SECTION 505 - PILING

505.01 Description. This section describes furnishing and installing foundation piles at locations and to elevations, penetration, and pile bearing capacities shown in the contract documents; and performing load tests as required.

For terminologies used in this section refer to: Section 101 – Terms, Abbreviations, and Definitions; ASTM D 653 - Standard Terminology Relating to Soil, Rock, and Contained Fluids.

505.02 Material.

(A) Reinforced Precast Non-Prestressed Concrete Piles. Construct reinforced precast non-prestressed concrete piles in accordance with details shown in the contract documents and Subsection 505.03(B) - Reinforced Precast Non-Prestressed Concrete Piles.

(B) Precast Prestressed Concrete Piles. Pretension and construct precast, prestressed concrete piles in accordance with details shown in the contract documents and Section 504 - Prestressed Concrete Members.

(C) Steel Piles. Use steel shapes of the weight and shape called for in the contract documents. Steel shall conform to ASTM A 328.

(D) Timber Piles. Timber piles shall conform to Subsection 714.04 - Timber Piles.

(E) Steel Shells for Cast-in-Place Piles. A core or mandrel may be used to drive metal shells. Provide metal shells with thickness and rigidity to withstand driving without damage. Once in place, and after core or mandrel, if any, has been withdrawn, shells shall withstand damage from soil pressures or driving of adjacent piles. Provide metal shells that are cylindrical, tapered, step tapered, or a combination of either.

505.03 Construction.

(A) General.

(1) Test Borings. Refer to Subsection 102.05 – Examination of Contract and Site of Work and the "Log of Test Borings" shown in the contract documents.

The "Log of Test Borings" is a record of data obtained from the State's subsurface investigation. The "Log of Test Borings" represents the State's opinion of the character of material

encountered in the test borings. This record is made available to the bidder as specified in Subsection 102.05 – Examination of Contract and Site of Work.

(2) Order List for Piling. If the contract documents calls for test piles and load test piles, furnish these piles in accordance with an itemized list supplied by the Engineer, showing number, length, and type of piles.

Shown lengths in itemized list are lengths assumed to remain in the completed structure. Lengths may be increased to suit the Contractor's method of operation, at no additional increase in contract price or contract time.

If the contract documents calls for pile testing, order only number, length, and pile type specified. The Engineer will furnish complete order list for production piles after reviewing information submitted as specified in Subsection 505.03(G) - Pile Test Program. Number and lengths of production piles will prevail over those on plans.

(B) Reinforced Precast Non-Prestressed Concrete Piles. Construct reinforced precast non-prestressed concrete piles in accordance with details shown in the contract documents. Furnish concrete having a minimum 28-day compressive strength of 5,000 pounds per square inch. Place reinforcing steel as specified in Section 602 - Reinforcing Steel.

Cast precast concrete piles in a horizontal position on a casting platform placed on a level and firm, unyielding support that will not settle. Construct forms as specified in Section 503 - Concrete Structures. Build forms of surfaced lumber, true to line, and with 1-inch chamfer strip at corners.

Leave side forms in place at least 24 hours after placing concrete. Do not subject pile to handling stresses until concrete has set for at least 10 days.

Furnish reinforcing of the unit type, rigidly fastened together and lowered into form before concrete is placed. Hold reinforcing securely in form using concrete blocks or other devices acceptable to the Engineer. Hold reinforcing securely so that centers of main bars are not closer to concrete surface than shown in the contract documents.

Place concrete with care to produce bond with reinforcing steel and to avoid formation of defects, including stone pockets or honeycombs.

Place concrete in each pile continuously and compact using vibrators or other means acceptable to the Engineer. Rod concrete thoroughly around reinforcing steel and spade well along sides. Overfill forms and screed off

surplus concrete. Before concrete has taken a hard set, float top surface and bring it to a smooth finish of uniform and even texture.

After casting and finishing, cover piles with damp burlap or duck. For piles to be installed in soil, fresh water, or on shore, keep piles damp for not less than 18 days. For piles to be installed in seawater, keep piles damp not less than 28 days. After concrete has taken its final set, a 4-inch-thick layer of continuously damp sand may be substituted for burlap or duck.

