method approved by the Contracting Officer. Void forms shall be anchored firmly so they will not move, float, or collapse during the placing of concrete. If a moving mandrel is used for forming the inner void, special precautions shall be taken to prevent fallout of inner surfaces, tensile cracks, and separation of concrete from strands.

2.3.3 Reinforcement and Embedments

Reinforcing steel, prestressing steel, and embedded items shall be accurately positioned in the forms and secured to prevent movement during concrete placement. All steel shall have a minimum concrete cover of 50 mm, 2 inches, except in marine or other corrosive environments where the minimum concrete cover shall be 65 mm. 2-1/2 inches.

2.3.4 Concrete Work

****

NOTE: Insert the ultimate compressive strength as required by the design. Select slump tolerance acceptable to industry in vicinity of project such as 50 to 100 mm (2 to 4 inches).

****

The concrete mix shall have an ultimate compressive strength of [_____] MPa psi at 28 days and a slump of [_____] to [_____] mm. inches. Concrete piles exposed to conditions of freezing and thawing shall contain from 4 to 7 percent entrained air provided by the use of an air-entraining admixture conforming to ASTM C 260. Concrete shall not be deposited in the forms until the placement of reinforcement and anchorages has been inspected and approved by the Contracting Officer. Each pile shall be produced of dense concrete with smooth surfaces. Concrete shall be placed promptly after mixing is completed and shall be deposited close to its final position in the form. Vibrator heads shall be smaller than the minimum distance between steel for pretensioning. Dimensional tolerances shall conform to PCI MNL-116. The ends of all piles and the corners of square piles shall be chamfered. Side forms shall not be removed until concrete has attained 24 MPa3500 psi compressive strength.

2.3.5 Pretensioning

Anchorages for tensioning the prestressing steel shall be a type approved by the Contracting Officer. The tension to which the steel is to be pretensioned shall be measured by the elongation of the steel and verified by the jack pressure reading on a gauge. The gauge shall have been recalibrated by a calibration laboratory approved by the Contracting Officer within 12 months of commencing work and every 6 months thereafter during the term of the contract. Means shall be provided for measuring the elongation of the steel to at least 3 mm. 1/8 inch. When the difference between the results of measurement and gauge reading is more than 5 percent, the cause of the discrepancy shall be corrected. The tensioning steel shall be given a uniform prestress prior to being brought to design prestress. The same initial prestress shall be induced in each unit when several units of prestressing steel in a pile are stretched simultaneously.

2.3.6 Detensioning

Releasing of prestressing force in pretensioned piles shall be performed in a manner that minimizes eccentricity of prestress. Tension in the strands shall be released from the anchorage gradually. In no case shall the stress be released after casting without approval by the Contracting Officer. The transfer of prestressing force shall be done when the concrete has reached a compressive strength of not less than 24 MPa.3500 psi.

2.3.7 Curing of Piles

Prior to the start of curing operations, the methods and details of curing shall be submitted for record and shall be approved by the Contracting Officers. All piles shall be cured in accordance with Section 4 of PCI MNL-116.

2.3.8 Build-Ups

****

NOTE: Insert the concrete strength as required by the design. Insert maximum percent of build-ups permitted for the project. The percent will depend on the criticality of the pile failure at the build-up; whether the top of the pile is designed as a moment connection; exposure of the piles to external physical or corrosive damage. Normally, for piles supporting piers exposed to seawater, limit the percentage of build-ups to 10 percent.

****

If, in driving pretensioned piles, the Contracting Officer determines that the pile length is insufficient so that the final elevation of the pile head is below the indicated cut-off elevation, the pile section may be extended to the required elevation by means of a cast-in-place reinforced concrete build-up in accordance with procedures for build-up without driving as detailed in PCI STD-112. Details of means for protecting the joints by a suitable mortar or epoxy shall be approved by the Contracting Officer. Build-ups to be driven shall conform to the details of "Build-up with Driving" shown in the standard drawings referenced above. Where build-ups are exposed to water, the Contractor shall protect the cast-in-place section from the water during the curing period. Concrete in build-up shall have a minimum ultimate compressive strength of [_____] MPa. psi. Build-ups will not be permitted on more than [_____] percent of the total number of piles. If this percent figure is exceeded or if in the judgment of the Contracting Officer the clustered location of the build-ups is undesirable, piles of insufficient length shall be withdrawn and replaced with longer piles. Payment for such withdrawal and replacement will be made in accordance with the CONTRACT CLAUSES.

