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USACE / NAVFAC / AFCEC / NASA **UFGS-35 59 13.14 20 (February 2018)**

Preparing Activity: NAVFAC **Superseding**
UFGS-35 59 13.14 20 (February 2010)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2022
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POLYMERIC PILES

02/18

ATTACHMENTS:

Pile Driving Log

-- End of Section Table of Contents --

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SECTION 35 59 13.14 20

POLYMERIC PILES
02/18

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NOTE: This guide specification covers the requirements for polymeric marine fender piling. The specification is tailored for lateral load-bearing (fender) piling, bracketed items will require editing for axial load-bearing and lateral load-bearing piles. The intended use of bearing piles is for low-capacity (40 ton or less) "short" piles. Further testing will be required before these products can be used to replace concrete or steel marine bearing piles for primary piling on a berthing pier but may have applications at Magnetic Silencing Facilities.

Load combinations for polymeric piling are in accordance with UFC 4-152-01.

Axial load-bearing piles may require a site specific geotechnical report, pile drivability studies, and dynamic or static load tests; this type of testing may not be required for typical "secondary" fender pile system placed in soft marine soils.

Adhere to UFC 1-300-02 **Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**

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****
NOTE: The extent and location of the work to be accomplished should be indicated on the project drawings or included in the project specification.
****

****
NOTE: For lateral load-bearing fender piles, show the following information on the drawings:

1. Locations and types of the fender piles. If more than one type of fender pile (primary, secondary, corner) is used, indicate the location of each pile type.

2. Design loads (design vessel(s), berthing angle, berthing velocity).

3. Size, shape, and length of piles.

4. Connection details.

5. Length of polymeric pile protection. (Ensure that the camels, separators or watercraft bear on the protective layer throughout the entire tidal range.)

6. Soil data, where available.

7. Embedment depth. (The piles are typically designed as pinned/pinned, therefore ensure that the bottom of the piles have lateral restraint but not moment fixity.)
****

PART 1 GENERAL

1.1 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

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.

ASTM INTERNATIONAL (ASTM)

ASTM D570	(1998; E 2010; R 2010) Standard Test Method for Water Absorption of Plastics
ASTM D746	(2014) Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
ASTM D883	(2020a) Standard Terminology Relating to Plastics
ASTM D1143/D1143M	(2007; R 2013) Piles Under Static Axial Compressive Load
ASTM D2240	(2015; E 2017) Standard Test Method for Rubber Property - Durometer Hardness
ASTM D2310	(2006; R 2012) Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
ASTM D2996	(2017) Standard Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
ASTM D3350	(2021) Polyethylene Plastics Pipe and Fittings Materials
ASTM D3689	(2007; E 2013; R 2013) Standard Test Methods for Deep Foundations Under Static Axial Tensile Load
ASTM D3966/D3966M	(2007; R 2013; E 2013) Standard Test Methods for Deep Foundations Under Lateral Load
ASTM D4060	(2019) Abrasion Resistance of Organic Coatings by the Taber Abraser
ASTM D4329	(2013) Standard Practice for Fluorescent UV Exposure of Plastics
ASTM D4945	(2017) Standard Test Method for High-Strain Dynamic Testing of Deep Foundations
ASTM D6109	(2013) Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastic Lumber and Related Products
ASTM D7258	(2017) Standard Specification for

Polymeric Piles

ASTM E84 (2020) Standard Test Method for Surface Burning Characteristics of Building Materials

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 385-1-1 (2014) Safety -- Safety and Health Requirements Manual

1.2 DEFINITIONS

See ASTM D883 for standard terminology related to plastics.

Axial load-bearing pile – A vertical or battered member driven into the ground to help support a load of any structure bearing upon it. Axial load-bearing piles are commonly divided into two kinds; point-bearing (end-bearing) and friction. A point-bearing pile derives a significant proportion of capacity at its tip and much less from contact with soil along the pile shaft. A friction pile derives its support principally from the soil along the pile shaft through the development of shearing resistance between the soil and the pile.

CFRP - Carbon Fiber Reinforced Polymers - Composite materials which consist of a polymer resin matrix, and carbon fiber reinforcement.

Extrusion - A manufacturing process where molten polymer is forced through a die of a desired shape to encapsulate fiberglass reinforced plastic or steel bars which run continuously throughout the length of the product without joints.

FRP - Fiber reinforced polymer. A polymer matrix, either thermoset or thermoplastic, reinforced with a fiber or other material with a sufficient aspect ratio (length to thickness) to provide a discernable reinforcing function in one or more directions.

GFRP - Glass fiber reinforced plastic. A composite made from fiberglass reinforcement in a plastic (polymer) matrix.

Lateral load-bearing pile – a vertical or battered member driven into the ground to resist lateral loads imposed upon it or a structure. A common application for a lateral load-bearing pile is to absorb lateral forces at points of impact and dissipate them horizontally into a structure and/or soil stratum. A fender pile is an example of a lateral load-bearing pile.

Polymer - Any of numerous natural and synthetic compounds of usually high molecular weight consisting of up to millions of repeated linked units, each a relatively light and simple molecule.

Polymeric Pile - Piling products characterized by the use of polymers, whereby (1) the pile strength or stiffness requires the inclusion of the polymer or (2) a minimum of 50 percent of the weight or volume is derived from the polymer. Polymeric piles may be reinforced by composite design for increased stiffness or strength.

Pultrusion - A continuous process for manufacturing composites that have a cross sectional shape. The process consists of pulling a fiber reinforcing material through a resin impregnation bath and through a shaping die, where the resin is subsequently cured.

Resin - Any of numerous physically similar polymerized synthetics or chemically modified natural resins. Two main types of polymers used for resins include thermoset and thermoplastic materials.