When removed from forms, pile surfaces shall be true, smooth, and even. Ensure pile straightness such that a line stretched from butt to tip on any face is not more than 1 inch from face of pile at any point. Do not transport or drive piles until piles have cured for at least 21 days and the minimum 28-day compressive strength has been attained. For concrete piles to be installed in salt or brackish water, cure before driving for not less than 30 days.

(C) Cast-In-Place Concrete Piles Cast in Shells. Drive shells or casings to required bearing and leave permanently in place. Remove and replace improperly driven, broken, or defective shells at no increase in contract price or contract time.

Clean insides of shells and casings and remove loose material and water from shells before placing concrete.

Do not place concrete until driving within a radius of 15 feet has been completed, or until all shells for any one bent have been completely driven. If those requirements cannot be met, stop driving within the limits specified until concrete in the last pile cast has set at least 7 days.

Place concrete continuously, and consolidate by vibrating or by an alternative method acceptable to the Engineer.

(D) Pile Driving Equipment.

(1) Pile Hammers.

(a) General. Drive piles with a steam, air, or diesel-type impact hammer. Gravity hammers will not be allowed.

Maintain valve mechanism and other parts of impact hammer in good working condition so that length of stroke and number of blows per minute, for which hammer is designed, is obtained.

(b) Steam or Air Hammers. Furnish steam or air hammers with boiler or air capacity specified by the manufacturers.

Equip boiler or compressor with an accurate pressure gage. Supply another pressure gage for occasional use at hammer intake.

Ensure weight of striking parts is not less than 1/3 weight of drive head and pile, and not less than 2,750 pounds.

(c) Diesel Hammers. Equip open-end (single acting) diesel hammers with device such as rings on the ram or scale (jump stick) extending above ram cylinder. Provide gage and chart from hammer manufacturer equating stroke and blows per minute for the proposed open-end diesel hammer.

Equip closed-end (double acting) diesel hammers with a bounce chamber pressure gage mounted near ground level. Submit a chart, calibrated within 90 days of Project use, to actual hammer performance by the manufacturer or its authorized personnel. Chart shall equate bounce chamber pressure to either equivalent energy or stroke. Identify type, size, and length of hose used during calibration. Use only the same type, size, and length of hose for pile driving.

Provide the Engineer with means to monitor diesel hammers, such as a Saximeter, to measure ram stroke and blows per minute.

(d) Non-Impact Hammers. Non-impact hammers, such as vibratory hammers, will be allowed only if the Contractor drives test piles and conducts load tests, at no increase in contract price or contract time, that satisfactorily meet project requirements.

Non-impact hammers will be used for installing production piles only. Establish pile tip elevation for safe support of pile load by load testing or by test piles driven with an impact hammer.

Drive production piles with vibratory hammers to tip elevation specified by the Engineer. Retap every pile with impact hammer acceptable to the Engineer to determine safe support of pile load.

(2) Driving Appurtenances.

(a) Hammer Cushion. Equip impact pile driving equipment with hammer cushions, in accordance with hammer manufacturer's recommendations, to prevent damage to hammer or pile and to ensure uniform driving behavior. Wood,

wire rope, or asbestos materials will not be allowed for use as hammer cushions. Place a striker plate, as recommended by hammer manufacturer, on hammer cushion. Inspect hammer cushion in the presence of the Engineer when pile driving begins at each structure, or after every 100 hours of pile driving, whichever is less. Replace hammer cushion when hammer cushion thickness is less than 75 percent of the original thickness.

(b) Pile Drive Head. Provide impact hammer drive heads to distribute hammer blows to pile heads. Align drive head axially with the hammer and pile. Guide drive head by leads that are not free-swinging. Fit drive head around pile head in such a manner as to prevent transfer of torsional forces during driving, while maintaining proper alignment of hammer and pile.

For steel and timber piling, cut pile head squarely and provide drive head to hold axis of pile in line with axis of hammer, in accordance with hammer manufacturer's recommendations. Ensure drive head distributes hammer blow throughout pile cross section.

For precast non-prestressed concrete and precast prestressed concrete piles, make pile head plane and perpendicular to longitudinal pile axis.

Provide steel casings or shells for cast-in-place piles, with driving heads, mandrels, or other devices acceptable to the Engineer, in accordance with the manufacturer's recommendation, such that casings or shells may be driven without damage.

(c) Pile Cushion. Use pile cushions consisting of laminated wood not less than 4 inches thick.