2.3.9 Splices

****

NOTE: Splicing of piles normally should not be

permitted except where extremely long or heavy piles are required. If splices are permitted, the drawings should indicate the splice detail. (See AASHTO-PCI standard drawings for typical splice detail.)
****

[Splicing of piles will not be permitted.] [Splices shall be as indicated on the drawings and payment for splices will be made as an adjustment to the contract price.]

2.4 FABRICATION OF POST-TENSIONED PILES

Piles shall be manufactured by the centrifugal casting process and cast in full lengths or in sections.

2.4.1 Metal Forms

Metal forms shall be used and shall be adequately braced and stiffened to prevent deformation under pressure of the wet concrete during spinning. The inside of forms including seams shall be smooth for thorough cleaning after each use. End forms must provide a true plane perpendicular to the axis of the cylindrical form with the following tolerances measured on the diameter: for abutting end-surfaces, 1.5 to 3 mm; 1/16 to 1/8 inch; for head end-surfaces, 13 mm; 1/2 inch; for point end-surfaces, 75 mm. 3 inches.

2.4.2 Nonprestressed Reinforcement

Each pile or pile section shall be reinforced with spiral steel as shown on the drawings. The spiral steel shall be held securely in position in the form during the spinning operation and positioned so there will be a minimum concrete cover of 32 mm 1-1/4 inches to the outer surface of the pile.

2.4.3 Longitudinal Ducts for Prestressing Steel

Sleeves used to form the longitudinal ducts in the pile wall for the prestressing steel shall be positioned so that there will be a minimum concrete cover of 38 mm 1-1/2 inches to the outer surface of the pile. The number, diameter, and arrangement of the longitudinal holes for the prestressing steel shall be as shown on the drawings.

2.4.4 Concrete

****
NOTE: Check with pile manufacturer for standard details which will vary with design requirements. Insert minimum ultimate concrete strength as required by the design, usually not less than 41 MPa (6000 psi).
****

Concrete shall have a minimum compressive strength of [_____] MPa psi in 28 days as determined by the standard cylinder tests of ASTM C 39. The fine and coarse aggregate shall be as nearly as possible of the same specific gravity. The concrete mix shall be so proportioned as to have zero slump to prevent any serious migration of the coarse aggregate during the centrifugal casting. Concrete test cylinders shall be cast on a vibrating table and a vertical force of about 1.334 kN (300 pounds) 300 pounds may be applied to the concrete cylinder during casting to aid compaction. Compaction and vibration shall be discontinued when excess water appears on the surface of the test cylinder.

2.4.5 Curing

After centrifugal casting, the pile or pile sections shall be steam-cured with the form on for a period of about 3 hours at a temperature not to exceed 71 degrees C. 160 degrees F. After the form has been removed, the pile or pile sections shall be further steam cured over a period of 12 hours in a manner to gradually reduce the temperature from 83 degrees C 150 degrees F to 11 degrees C 20 degrees Fhigher than ambient temperature. Alternatively, membrane curing or water curing may be used after the initial steam curing. Membrane curing compound shall be applied to all surfaces of the pile or pile sections to retain water for complete hydration.

2.4.6 Pile Assembly

If piles are made up of sections, the pile sections shall not be assembled together into a pile until the compressive strength of the concrete is at least 28 MPa 4000 psi as determined by test cylinders cured in the same manner as the pile sections. If membrane curing has been used, the abutting end-surfaces of all sections shall be sand-blasted to remove membrane curing compound. Pile sections shall be positioned in accurate alignment so that the axis of the pile does not deviate from a straight line more than 3 mm 1/8 inch per 3 m 10 feet of length. Adjacent sections shall be positioned so that the maximum deviation of the outside surfaces at the joint will not exceed 5 mm 1/4 inch and so that the maximum deviation circumferentially in the alignment of the prestressing cable ducts at the joint will not exceed 6 mm. 1/4 inch. The abutting end-surfaces of each section shall be covered with a sealing material of sufficient thickness to fill all voids between the end-surfaces (except the prestressing cable ducts) when the sections are brought together under compression. This sealing material shall attain a minimum ultimate compressive strength equal to or greater than that of the concrete and must be as resistant to exposure and weathering as is the concrete.