Thermoset Plastics (thermosets) - Refer to a range of polymer materials that once cured do not flow or melt when heated. Thermoset materials are transformed through the addition of energy into a stronger substance. Thermoset materials are usually liquid or malleable prior to curing and designed to be molded into their final form; or used as adhesive. Thermoset polymer resins can be transformed into plastics or rubbers by cross-linking. A thermoset material cannot be melted and re-molded after it is cured. Thermoset materials are generally stronger than thermoplastic materials. They are also better suited to high temperature applications. They are not easily recyclable like thermoplastics, which can be melted and re-molded. Examples of thermoset plastics include: natural rubber, Bakelite, Urea-Formaldehyde, Melamine, Polyester Resin, and Epoxy Resin.

Thermoplastics - Most thermoplastics are high molecular weight polymer chains, mostly joined through weak dispersion forces and more rarely dipole-dipole interactions. Thermoplastic polymers are usually contrasted with thermosetting polymers, which cannot go through melt/freeze cycles. Many thermoplastic materials are addition polymers (chain growth polymers), such as polyethylene and polypropylene.

1.3 SUBMITTALS

****

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters 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, Air Force, and NASA projects.

The "S" classification indicates submittals required

as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force, and NASA projects, or choose the second bracketed item for Army projects.
****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Polymeric piles; G[, [_____]]

SD-03 Product Data

Polymeric Piles; G[, [_____]]

Pile Driving Equipment; G[, [_____]]

Driving Helmet; G[, [_____]]

Pile Caps; G[, [_____]]

Pile Driving Tips; G[, [_____]]

Driving Pads; G[, [_____]]

Pile Tops; G[, [_____]]

HDPE Sleeve; G[, [_____]]

Manufacturer's Warranty; G[, [_____]]

Contractor's Warranty; G[, [_____]]

SD-05 Design Data

Polymeric Piles; G[, [_____]]

Allowable Bending Moment

Allowable Stresses

Concrete Mix Design; G[, [_____]]

[Wave Equation Analysis; G[, [_____]]

][Order List; G[, [_____]]

] SD-06 Test Reports

Material Test Reports; G[, [_____]]

[Performance Test Data; G[, [_____]]

] Allowable Stresses

Delivery Inspection List

[Pile Driving Analyzer; G[, [_____]]

][Dynamic Testing of Piles; G[, [_____]]

] SD-07 Certificates

Driving Hammer; G[, [_____]]

Polymeric Piles; G[, [_____]]

SD-11 Closeout Submittals

Pile Records

1.4 DELIVERY, STORAGE, AND HANDLING

Inspect each pile for surface damage, cracks, blemishes, scaring and straightness upon delivery. Record the condition of each pile and submit the delivery inspection list to the Contracting Officer. Do not incorporate materials damaged in transport from plant to site. Handle the piles with ropes or nylon slings without dropping, breaking, bruising or penetrating outer surface with tools. Do not use cant dogs, peaveys, hooks or pikepoles. Protect piles from damage. Store piles above the ground on blocking which is shaped or padded and prevent scaring or sagging of the piles. Cover and arrange storage racks to permit air circulation.

1.5 BASIS OF BIDS

1.5.1 Polymeric Piles

Base bids on the type, number, diameter, and length of piles as indicated. Should the total number of piles vary from that specified as the basis for bidding, the Contract price will be adjusted in accordance with Contract Clause entitled "Changes". Adjustment in Contract price will not be made for cutting off piles, for any portion of a pile remaining above the cutoff elevation, or for broken, damaged or rejected piles.

PART 2 PRODUCTS

2.1 PILE CLASSIFICATION

1. Type I - Polymeric only

****
NOTE: Solid and tubular polymeric section are included.
****

2. Type II - Polymeric with reinforcement in the form of chopped,

milled or continuous fiber or mineral

****
NOTE: The most common Type II piles are recycled HDPE reinforced with chopped glass fibers and composite plastic lumber.
****

3. Type III - Polymeric with reinforcement in the form of metallic bars, or cages, or shapes

****
NOTE: The most common Type III piles are plastic piles with steel reinforcing or a steel pipe core.
****

4. Type IV - Polymeric with reinforcement in the form of non-metallic bars or cages

****
NOTE: The most common Type IV piles are plastic piles with a fiberglass reinforcing cage.
****

5. Type V - Polymeric composite tube with a concrete core

****
NOTE: The most common Type V piles are fiberglass tubes with concrete fill placed prior to driving.
****

6. Type VI - Any other polymeric piling meeting the requirements of this specification and not otherwise described above, such as hollow polymeric composite tubes driven without a concrete core.

****
NOTE: The Type VI pile section provides for new types of polymeric pilings. Examples of "new" piling types with respect to ASTM D7258, include polymeric composite tube installed (driven) without a concrete core.
****

2.2 POLYMERIC PILES

Provide polymeric piles manufactured as specified. Include dimensions, material specifications, and method of manufacturing. Provide all polymeric piles of a particular type manufactured by a single manufacturer. Permanently tag each pile with the pile's serial number, date of fabrication and manufacturer's name. Place the stamp or tag two to four feet from the top of the pile and ensure it is visible after installation. Splices will not be permitted, unless approved by the Contracting Officer. Provide pile driving tips, when required, per manufacturer's recommendations.

2.3 PERFORMANCE REQUIREMENTS

****

NOTE to Designer: Polymeric piles are not recommended for the replacement of single fender piles when the polymeric pile stiffness is different than that of the pile being replaced. When this occurs, the more flexible pile will not carry its share of the berthing load. As an example, polymeric piles will usually be more flexible than timber piles, in which case the timber piles adjacent to the polymeric piles will take increased loads, which may cause the piles to fail. Therefore, single or limited replacement of the timber piles are not recommended. Transverse misalignment of the piles can also cause individual piles to fail, and precautions to minimize this occurrence should be taken.