Replace pile cushion before damage to the piles occurs, and when cushion has compressed more than 1/2 the original thickness, or is smoking or burning. Ensure cushion does not restrain pile head from rotating in the helmet. Make pile cushion dimensions match cross-sectional area of pile top, such that hammer blow is distributed throughout pile cross-section.

(d) Leads. Use fixed or semi-fixed pile driver leads to support piles in line and position. Construct leads to allow freedom of movement of the hammer while maintaining axial alignment of hammer and pile. Hold leads in position by guys and rigid braces. Do not permit driven pile section to extend

above leads. Embed leads in the ground or constrain pile in structural frame, such as a template, to maintain alignment. Furnish leads of sufficient length to ensure that use of a follower is not necessary. When driving battered piles, use inclined leads that permit proper pile alignments.

Rig semi-fixed leads to maintain hammer travel in line with pile axis. Provide support to drive pile within specified accuracy tolerance. Fit semi-fixed leads with pile gate at bottom of leads. For batter piles, install horizontal brace between crane and leads.

(e) Templates. Provide fixed template to maintain pile in proper position and alignment during driving with semi-fixed leads. For piles on land, locate template within 5 feet of cut-off or within 5 feet of ground line, whichever is less. For piles in water, locate template within 5 feet of cut-off or within 5 feet of the waterline, whichever is less. Templates attached to a barge (floating templates) will not be allowed. Where practicable, place template so that pile can be driven to cut-off elevation before template is removed.

When driving piles with a follower using floating equipment, provide double template or other equipment acceptable to the Engineer, to maintain alignment of hammer, follower, and pile. Use double template consisting of a pile template, within 5 feet of cut-off elevation, and a second upper support above the water surface for the leads. Ensure that individual pile positions of the second upper template are adjustable in size, to serve as a guide for both pile and follower. Ensure that templates do not restrict vertical movement of the pile.

(f) Additional Equipment. If required penetration is not achieved, provide a heavier hammer or other methods acceptable to the Engineer at no increase in contract price or contract time.

(3) Acceptance of Pile Driving Equipment. Furnish pile driving equipment subject to acceptance by the Engineer. Acceptance of pile driving equipment includes dynamic analysis of pile driving equipment using the wave equation. When specified in the contract documents or ordered by the Engineer, the Contractor shall conduct dynamic testing of driving system using dynamic analyzer.

Do not transport driving equipment until the Engineer has accepted wave equation analysis of pile driving equipment.

Submit wave equation analysis of proposed pile driving equipment at least 25 working days before pile driving. Conduct analysis as specified in requirements of Subsection 505.03(J)(2)(b) - Dynamic Analysis. A Hawaii Licensed Civil Engineer, specializing in Geotechnical Engineering, shall stamp analysis. If necessary, the Licensed Engineer shall provide record of experience in Geotechnical Engineering. Include the following in proposed equipment analysis submittal:

(a) Pile Driving Equipment Information as listed on the "PILE AND DRIVING EQUIPMENT DATA FORM". The Engineer will include form in the contract documents or supply upon request.

(b) Complete computer printout of the analysis.

(c) Graph showing driving resistance in blows per foot versus pile bearing capacity. Show on graph the range of energy levels, such as stroke and bounce chamber pressure, at which hammer will be operated for various soil conditions anticipated.

(d) Graph showing driving resistance in blows per foot versus maximum driving stresses (both tension and compression) in kips per square inch. Show on graph the range of energy levels, such as stroke and bounce chamber pressure, at which the Contractor shall operate hammer for various soil conditions anticipated.

(e) For variable energy hammers, chart of various capacities showing driving resistance in blows per foot versus hammer energy level. Measure energy as appropriate for hammer. Capacities shall be equal to 50 percent and 100 percent of the pile bearing capacities shown on plans.