2.4.7 Post Tensioning

Piles shall not be prestressed until the concrete has attained a compressive strength of 28 MPa. 4000 psi. The prestressing cables shall be tensioned to an average unit stress as indicated on the drawings. The specified tension shall be measured by the elongation of the steel and verified by a pressure gauge on the stressing jack. The jack gauge shall have been calibrated within the past 6 months by a laboratory approved by the Contracting Officer. Means shall be provided for measuring the elongation of the steel to at least the nearest 3 mm. 1/8 inch.When the difference between the results of measurement and gauge reading is more than 5 percent, the cause of the discrepancy shall be determined and corrected. The tension in the cables shall be maintained by mechanical end-locks or anchors until final stress transfer. The aggregate prestress loss through transfer of stressing force from the jack to the temporary anchorage shall not exceed an average of 10 percent in any one cable or an average of 5 percent for all cables in any one pile.

2.4.8 Grouting

After completion of prestressing, the cable ducts shall be flushed clean and completely filled with grout consisting of portland cement and water mixed to a consistency suitable for pumping. The grout shall have a minimum 28-day compressive strength of 28 MPa 4000 psi as determined by tests on 50 by 50 by 50 mm 2-by 2-by 2-inch cubes and conforming to ASTM C 109/C 109M. After each cable duct has been filled with grout and the end closed off, the grout pressure shall be raised to a minimum of 690 kPa 100 psi which pressure shall be maintained by the grout pump for a minimum of 1 minute. The prestressing force shall be maintained by mechanical endlocks or anchors until the grout has attained sufficient strength to maintain the required effective prestress. During this period the pile shall not be moved or handled in any manner that could result in damage to the grout.

2.4.9 Stress Transfer

The transfer of the prestressing force from temporary end-locks to grouted cables shall not be done until the concrete and the grout have reached a compressive strength of not less than 29 MPa. 4000 psi. The prestressing cables shall be considered to be without slippage with the removal of the end-locks when, upon cutting the wires between the end of the pile and the anchor with a burning torch, the wires do not part under stress with a "cup and cone" fracture but are burned through with the torch.

2.5 MANUFACTURING CONTROLS

2.5.1 Initial Sampling and Testing

Testing shall be performed by an approved commercial testing laboratory or by an approved laboratory maintained by the manufacturer of the material.

2.5.1.1 Aggregates

Fine and coarse aggregates shall be tested for conformance with ASTM C 33.

2.5.1.2 Cement Test

Cement shall be tested at the mill or at the mixing plant for conformance with ASTM C 150.

2.5.1.3 Mix Proportions

Prior to commencing pile fabrication, the Contractor shall furnish a statement giving the maximum nominal coarse aggregate size and the proportions of all ingredients that will be used in the manufacture of each strength of concrete and lightweight concrete, proposed for use. Aggregate weights shall be based on the saturated surface dry condition. The statement shall be accompanied by test results from an independent commercial testing laboratory, attesting that the proportions selected will produce concrete of the qualities indicated. No substitutions shall be made in the materials used in the work without additional tests to show that the quality of the concrete is satisfactory. The statement shall also be accompanied by test results demonstrating compliance of aggregate and cement, as specified herein.

2.5.2 Sampling and Testing During Fabrication

2.5.2.1 Aggregate

Twice during each shift when the concrete plant is operating, the gradation of each size of aggregate shall be tested in accordance with ASTM C 136.

At least one test of moisture content of coarse aggregate, in accordance with ASTM C 566, and at least two tests of moisture content of fine aggregate, in accordance with ASTM C 70 or ASTM C 566, shall be made per shift.

2.5.2.2 Slump and Strength of Concrete

****

NOTE: Select minimum strength value below specified strength, such as 3.4 MPa (500 psi). (See ACI 318/R318.)

****

Two slump tests in accordance with ASTM C 143 shall be made for each 40 cubic meters 50 cubic yards of concrete produced per shift. Samples of fresh concrete shall be taken in accordance with ASTM C 172. Cylinders shall be molded and cured in accordance with ASTM C 31/C 31M, and tested in accordance with ASTM C 39. Samples for each class of concrete shall be taken not less than once a day nor less than once for each 40 cubic meters 50 cubic yards of concrete placed. Each strength test result shall be the average of two cylinders from the same sample tested at 28 days. Additional specimens shall be molded as needed by the Contractor or pile manufacturer. The Contractor or pile manufacturer shall mold, ship, cure, and test the cylinders. The cylinders shall be cured in the same manner as the piles and shall be placed at the point where the poorest curing conditions are offered. Evaluation of the compressive test results tested at 28 days shall be in accordance with ACI 214R. The Contractor or pile manufacturer shall certify that the sampling and test methods conform to the requirements of ASTM C 31/C 31M and ASTM C 39 and that sufficient samples were taken to evaluate the concrete as follows: The average of three consecutive strength tests shall equal or exceed the specified strength and no individual strength test result shall have less than the specified strength by more than [_____] MPa. psi. All test results shall be submitted to the Contracting Officer.