Comparison values for a typical timber pile

Typical ASD Design Properties for treated Southern Yellow Pine (SYP) marine pile per ASTM D25:

Allowable Axial compression:	**1250 psi**
Allowable Bending Strength	**1950 psi**
Allowable Shear Perpendicular to Grain	**160 psi**
Allowable Compression Perp. to grain	**440 psi**
Modulus of Elasticity	**1,500,000 psi**
Modulus of Rupture(MOR)	**7,300 psi**
90 percent MOR (accidental berthing)	**6,570 psi**
"Operational" Bending Strength	**3,900 psi**

For a 12 in. butt 50 ft long SYP pile with a 7 in. tip treated for marine use (Bending moments taken at mid height).

Allowable Axial Capacity "short"	**24 ton (48 kip)**
Mid Height Diameter	**9.5 in.**
Mid Height Section Modulus	**84.2 in.^3**
Mid Height Moment of Inertia	**400.0 in.^4**
Stiffness = 'E' x 'I'	**600,000.0 kip-in^2**
Allowable Moment Capacity (FS = 3.73)	**13.7 kip-ft**
Operational Moment Capacity (FS = 1.87)	**27.3 kip-ft**
Accidental Moment Capacity (FS = 1.11)	**46.1 kip-ft**

See UFC 4-152-01 Section 5-4.4.3(a) for allowable timber stresses on fender piles for normal/operational and accidental berthing. FS = Factor of Safety based on rupture strength = 7.3 ksi x 84.2 in^3/12 = 51.2 kip-ft. Axial capacity does not consider Euler buckling (Short Column).

For pultruded members the minimum factor of safety is 2.5 for flexure and 3.0 for compression, shear, and connections.

****

Determine the cross-sectional dimensions of piles on the basis of the ability to perform satisfactorily under the physical loading and environmental conditions imposed and to effectively perform the energy absorption properties desired. Submit[the Performance Test Data] to substantiate the performance. The performance requirements listed are allowable (service level) values. For berthing/flexure the minimum factor of safety is [2.0][2.5] for normal/operational loads. For compression and shear, the minimum factor of safety is [2.5][3.0].

2.4 PERFORMANCE CHARACTERISTICS

****

NOTE: The designer must fill in the required performance characteristics for each pile, for a particular application. Provide a separate table for each pile type and application.

****

Provide the following performance characteristics for each pile:

PERFORMANCE CHARACTERISTICS			
Description	Value	Units	Test Method
Structural Outer Dimension/Diameter	[_____]	mm in.	N/A, +/- 10 percent
Allowable Moment Capacity	[_____]	kNm kip-ft	ASTM D7258
Allowable Axial Capacity - Short Column	[_____]	kg kip	ASTM D7258
Flexural Rigidity (EI)	[_____]	$kg\text{-}mm^2$ $lb\text{-}in^2$	ASTM D6109, +/- 10 percent
Allowable Shear Capacity	[_____]	kg kip	ASTM D7258

2.4.1 Allowable Moment Capacity

Submit the allowable bending moment for the particular pile selected based on the ASTM testing procedures indicated.

2.4.2 Allowable Axial Capacity

****

NOTE: Allowable axial capacity is the structural capacity of the piling. See UFC 3-220-01 for geotechnical capacity. A load test may be appropriate for critical load bearing applications to allow the use of the lowest geotechnical factor of safety.

****

Submit the allowable axial capacity based on the ASTM testing procedures indicated. Unless noted otherwise the allowable axial capacity must be based on a short member without considering slenderness effects.

2.4.3 Flexural Rigidity (EI)

****

NOTE: Maximum deflection and operational level

deflections are based on the Flexural Rigidity of the member. Consider service level deflections under all operational load combinations in UFC 4-152-01. Pay special attention to environmental loads which may cycle the product into a state of fatigue. For bearing piles consider deflection limits stated in UFC 1-200-01.

****

Flexural rigidity "EI" is defined as the product of Modulus of Elasticity "E" times Moment of Inertia "I". "EI" is related to the slope of a moment-deflection curve in accordance with ASTM D6109. Determine the values for "EI" from the peak load at failure.

2.4.4 Allowable Shear Capacity

Submit the allowable shear capacity based on the ASTM testing procedures indicated.

2.4.5 Allowable Stresses

Submit the following: allowable flexural stress, allowable shear stress, allowable bearing stress perpendicular to the member, allowable bearing stress parallel to the member, allowable tensile stress, and allowable compressive stress. See paragraph PERFORMANCE REQUIREMENTS for minimum factor of safety.[Use allowable tensile and compressive stresses for Wave Equation Analysis.]

2.5 SIZE TOLERANCES

Unless specified otherwise refer to the tolerances listed in ASTM D7258.

2.6 MATERIALS

2.6.1 Physical Properties

****

NOTE: The designer must select the appropriate pile types and fill in the required physical properties for each pile. Properties which do not apply to a particular pile type may be deleted or indicated as n/a.

****

Submit Material Test Reports, as applicable, for each type of material. See below for the required:

1. Water Absorption, ASTM D570, < 3 percent at 24 hours.

2. Brittleness, ASTM D746, no break.

3. Hardness, ASTM D2240 Shore D, [60].

4. Ultraviolet, ASTM D4329, [2 percent] change in Shore D Durometer Hardness after 500 hours of exposure.

5. Flame Spread Rating, ASTM E84, <200.

2.6.2 Type III and IV Polymeric Piles

2.6.2.1 Placement of Reinforcing

In accordance with ASTM D7258, place longitudinal reinforcement within 5 percent of the specified radial location as measured from centroid of the cross-section of the pile. Longitudinal reinforcement will not twist more than 5 degrees over any 6.1 m 20 foot section of the pile. The minimum cover is 25 mm 1 inch.