Use the following efficiencies for hammer types shown in the wave equation analysis:

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TABLE 505.03-1 – HAMMER EFFICIENCY	
Hammer Type	**Efficiency (percent)**
Single Acting Air/Steam	67
Double Acting Air/Steam	50
Diesel	80

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TABLE 505.03-2 - MAXIMUM ALLOWABLE PILE DRIVING STRESS	
Pile Type	**Maximum Allowable Driving Stress**
Reinforced Concrete Pile (a) Tensile Stress (b) Compressive Stress	 0 $(0.6)(F'_C)$
Prestressed Concrete Pile (a) Tensile Stress (b) Compressive Stress[KW33]	 $0.25\sqrt{F'_c} + F_{ep}$ [(0.85)(F'C)] – Fep
Steel Pile	$(0.9)(F_Y)$
Timber Pile	$(3.0)(F_S)$
Where: F'_C = 28-Day Design Compressive Strength of Concrete F_{ep} = Effective Prestress Value of the Strands F_Y = Yield Point of the Steel Material F_S = Allowable Design Stress of the Timber Pile	

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The Engineer will use above criteria in evaluating wave equation results and will notify the Contractor of the results within 15 working days of receiving required information listed in Subsection 505.03(D)(3) – Acceptance of Pile Driving Equipment. If analysis shows that pile damage will occur, or that equipment is unable to drive pile to pile bearing capacity shown in the contract documents, the Contractor shall resubmit new analysis modifying proposed methods, equipment, or driving system, at no increase in contract price or contract time. The Contractor shall continue to resubmit until subsequent analysis indicates that piles can be driven to desired pile bearing capacities and pile tip elevations without damage. Show modifications, adjustments, and controls necessary to ensure that driving system will not induce excessive stresses. List changes in the "PILE AND DRIVING EQUIPMENT DATA FORM". The Engineer will notify the Contractor of acceptance or rejection of revised driving system analysis within 10 working days of receipt of revised analysis. Acceptance of proposed method does not relieve the Contractor of the responsibility to provide an installed pile, free of defects, to the required pile tip elevation and bearing capacity.

The Contractor shall conduct dynamic load testing using dynamic analyzer only when specified in the contract documents or when deemed necessary by the Engineer. Conduct dynamic load testing as specified in Subsection 505.03(G)(4) - Dynamic Load Test. Conduct dynamic testing only after wave equation analysis confirms that system has met stress requirements as specified in TABLE 505.03-2 – Maximum Allowable Pile Driving Stress. When dynamic testing is performed, the Engineer will give preference to results using dynamic analyzer over results using the wave equation. If necessary, modify driving system to maintain stresses below specified limits at no increase in contract price or contract time.

The Engineer will allow changes to the driving system only after resubmission and acceptance of information required in this Subsection.

(4) Alternative Criteria for Pile Driving Equipment Acceptance. The Contractor shall submit alternative criteria for pile driving equipment acceptance only when the contract documents state that wave equation analysis is not to be used or when the Engineer waives the wave equation analysis method in writing. The Contractor shall include requirements of Table 505.03-3 – Minimum Pile Hammer Requirements in submitted alternative criteria. Do not transport driving equipment to project site until the Engineer accepts equipment.

Submit pile driving equipment information as listed on the "PILE AND DRIVING EQUIPMENT DATA FORM" at least 25 working days before driving piles. Meet minimum pile hammer requirements in

Table 505.03-3 – Minimum Pile Hammer Requirements.

If the Engineer determines that hammer is unable to transfer sufficient energy to the pile, remove hammer from service until repaired or replace with equipment acceptable to the Engineer. The Engineer will permit variations in driving system only with written acceptance. The Engineer will consider changes in driving system only after a new "PILE AND DRIVING EQUIPMENT DATA FORM" has been submitted. The Engineer will notify the Contractor of acceptance or rejection of proposed change in driving equipment within 10 working days of receipt of the data form.

TABLE 505.03-3 - MINIMUM PILE HAMMER REQUIREMENTS

Pile Bearing Capacity (Ultimate) (Kips)	Minimum Manufacturer's Rated Hammer Energy (Foot-Pounds)
180 and Less	9,000
181 to 300	15,000
301 to 420	20,000
421 to 540	24,000
541 to 600	26,000
601 and Over	Wave Equation Required

(E) Pile Driving Aids.

(1) Followers. Followers will be allowed if acceptable to the Engineer as part of the Contractor's driving system or when specified in the contract documents.

Account for follower use in wave equation analysis and dynamic testing at no additional increase in contract price or contract time.

When followers are used, drive first pile in each pier bent and every tenth pile thereafter as indicator piles, driven full length and without follower. Hold and maintain follower and pile in proper alignment during driving. Provide follower that will permit piles to be driven to required pile tip elevation determined by driving full-length indicator piles. Verify final position and alignment of first two piles

installed with followers as specified in Subsection 505.03(H)(5) - Accuracy of Driving. Do not install additional piles until verification is made for each substructure unit. Submit pile location data for each substructure unit.