2.5.3 Changes in Proportions

If the test results of the laboratory cured cylinders at 28 days fall below the specified compressive strength, adjustments in the proportions, the water content, or both shall be made as necessary; if the test results of the field-cured specimens fall below the specified strength, changes in the casting, handling, or storage method and the moisture and curing procedures of such specimens shall be made as necessary to secure the specified strength. All changes shall be submitted in writing to the Contracting Officer. The slump shall be as specified.

PART 3 EXECUTION

3.1 INSTALLATION

3.1.1 Handling and Driving

****

NOTE: Check with pile manufacturer for standard details which will vary with design requirements. Insert minimum ultimate concrete strength as required by the design, usually not less than 41 MPa (6000 psi).

****

Piles or pile sections shall not be handled or moved in any manner that would result in cracking or permanent damage to the concrete or to the grout surrounding the prestressing cables. Piles shall not be driven until the concrete has attained a minimum strength of [_____] MPa. psi. Piles may be driven without pile guides or leads providing a hammer guide frame is used to keep the pile and hammer in alignment.

3.1.2 Pile Driving

****

NOTE: The last sentence, concerning tip elevation and driving resistance, should be edited to conform to subsurface conditions and type of pile (friction or end-bearing).

****

Excavation shall be stopped at 300 mm 1 foot above foundation grade before piles are driven. When pile driving is completed, excavation shall be completed to lines and grade shown. Piles shall be driven continuously and without interruption to or below the "calculated" tip elevation to reach a driving resistance in accordance with the schedule which the Contracting Officer will prepare from the load test results. Soil and water rising inside the pile more than 3 m 10 feet above the original ground or water level or to within 1.5 m 5 feet of the pile top shall be removed from inside hollow concrete piles before driving is continued. Vent holes to release internal pressure shall be provided as required when driving cylinder piles. The pile hammer used for driving shall be the same type, operated at the same rate and in the same manner, as that used for driving the test piles. Diesel-powered hammers shall be operated at the rate recommended by the manufacturer throughout the entire driving period. Sufficient pressure shall be maintained at the steam hammer so that:

a. For a double-acting hammer, the number of blows per minute during and at the completion of driving of the pile is equal approximately to that at which the hammer is rated.

b. For a single-acting hammer, there is a full upward stroke of the ram.

c. For a differential type hammer, there is a slight rise of the hammer base during each upward stroke.

If a pile fails to reach "calculated" tip elevation or if a pile reaches the "calculated" tip elevation without reaching the required driving resistance, the Contractor shall notify the Contracting Officer and perform corrective measures as directed by him.

3.1.3 Jetting of Piles

****

NOTE: Jetting should generally not be permitted for piles:

a. Dependent on side friction in fine-grained low permeability soils (high clay or silt content) where considerable time is required for the soil to reconsolidate around the piles.

b. Subject to uplift or lateral forces.

c. Adjacent to existing structures.

d. In closely spaced clusters unless the load capacity is confirmed by test.

****

[Jetting of piles will not be permitted] [When jetting of piles is permitted by the Contracting Officer, jetting shall be discontinued at a depth approximately 1.5 m 5 feet above the "calculated" tip elevation; the remaining penetration shall be achieved by driving. Before starting the driving of the final 1.5 m, 5 feet, the pile shall be firmly seated in place by the application of a number of reduced energy hammer blows].

3.1.4 Cutting of Piles

When necessary and approved by the Contracting Officer, cutting of piles shall be with pneumatic tools, sawing, or other approved methods. The use of explosives for cutting will not be permitted.

3.1.5 Protection of Piles

****

NOTE: Delete reference to batter piles when not applicable to the project.

****

Care shall be taken to avoid damage to the piles in handling piles, in placing the pile in the leads, and during the pile driving operations. Where pile or projecting reinforcement orientation is essential, special care shall be taken to maintain the orientation during driving. Special care shall be taken in supporting battered piles to prevent excessive bending stresses in the pile. The top of the pile shall be squared to the longitudinal axis of the pile. If the Contractor elects to use a pile head with projecting strands or mild steel reinforcing, a special driving head shall be used to prevent damage to the reinforcement and prevent direct impact forces from being transmitted through the reinforcement.