2.6.3 Type V Polymeric Piles

2.6.3.1 Polymeric Composite Tube

Manufacture polymeric composite pile comprising of material which provides the tube strength. Manufacture the tube in accordance with ASTM D2996 and ASTM D2310.

2.6.3.2 Outer Surface

Furnish an outer surface comprising of a suitable, high impact, marine grade coating that provides a protective barrier as well as wear and impact resistance. It must provide an ultraviolet and chemical resistant barrier of at least 0.75 mm 0.03 inch thickness and be of a black opaque color.

2.6.3.3 Inner Surface

Provide an inner surface of a pure polymeric liner layer of at least 0.64 mm 0.025 inch thickness for alkalinity resistance. Roughen or wrinkle the inner surface to provide adhesion of the inner shell to the concrete fill.

2.6.3.4 Concrete Fill

Fill the composite tube completely with concrete in accordance with the manufacturer's written instructions. Furnish concrete with a minimum 28-day compressive strength of 41.4 MPa 5,000 psi. Submit a concrete mix design certifying that the proportioning of the mix is in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE for specified strength and is based upon aggregate data which has been determined by laboratory tests during the last twelve months.

2.6.3.5 HDPE Sleeve

Provide HDPE sleeve per paragraph POLYMERIC PILE PROTECTION.

2.6.3.6 Type VI Hollow Polymeric Piles

2.6.3.6.1 Hollow Polymeric Composite Tube

Furnish hollow polymeric composite tube satisfying the requirements of ASTM D7258.

2.6.3.6.2 Concrete Fill

****

NOTE: For lateral-load bearing (fender) piles, at a minimum place a concrete "plug" a distance D above and a distance of 2*D below the upper support to

prevent crushing/local buckling of the hollow tube at the point of impact (D = outside diameter of the pile).

****

Fill the composite tube with concrete [to [_____] m [_____] ft below the pile top][from the pile top to the mudline] after driving. Provide concrete with a minimum 28-day compressive strength of 34.5 MPa 5,000 psi. Submit a concrete mix design certifying that the proportioning of the mix is in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE for specified strength and is based upon aggregate data which has been determined by laboratory tests during the last twelve months.

2.6.3.6.3 HDPE Sleeve

Provide HDPE sleeve per paragraph POLYMERIC PILE PROTECTION.

2.7 PILE FINISHING

2.7.1 Polymeric Pile Protection

Furnish the polymeric piles such that the rubbing surface of the piles has an abrasion resistance less than 0.5g per ASTM D4060. If the materials are reactive to seawater, protect the pile by encasing in an HDPE sleeve or abrasion resistant polymer, with a minimum thickness of 13 mm 1/2 inch.[Extend the protective encasement, as a minimum, from 0.6 m 2 feet below the mean lower low water (MLLW) to 0.3 m 1 feet below the pile support, unless indicated otherwise.]

****

NOTE: The length of protection may need to be increased for barges or other flat sided vessels and for systems supporting deep draft separators. The contact surface for barges may be near the deck level if there is a rail, or if the piles are sloped the contact area may be near the bottom of the hull. The contact areas must consider the upper and lower rub strips for deep draft separators.

****

2.7.1.1 HDPE Sleeve

Provide ASTM D3350, 2 - 3 percent carbon black UV stabilized HDPE sleeve. Attach as indicated or per Manufacturer's recommendation to protect the lateral load-bearing pile. Provide length as indicated in paragraph POLYMERIC PILE PROTECTION. Furnish sleeve with minimum wall thickness of 13 mm 1/2 inch, and hardness of 62 (Shore D) per ASTM D2240.

2.7.2 Surface Condition

Ensure that the pile surface exhibiting roughness or corrugations due to manufacturing processes, do not have depressions or projections greater than 12 mm 1/2 inch and less than 5,800 mm^2 9 in^2 in surface area. The surface of the pile is required to be free of any cracks or splits, in any orientation.

2.7.3 Pile Cover

Furnish the polymeric piles with approved pile tops, concrete fill sloped to drain, or encapsulated in polymeric material.

2.7.3.1 Pile Tops

Furnish the polymeric top with a thickness of approximately 6 mm 0.25 inches and color to match the pile. Secure the top in place with 6 mm diameter by 38 mm 1/4 inch diameter by 1 1/2 inch long Type 316 stainless steel screws spaced a maximum of 100 mm 4 inches on center. Center the screws in the ribbon band of the top. Use appropriate screw types for the matrix material and place in pilot holes.

2.8 SOURCE QUALITY CONTROL

2.8.1 Plant Inspection

The Contracting Officer reserves the right to perform plant inspection of the polymeric pile manufacturing process. Provide the Contracting Officer a minimum two weeks advance notice, indicating the date manufacturing is to start and tests that will be conducted. Allow the Contracting Officer unlimited access to the plant and inspection privileges for each facet of the manufacturing process.

2.8.2 Curing

2.8.2.1 Type I, II, III, IV and VI Polymeric Piles

Cure piles at the plant as recommended by the manufacturers prior to shipment to the site.

2.8.2.2 Type V Polymeric Piles

Fill Type V piles with concrete prior to driving. Support the pile to prevent sag during concrete placement and curing. Cure a minimum of one week prior to placement of the concrete fill. Move piles to curing table within 20 minutes of wet concrete placement. Do not handle or transport piles for seven days or until concrete has reached 85 percent of the 28 day compressive strength. Drive concrete filled piles after full strength has been obtained or after 28 days of curing.