(2) Water Jets. Jetting will be allowed only if acceptable to the Engineer as part of the Contractor's driving system, or when specified in the contract documents.

Determine number of jets and volume and pressure of water at jet nozzle necessary to erode material next to the pile without affecting lateral stability of the final in-place pile. Cease jetting when project site, stability of embankment, and improvements are endangered by jetting operation. Restore damage to project site and improvements at no increase in contract price or contract time. Acceptance of proposed method does not relieve the Contractor of the responsibility to install piles free of defects to the required pile tip elevation and bearing capacity.

Ensure jetting plant has sufficient capacity to deliver consistent pressure equivalent to at least 100 pounds per square inch at two 3/4-inch jet nozzles. Stop jetting and remove pipes when pile tip is a minimum of 5 feet above prescribed tip elevation. Drive pile to required pile bearing capacity with impact hammer. Control, treat if necessary, and dispose of jet water.

(3) Drilling. Drill in locations where piles will be driven through embankments that are more than 5 feet deep or when required in the contract documents.

Make hole diameter equal to pile diameter plus 6 inches.

Unless otherwise specified, use auger or wet-rotary drill . Use same drilling method for test piles and production piles. Construct drilled holes such that finished holes will allow piles to stand accurately in positions shown in the contract documents.

Drill in a manner that will not impair carrying capacity of piles already in place or safety of existing adjacent structures.

If the Engineer concludes that drilling has disturbed load bearing capacities of previously installed piles, restore those piles to conditions conforming to the contract documents. Redrive or perform other remedial measures acceptable to the Engineer, at no increase in contract price or contract time. Begin remedial measures after completing drilling operations in the area.

Drive piles in holes drilled through embankments. After

driving pile, fill space around pile to the ground surface with dry, calcareous sand. Sand shall have a minimum sand equivalent (SE) value of 70 or coarse aggregate conforming to AASHTO M 43 size number 8. Dispose of material resulting from drilling holes.

Drill holes through natural ground only when required in the contract documents. For piles driven through natural ground, make drilled holes sufficiently large to allow penetration of piles to specified depth, but not larger than diameter or diagonal of pile cross-section. If subsurface obstructions are encountered, such as boulders or rock layers, hole diameter may be increased to the least dimension adequate for pile installation.

Except for piles specified in the contract documents as end-bearing, stop drilling at least 5 feet above pile tip elevation, or as ordered by the Engineer. Drive pile with impact hammer to specified blow count. For end-bearing piles on rock or hardpan, drill to surface of rock or hardpan. Tap planted piles with impact hammer. Do not use spud (short, strong, driven member that is removed) to make hole for inserting pile.

(F) Preparation for Driving.

(1) Excavation. Do not drill holes for piles or drive piles until after foundation excavation has been completed and accepted in writing by the Engineer. Remove materials forced up between piles to the correct elevation, at no increase in contract price or contract time, before placing foundation concrete.

(2) Concrete Pile Splices. Piles shown on plans are full-length piles. Piles longer than 100 feet may be spliced not more than once, to suit the Contractor's operation, provided piles are mechanically spliced. Design strengths of splice shall be no less than strengths of unspliced pile in tension, compression, bending, and torsion. Use metal with minimum corrosion life of 100 years. Provide splices at no additional increase in contract price or contract time.

(3) Pile Shoes. When specified in the contract documents, provide and install pile shoes of the type and dimensions indicated. Prefabricate shoes for steel piles from cast steel conforming to AASHTO M 103M.

(4) Collars. Provide collar bands to protect timber piles against splitting and brooming, where necessary.

(5) Compressive Strength of Concrete Piles. Do not drive prestressed concrete piles until concrete has reached the minimum compressive strength , as determined by test cylinders, and not earlier

than 7 days after casting.

Do not drive precast non-prestressed concrete piles until the conditions specified in Subsection 505.03(B) - Reinforced Precast Non-Prestressed Concrete Piles have been met.

(G) Pile Test Program.

(1) General. The Contractor shall conduct pile test program that includes driving test piles successfully and performing static and dynamic pile load tests, when required.

Cast test piles full length without splice, and drive without a follower.

Make length of test piles used as indicator piles and test piles used for dynamic load test only, 15 feet longer than length from estimated pile tip elevation to cut-off elevation shown in the contract documents.