3.1.6 Tolerances in Driving

****

NOTE: Delete reference to batter piles when not applicable to the project.

Insert the allowable tolerance which would depend upon such things as pile size, cap details, site conditions, size of pile groupings, structure, etc. Tolerance should range from 75 to 150 mm (3 to 6 inches) with a lesser tolerance for smaller piles and a greater tolerance for larger piles.

****

All piles shall be driven with a variation of not more than 20 mm per meter 0.25 inch per foot of pile length from the vertical for plumb piles or more than 40 mm per meter 0.50 inch per foot of pile length from the required angle for batter piles. Top of pile shall be within [_____] mm inches of the location indicated. Manipulation of piles to force them into position will not be permitted. All piles will be checked for heave. Piles found to have heaved shall be redriven to the required point elevation.

3.1.7 Build-Ups

If any pile does not attain sufficient resistance or penetration when the pile head is at the established cut-off elevation, driving shall continue until the required resistance or penetration is reached. The pile shall be built-up to the specified cut-off elevation by a cast-in-place extension of the pile, by a pile section, or by use of an acceptable length of pile cut-off. The splice between the pile and build-up shall be accomplished by a poured plug of reinforced concrete extending a minimum of one outside-pile-diameter into the pile and an equal length into the build-up where possible. The splice plug may be an extension of the pile-to-cap connecting plug. If pile tops are damaged during driving, the damaged portion shall be removed and the pile built-up as necessary.

3.2 PILE DRIVING EQUIPMENT

3.2.1 Pile Hammers

****

NOTE: Delete reference to hollow concrete piles when not applicable to the project.

****

The hammer used shall have a delivered energy suitable for the total weight of the pile, the character or subsurface material to be encountered, and the pile capacity to be developed. For piles weighing less than 5.8 kN per meter (400 pounds per foot) 400 pounds per foot the driving energy of the hammer shall be not less than 0.3 N-m (1 foot-pound) 1 foot-pound of energy per meter foot of pile but not less than 20.3 kN-m (15,000 foot-pounds), 15,000 foot-pounds, the hammer for heavier piles, except hollow concrete piles, shall deliver not less than 40.7 kN-m (30,000 foot-pounds) 30,000 foot-pounds of energy. For hollow concrete piles, hammers shall deliver not less than 54.2 kN-m (40,000 foot-pounds) 40,000 foot-pounds of energy for piles having an outside diameter of 900 to 1350 mm, 36 to 53 inches, inclusive, and 65.1 kN-m (48,000 foot-pounds) 48,000 foot-pounds of energy for larger piles.

3.2.2 Driving Helmets and Pile Cushions

A driving helmet or cap including a pile cushion shall be used between the top of the pile and the ram to prevent impact damage to the pile. The driving helmet or cap and pile cushion combination shall be capable of protecting the head of the pile, minimize energy absorption and dissipation, and transmit hammer energy uniformly over the top of the pile. The driving helmet or cap shall fit loosely around the top of the pile so that the pile is not restrained by the driving cap if the pile tends to rotate during driving. The pile cushion may be of solid wood or of laminated construction, shall completely cover the top surface of the pile, and shall be retained by the driving helmet. The minimum thickness of the pile cushion shall be 75 mm (3 inches) 3 inches and the thickness shall be increased so as to be suitable for the size and length of pile, character of subsurface material to be encountered, hammer characteristics, and the required driving resistance. The pile cushion shall be replaced if it has been highly compressed, charred, or burned or has become deteriorated in any manner during driving.

3.2.3 Capblocks

The capblock used between the driving cap and the hammer ram may be of solid hardwood block with grain parallel to the pile axis and enclosed in a close fitting steel housing or may consist of aluminum and approved industrial type plastic laminate discs stacked alternately in a steel housing. Steel plates shall be used at the top and the bottom of the capblock. Where the block is other than that specified above, the Contractor shall submit to the Contracting Officer at least 2 weeks before the start of test pile driving operations, detailed drawings of the capblock he proposes to use accompanied by records of the successful use. The capblock shall be replaced if it has been damaged, highly compressed, charred, or burned or has become spongy or deteriorated in any manner. If a wood capblock is used, it shall not be replaced during the final driving of any pile. Under no circumstances will the use of small wood blocks, wood chips, rope, or other material permitting excessive loss of hammer energy be permitted.