2.9 DRIVABILITY

Furnish piles capable of being driven by contractors vibratory, air, steam, diesel or hydraulic hammers without damage to the pile anywhere along its length, with the exception of a sacrificial 0.6 m 2 ft at pile head.

2.10 MANUFACTURER'S WARRANTY

Warranty all polymeric piles to be free from defects in materials and workmanship for a period of ten years. The Contracting Officer has the right to require complete replacement of any pile with material or workmanship defects. All construction costs related to the repair or replacement of the defective piles are at Manufacturer's expense. This warranty need not cover repairs required as a result of normal wear and tear, misuse, mishandling, extreme weather, failure to perform routine maintenance, non-recommended or improperly executed alterations by anyone other than the Manufacturer, tampering, loading of the pile beyond its rated capacity, improper installation, or other use inconsistent with Manufacturer's specifications.

2.11 CONTRACTOR'S WARRANTY

Warranty all polymeric piles to be free from defects in materials caused by mishandling prior to installation and improper installation for a period of 5 years. The Contracting Officer has the right to require complete replacement of any pile deemed by the Contracting Officer to have defects due to mishandling or improper installation. All construction costs related to the repair or replacement of the defective piles are at the Contractor's expense.

PART 3 EXECUTION

3.1 PILE DRIVING EQUIPMENT

Select the proposed pile driving equipment, including hammers and other required items, and submit complete descriptions of the proposed equipment. Provide driving helmet, pile caps, pile driving tips and driving pads as recommended by the pile Manufacturer for the polymeric piles.[Final approval of the proposed equipment is subject to the satisfactory completion and approval of pile tests.] Changes in the selected pile driving equipment will not be allowed after the equipment has been approved except as[specified and] directed. No additional contract time will be allowed for Contractor proposed changes in the equipment.

3.1.1 Pile Driving Hammers

Provide impact[or vibratory] type pile driving hammers.

3.1.1.1 Impact Hammers

Use an air, steam, diesel or hydraulic powered hammer, of an approved type. The capacity of the driving hammer is required to meet or exceed the hammer manufacturer's recommendation for the total weight of pile and character of subsurface material to be encountered. In accordance with paragraph SUBMITTALS, submit the following information for each impact hammer proposed:

a. Make and model.

b. Ram weight.

c. Anvil weight.

d. Rated stroke.

e. Rated energy range.

f. Rated speed.

g. Steam or air pressure, hammer, and boiler[and][or] compressor.

[h. Rated bounce chamber pressure curves or charts, including pressure correction chart for type and length of hose used with pressure gage.

] i. Pile driving cap, make, and weight.

j. Cushion block dimensions and material type.

k. Power pack description.

[3.1.1.2 Vibratory Hammers

[The use of vibratory hammers is dependent upon satisfactory driving and load testing of piles.][Final approval of the proposed hammer and other driving equipment is subject to the satisfactory completion and approval of the pile tests.][The size or capacity of hammers must be as recommended by the hammer manufacturer for the total pile mass weight and the character of the soil formation to be penetrated.]Provide a rigid connection between the hammer and the pile. In accordance with paragraph SUBMITTALS, submit the following information for each vibratory hammer proposed:

a. Make and model.

b. Eccentric moment.

c. Dynamic force.

d. Steady state frequency or frequency range.

e. Vibrating weight.

f. Amplitude.

g. Maximum pull capacity.

h. Non-vibrating weight.

i. Power pack description.

]3.1.2 Pile Driving Leads

Support and guide hammers with[suspended leads,] fixed extended leads or fixed underhung leads.[Operate vibratory hammers free hanging without leads.][For driving battered piles, support and guide impact hammers with three-axis, fixed-extended leads capable of 1 H and 2-1/2 V fore and aft batter and 1 H on 6 V side batter, with 30 degree rotation each side of an axis running along the center line of rotation of the crane through the center line of the leads.][For driving battered piles, support and guide vibratory hammers with fixed extended leads or templates.][Provide two intermediate supports for the pile in the leads to reduce the unbraced length of the pile during driving.]

3.1.3 Pile Extractors

Use vibratory pile extractors for pile extraction.

[3.1.4 Jetting Equipment

Provide jetting equipment with at least removable or fixed jet of the water or combination air-water type. Design water jet so that the discharge volume and pressure are sufficient to freely erode the material immediately under and adjacent to piles without resulting in pile drift. Submit jetting equipment including plant description, volume of water and pressure, and size and length of hoses and pipes in accordance with paragraph SUBMITTALS.

][3.2 PRELIMINARY WORK

[3.2.1 Wave Equation Analysis of Pile Drivability

****
NOTE: This section may be applicable for axial load-bearing piles only.
****

a. Prior to driving any pile, submit a pile Wave Equation Analysis, performed by the Contractor's Geotechnical Consultant, for each size pile and distinct subsurface profile condition. Take the following into account for the analysis: the proposed hammer assembly, pile cap block and cushion characteristics, the pile properties and estimated lengths and the soil properties anticipated to be encountered throughout the installed pile length based on static capacity analysis with consideration of driving gain/loss factors. Only one specific model of pile hammer may be used for each pile type and capacity.

b. Demonstrate with the Wave Equation Analysis that the piles will not be damaged during driving and the driving stresses will be maintained within the limits stated in paragraph ALLOWABLE STRESSES. Indicate the blow count necessary to achieve the required ultimate static pile capacities.

c. Upon completion of the dynamic and static testing programs outlined in this specification section, perform a refined Wave Equation Analysis taking into consideration the evaluated capacities, gain/loss factors and recommended production pile lengths. Develop production pile driving criteria based on the results of the refined Wave Equation Evaluations.

d. Furnish pile driving equipment approved by the Contractor's Geotechnical Consultant. Complete the attached pile and driving equipment data form, including hammer information, in full as part of the submittal of the results of the Wave Equation Analyses.

e. The cost of performing the Wave Equation Analyses must be paid for by the Contractor. Include the cost in the base bid.