3.3 FIELD TESTS AND INSPECTIONS

3.3.1 Test Piles

Test piles shall be of the type and shall be driven in the manner specified elsewhere in this section for all piling. The Contracting Officer will use test pile and load test data as well as test reports on soil samples to determine "calculated" pile tip elevations and the necessary driving resistance. Test piles that are located within the tolerances indicated for all piles that provide a safe design capacity as determined by the results of a satisfactory load test may be used in the finished work. [_____] test piles shall be driven [at the locations indicated] [in the vicinity of the soil boring test holes Nos. [_____], [_____], and [_____]]. If jetting is permitted, it will be permitted by the Contracting Officer only when testing piles shall clearly establish the validity of its use. Test piles shall be driven to the tip elevation specified or indicated for bidding lengths. [_____] test piles shall be withdrawn as indicated after reaching the "calculated" tip elevation in order to provide for visual inspection of the pile.

3.3.2 Load Tests

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NOTE: The requirement for performing the load tests under the direct supervision of a registered professional engineer may be waived by those agencies as defined. The provisions of ASTM D 1143, such as pile set-up time after driving, test load, method of applying load, loading and unloading procedures, instrumentation, etc., should be carefully examined and modified as necessary to fit the specific load test being conducted.

****

Load tests shall be in accordance with ASTM D 1143, [_____] loading method. The load tests at locations shown or directed shall be made on test piles placed to the tip elevation used for establishing lengths of piles for bidding, except as otherwise directed by the Contracting Officer. Loading, testing, and recording of data shall be under the direct supervision of a registered professional engineer. The analysis of the load test data shall be [done by] [under the supervision of] the registered professional engineer. The registered professional engineer shall be provided and paid by the Contractor. The installation of contract piles shall not proceed in a new area with substantially different subsoil conditions until a satisfactory load test has been performed in that area.

3.3.3 Safe Design Capacity

****

NOTE: When it is desirable to show analysis for determination of pile capacities from load tests and for relating load test capacities to job capacities, the following shall be included:

Pile Capacity: The capacity, as driven, of single piles not in clusters in the structure shall be not less than [_____] metric tons (tons). The capacity will be determined by the following formulas, modified according to the data obtained by the load tests:

For single-acting hammers: R = (166.7 WH)/(s+2.54 P/W) (2WH)/(S + 0.1 P/W)

For double-acting hammers: R = (166.9E)/(S+2.54 P/W) (2E)/(S + 0.1 P/W)

Where: R is the allowable static pile load in newtons pounds.

W is the weight of the striking part of the hammer in newtons pounds.

H is the effective height of fall in meters feet.

E is the actual energy delivered by the hammer per blow in N-m foot-pounds.

S is the average net penetration in mm inches per blow for the last five blows after the pile has been driven to a depth where successive blows produce approximately equal net penetration (a minimum distance of 1 meter 3 feet for friction piles).

P is the weight of the pile in N pounds. If P is less than W, P/W shall be taken as unity.

Dynamic pile stresses should not exceed the crushing strength of piles.

****

Test piles shall be loaded to twice the anticipated working load unless failure occurs first. The safe design capacity of a test pile as determined from the results of load tests shall be the less of the two values computed according to the following:

a. One-half the load which causes a net settlement after rebound of not more than 0.23 mm per metric ton 0.01-inch per ton of total test load.

b. One-half of that load which causes a gross settlement of not more than 25 mm 1 inch provided the load settlement curve shows no sign of failure.

3.4 SPECIAL INSPECTION AND TESTING FOR SEISMIC-RESISTING SYSTEMS

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NOTE: Include this paragraph only when special inspection and testing for seismic-resisting systems is required by paragraph 3.2 of FEMA 302, NEHRP RECOMMENDED PROVISIONS FOR SEISMIC REGULATIONS FOR NEW BUILDINGS AND OTHER STRUCTURES.

This paragraph will be applicable to both new buildings designed according to TI 809-04, SEISMIC DESIGN FOR BUILDINGS, and to existing building seismic rehabilitation designs done according to TI 809-05, SEISMIC EVALUATION AND REHABILITATION FOR BUILDINGS.

The designer must indicate on the drawings all locations and all features for which special inspection and testing is required in accordance with Chapter 3 of FEMA 302. This includes indicating the locations of all structural components and connections requiring inspection.

Add any additional requirements as necessary.

****

Special inspections and testing for seismic-resisting systems and components shall be done in accordance with Section 01452 SPECIAL INSPECTION FOR SEISMIC-RESISTING SYSTEMS.

-- End of Section --