][3.2.2 Order List

Submit an itemized list for piles to the Contracting Officer for approval prior to placing the order with the supplier. Indicate the pile lengths required at each location as shown on the plans and the corresponding ordered length of each pile on the list.[Complete load testing and refined wave equation analysis prior to submission of an order list.]

]]3.3 INSTALLATION

3.3.1 On Site Storage

Continually support all stored piles in a manner which minimizes creep, saddling and sag.

3.3.2 Preexcavation

3.3.2.1 Jetting of Piles

****

NOTE: Jetting should generally not be permitted for piles:

1. When capacity is dependent on side friction in fine-grained, low-permeability soils high clay or silt content) where considerable time is required for soil to reconsolidate around the piles.

2. Subject to uplift.

3. Adjacent to existing structures.

4. In closely spaced clusters unless the load capacity is confirmed by test and unless all jetting is done before final driving of any pile in the cluster.

****

Jetting of piles is not permitted without the approval of the Contracting Officer.

3.3.2.2 Spudding of Piles

Spudding of piles is not permitted without the approval of the Contracting Officer. If spudding is allowed, limit it to an elevation 1.5 meters 5 feet above the specified pile tip elevation.

3.3.2.3 Predrilling of Piles

****

NOTE: If predrilling is permitted by the Geotechnical Engineer of Record, it is recommended to use an auger smaller than the diameter of the pile.

****

Predrilling of piles is not permitted without the approval of the Contracting Officer. If predrilling is allowed, limit it to an elevation 1.5 meter 5 feet above the specified pile tip elevation.

3.3.3 Driving Piles

Notify Contracting Officer 10 days prior to driving of[test] piles[and load test]. Drive piles to[indicated][or below calculated] tip elevation[to reach a driving resistance established by the wave equation analyses (WEAP) in accordance with the schedule which the will prepare from the test-pile driving data]. During initial driving and until pile tip has penetrated beyond layers of very soft soil [or below bottom of predrilled or prejetted holes], use a reduced driving energy of the hammer as required to prevent pile damage. Refusal criteria must be established by the Contracting Officer. If a pile fails to reach the indicated[or calculated] tip elevation,[or if a pile reaches[calculated] tip elevation without reaching required driving resistance,] notify Contracting Officer, provide pile record and perform corrective measures as directed. Provide hearing protection in accordance with EM 385-1-1. Piles may be driven without pile guides or leads providing a hammer guide frame is used to keep the pile and hammer in alignment.

3.3.3.1   Protection of Piles

Square the heads and tips of piles to the driving axis. Laterally support piles during driving, but do not unduly restrain piles from rotation in the leads. The use of swinging or hanging leads is at the Contractor's risk. Repair any damage incurred by such use at the Contractor's expense.

3.3.3.2   Tolerances in Driving

Drive piles in the locations indicated. Place each pile, at its contact with the design mudline or mudline elevation indicated in the construction documents, no further than 40 mm per meter 0.5 inch per foot of free pile length (length in meters feet above the average soil contact line at each pile)in a direction parallel to the pier face and 10 mm per meter 0.125 inch per foot of the free pile length in a direction perpendicular to the pier face. Remove and replace with new piles those damaged, mislocated, driven below the design cutoff, or driven out of alignment.

3.3.4   Buoyant Piles

After driving buoyant piles, provide temporary framing or weights to prevent the pile from floating up out of the ground. Keep the temporary framing or weights in place until the pile is secured in place. If there is sufficient friction provided by the soil to prevent the pile from floating, the Contractor may, at his own risk, waive the temporary framing or weight requirement.

3.3.5   Pile Cutoff

Provide each polymeric pile a minimum of 0.6 meter 2 feet longer than the specified length to allow the top to be cut off if it is damaged during driving. Cut off piles with a smooth level cut using pneumatic tools, sawing, or other suitable methods per the polymeric pile Manufacturer's recommendations. Use of explosives for cutting is not permitted. Cut off pile heads level and sound. Cut off piles at no additional cost to the Government.

3.3.6   Fastening

Fasten the polymeric piles as indicated.

[3.4   PILE TESTS

****

NOTE: Pile tests may be applicable for axial load-bearing piles.

This specification allows for two types of pile tests: pile driving tests and pile load tests. Pile driving tests are used to determine the blow count required to drive a pile to a given penetration or to refusal on a hard layer. Pile driving tests may be performed with a pile driving analyzer attached to piles to record the information listed below. Pile load tests are used to determine pile

capacity. The combination of pile driving tests and pile load tests gives information on pile capacity versus refusal blow count. Pile driving analyzer data may be used in some instances in place of pile load tests to reduce the number of load tests required for a project.
****

[3.4.1 Dynamic Testing of Piles

[Provide][Employ]a specialty engineering firm to perform dynamic testing of piles[and job piles] to determine velocity of stress wave propagation, acceleration, monitor hammer and drive system performance, assess pile installation stresses and integrity[, and to evaluate pile capacity]. Furnish personnel experienced in performing wave equation analysis, dynamic testing, the use of the Pile Driving Analyzer and its related equipment, and interpretation of results to install and operate the testing equipment and to interpret its results. Furnish equipment to obtain dynamic measurements, record, reduce and display its data and meet the requirement of ASTM D4945. The equipment must have been calibrated within 12 months thereafter throughout the contract duration. Supply all power requirements for operating the equipment. Submit Pile Driving Analyzer data within one [day][week] after each test is completed.

3.4.1.1 Test Piles

Perform dynamic testing on [_____] test piles as indicated. Test piles are at least [3 m10 ft] longer than minimum indicated job pile length. Perform testing during the full length of pile driving.[Restrike piles installed as part of pile driving test after a minimum waiting period of [_____] days.][Warm up the hammer prior to restriking.][Restrike the pile for 50 blows or until the pile penetrates an additional 75 mm 3 inches, whichever occurs first. In the event the pile movement is less than one-quarter inch during restrike, the restrike may be terminated after 20 blows.]

3.4.1.2 Job Piles

Perform dynamic pile testing on [_____] job piles during the full length of initial driving[and during restrike driving]. Tested piles must be as [indicated] [selected by the Contracting Officer over the duration of installation]. The Contracting Officer will direct testing of additional piles if the hammer or driving system is modified or replaced.

3.4.1.3 Reports

Prepare and submit a summary report of dynamic test results for test piles. Submit reports of the dynamic testing of piles within[seven days][two weeks] after dynamic testing is completed. Discuss in the report pile capacity obtained from dynamic testing, velocity of stress wave propagation, acceleration, evaluation of hammer and driving system performance, driving stress levels, and pile integrity. Perform[a CAPWAPC, or similar, analysis of the dynamic test data on data obtained from the end of initial driving and the beginning of restrike for [_____] test piles as directed. Use the analysis to predict pile capacity, establish resistance distribution, and predict quake and damping factors.] Include refined wave equation analyses incorporating the results of dynamic testing and analysis.[For job piles, prepare and submit a field summary report. Include energy transferred to the pile, calculated driving stresses, pile integrity and estimated pile capacity at the time of testing in the field summary report.] Include in the report for the test piles[and the monthly report for job piles] the pile driving record as an attachment and also address the items listed in ASTM D4945, paragraph titled "Dynamic Testing."

][3.4.2 Pile Load Tests

****

NOTE: Each ASTM pile load test specification listed offers a number of options as to how the test is performed. Specify the required load testing option and any modifications to include other desired requirements.

Insert the number of test piles to be load tested. The safe design capacity of a test pile to be determined based on the failure criteria indicated.

****

Perform load tests at locations shown, or as directed. Provide testing and measuring equipment, perform loading, and provide observation facilities for personnel to inspect, record, and analyze settlement/movement and deflection of piles under test loads. Do not mobilize load test equipment until directed by the Contracting Officer. Perform pile load tests under the supervision of a registered professional engineer provided by the Contractor and experienced in conducting pile load tests. Loading frames and equipment for pile load tests must be ready to be placed in operation as soon as a load test pile has been driven. Provide loading equipment of sufficient capacity to apply the maximum load specified in a safe manner. Start loading of each test pile when directed.

The Contractor is responsible for the application of loads. Accurately determine and control the magnitude of applied loads using a calibrated load cell and readout device. The design working load, as confirmed by the results of load tests, will be determined by the Contracting Officer. Load test piles indicated or directed to be driven in permanent locations may be incorporated into the work if, after satisfactory completion of load test, they are approved for inclusion in the work. Any pile load test not accomplished in accordance with this specification will be rejected. A new pile load test must be conducted for each rejected pile load test. The Contractor must compile a report for each pile load test including, as a minimum, all applicable information required by the specified test.

[3.4.2.1 Compressive Load Test

Perform [_____] pile compressive load tests in accordance with ASTM D1143/D1143M [, as modified]. Apply a compressive load of [_____] kN ton to each compressive load test pile.

][3.4.2.2 Tensile Load Test

Perform [_____] pile tensile load tests in accordance with ASTM D3689[, as modified]. Apply a tensile load of [_____] kN tons to each tensile load test pile.

][3.4.2.3   Lateral Load Test

Perform [_____] pile lateral load tests in accordance with ASTM D3966/D3966M[, as modified]. Perform lateral load tests consisting of jacking two piles apart with a hydraulic jack, with one pile serving as the reaction pile for the other. Apply a lateral load of [_____] kN tons to each pair of lateral load test piles. Take required movement readings and record for each pile.

]3.4.2.4   Safe Design Capacity

Load test piles to twice the anticipated working load unless failure occurs first. The safe design capacity of a load test as determined from the results of load tests is the lesser of the two values computed according to the following:

a. One-half the load that causes a net settlement after rebound of not more than 0.029 mm per kN 0.01 inch per ton of total test load.

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

]]3.5   FIELD TREATMENT

3.5.1   Polymeric Work

Field treat cuts, bevels, notches, refacing and abrasions made in the field in accordance with the Manufacturer's recommendations.

3.6   FIELD QUALITY CONTROL

3.6.1   Inspections

Inspect piles when delivered and when in the leads immediately before driving. Secure piles in their proper alignment.

When Government inspections result in product rejection, promptly segregate and remove rejected material from the premises. The Government may also charge the Contractor an additional cost of inspection or testing when prior rejection makes reinspection or retesting necessary.

3.6.1.1   Straightness

ASTM D7258. Reject piles not meeting with the straightness criteria.

3.6.1.2   Cracks and Defects

Inspect each pile for cracks and defects prior to driving. After the piles are installed and all connections to the structure are completed, inspect each pile again for cracks and defects. Notify the Contracting Officer of any cracking or other defects observed and await direction. The Contracting Officer may reject any piles with defects. The Contractor is responsible for all costs incurred to replace the rejected piles.

3.6.2   Pile Driving Inspection

Perform special inspection of the pile installation. Employ approved Special Inspectors as required in the paragraph QC SPECIALIST DUTIES AND QUALIFICATIONS in Section [01 45 00.00 10] [01 45 00.00 20] [01 45 00.00 40

] QUALITY CONTROL.

3.6.3 Pile Records

For each pile, keep a legible record of the number of blows required for each 0.30 m foot of penetration[and the number of blows for the last 150 mm 6 inch penetration or fraction thereof]. Include in the record the beginning and ending times of each operation during driving of pile, type and size of the hammer used, rate of operation, stroke or equivalent stroke for diesel hammer, type of driving helmet, and type and dimension of the hammer cushion (capblock) and pile cushion used. Record re-tap data and any unusual occurrence during driving of the pile. Include in the record performance characteristics of jet pump, unassisted penetration of pile, jet-assisted penetration of pile, and tip elevation before driving and at end of driving. Notify Contracting Officer 10 days prior to driving of piles. Submit complete and accurate records of installed piles to Contracting Officer within 15 calendar days after completion of the pile driving. Make pile-driving records available to the Contracting Officer at the job site within 24 hours of each day's pile driving. A preprinted form for recording pile driving data, the Pile Driving Log, is included at the end of this section.

PILE DRIVING LOG

CONTRACT NO.___________________________ CONTRACT NAME_________________________
CONTRACTOR_________________________________ TYPE OF PILE_______________________
PILE LOCATION_____________ PILE SIZE: BUTT/TIP: ________ LENGTH_________
GROUND ELEVATION_________________________ CUT OFF ELEVATION______________
PILE TIP ELEVATION_________________ VERTICAL (_____) BATTER 1 ON (_____)
SPLICES ELEVATION____________________ COMPANY____________________________

HAMMER: MAKE & MODEL_________________ WT. RAM______________________
STROKE______________________ RAM RATED ENERGY___________________________
DESCRIPTION & DIMENSIONS OF DRIVING CAP_____________________________
CUSHION MATERIALS & THICKNESS____

INSPECTOR____

"DEPTH" COLUMN OF PILE DRIVING RECORD REFERENCED TO MUDLINE ELEVATION

TIME: START DRIVING_______ FINISH DRIVING________ DRIVING TIME_________
INTERRUPTIONS (TIME, TIP ELEV. & REASON)_________________________________
JET PRESSURE & ELEVATIONS____

DRIVING RESISTANCE

DEPTH M	NO. OF BLOWS	DEPTH M	NO. OF BLOWS	DEPTH M	NO. OF BLOWS	DEPTH M	NO. OF BLOWS
0	_____	3.0	_____	7.0	_____	10.0	_____
0.3	_____	3.3	_____	7.3	_____	10.3	_____
0.6	_____	3.6	_____	7.6	_____	10.6	_____
0.9	_____	3.9	_____	7.9	_____	10.9	_____
1.2	_____	4.2	_____	8.2	_____	11.2	_____
1.5	_____	4.5	_____	8.5	_____	11.5	_____
1.8	_____	4.8	_____	8.8	_____	11.8	_____
2.1	_____	5.1	_____	9.1	_____	12.1	_____
2.4	_____	5.4	_____	9.4	_____	12.4	_____
2.7	_____	5.7	_____	9.7	_____	12.7	_____

REMARKS____
____
____
____

PILE TOP ELEVATION: FROM DRAWING ________________

TIP ELEVATION = GROUND ELEVATION - DRIVEN DEPTH = ________________

DRIVEN LENGTH = PILE TOP ELEVATION - TIP ELEVATION = ________________

CUT OFF LENGTH = PILE LENGTH - DRIVEN LENGTH = ________________

PILE DRIVING LOG

CONTRACT NO.__________________________ CONTRACT NAME_________________________
CONTRACTOR________________________________ TYPE OF PILE_______________________
PILE LOCATION_____________ PILE SIZE: BUTT/TIP: ________ LENGTH_________
GROUND ELEVATION__________________________ PILE TOP ELEVATION______________
PILE TIP ELEVATION_________________ COMPANY_____________________________

HAMMER: MAKE & MODEL_________________ WT. RAM______________________
STROKE______________________ RAM RATED ENERGY_____________________________
DESCRIPTION & DIMENSIONS OF DRIVING CAP_________________________________
CUSHION MATERIALS & THICKNESS____

INSPECTOR____

"DEPTH" COLUMN OF PILE DRIVING RECORD REFERENCED TO MUDLINE ELEVATION

TIME: START DRIVING_______ FINISH DRIVING________ DRIVING TIME_________
INTERRUPTIONS (TIME, TIP ELEV. & REASON)___________________________________
JET PRESSURE & ELEVATIONS____

DEPTH FT.	NO. OF BLOWS	DEPTH FT.	NO. OF BLOWS	DEPTH FT.	NO. OF BLOWS	DEPTH FT.	NO. OF BLOWS
0	______	16	______	32	______	48	______
1	______	17	______	33	______	49	______
2	______	18	______	34	______	50	______
3	______	19	______	35	______	51	______
4	______	20	______	36	______	52	______
5	______	21	______	37	______	53	______
6	______	22	______	38	______	54	______
7	______	23	______	39	______	55	______
8	______	24	______	40	______	56	______
9	______	25	______	41	______	57	______
10	______	26	______	42	______	58	______
11	______	27	______	43	______	59	______
12	______	28	______	44	______	60	______
13	______	29	______	45	______	61	______
14	______	30	______	46	______	62	______
15	______	31	______	47	______	63	______

REMARKS____

____

____

____

PILE TOP ELEVATION: FROM DRAWING ________________

TIP ELEVATION = GROUND ELEVATION - DRIVEN DEPTH = ________________

DRIVEN LENGTH = PILE TOP ELEVATION - TIP ELEVATION = ________________

PILE DRIVING LOG

CUT OFF LENGTH = PILE LENGTH - DRIVEN LENGTH = ________________

-- End of Section --