Make length of test pile used to perform static load test 15 feet longer than length from estimated pile tip elevation to the level ground surface on which base of cribbing rests, or level platform over water from which load test is to be done.

Furnish, drive, or place test piles of the number, length, and type specified. Remove test piles that are not part of the completed structure to at least two feet below ground surface or finish grade, whichever is lower. Incorporate test piles that are part of the completed structure into the structure in accordance with requirements for production piles of the same type.

Do not order production piles until the Engineer analyzes driving and load tests and provides written pile order list. The Engineer will provide pile order list within 7 working days after specified pile testing has been completed.

(2) Driving Test Piles. Drive test piles with impact hammer. Use driving equipment conforming to the contract documents, and identical to equipment proposed for use on production piles. Before driving test pile, excavate ground at each test pile location to footing bottom elevation.

Drive test piles at locations shown in the contract documents and to depths ordered by the Engineer, unless new location is requested in writing by the Contractor and approved by the Engineer. Drive test piles to refusal criteria determined by the Engineer at estimated pile tip elevation. Base refusal criteria at estimated pile tip

elevation on the following: Subsection 505.03(G)(4) - Dynamic Load Test for static and dynamic load test piles; and Subsection 505.03(J)(2)(b) - Dynamic Analysis for indicator piles.

The Engineer will require test piles that do not attain specified hammer blow count at the plan tip elevation to set up for at least 72 hours or less before redriving. A cold hammer will not be allowed for redriving. Warm up hammer before driving begins by applying at least 20 blows of continuous hammer strikes to a suitable object that is not part of the structure. If specified hammer blow count cannot be attained on redriving, the Engineer may order a portion or all remaining test pile length to be driven and the set up and redrive procedure repeated. If hammer blow count cannot be attained and test piles are driven to a depth 10 feet below estimated tip elevation, splice and redrive test piles until required bearing is attained.

(3) Static Load Tests. Apply test load placed upon suitable platform supported by pile equipped with apparatus for accurately measuring test load and pile settlement under each load increment.

When specified in the contract documents, the Contractor shall perform dynamic load testing as specified in Subsection 505.03(G)(4) - Dynamic Load Test, of test piles that will be statically load tested.

Perform static load test in accordance with ASTM D 1143. Supply testing and measuring equipment for load test. Conduct testing and supply measuring equipment in accordance with ASTM D 1143, except that loading system shall be capable of supporting load equal to 150 percent of pile bearing capacity (ultimate).

Submit detailed plans and design calculations of proposed loading apparatus prepared and stamped by a Hawaii Licensed Structural Engineer. Include soils support values provided by a Hawaii Licensed Civil Engineer experienced in Geotechnical Engineering.

Design and construct loading system to allow various increments of the load to be placed gradually, without causing vibration to the test pile. Design cribbing or foundation support to prevent excessive settlement of the load test. Include in submittal the method of establishing reference beam and dial support system. Allow the State at least 3 weeks to review each submittal or resubmittal for acceptance.

Pile bearing capacity (ultimate) is defined as the load that produces a settlement at pile head failure, when tested under axial

compressive load for piles 24 inches or less in diameter or width, equal to:

TABLE 503.03-4 – PILE BEARING CAPACITY (ULTIMATE)
SF = S + (0.15 + 0.008D)
Where: SF = Settlement at failure in inches D = Pile diameter or width in inches S = Elastic deformation of total pile length in inches

Measure top elevation of test pile immediately after driving and again just before load testing to check for heave. Redrive or jack piles that heave more than 1/4 inch, to original elevation before testing.

The Contractor shall estimate pile bearing capacity by dynamic testing using the dynamic analyzer. The Contractor shall use alternative method of estimating pile bearing capacity by the wave equation, only when specified in the contract documents.

After load test has been completed, the Engineer may revise pile tip elevations to conform to pile bearing capacity requirements. The Engineer will indicate revised pile tip elevations, if required, in writing as specified in Subsection 505.03(A)(2) - Order List for Piling.

If load test piles are too long after driving, cut excess portion as ordered by the Engineer.

Allow one week after driving piles before placing loads on piles. Conduct pile load test within 7 working days. The 7 working days shall begin the next working day following a satisfactory inspection of the pile test set-up.

(4) Dynamic Load Test. When specified in the contract documents, and while driving piles designated as dynamic load test piles, the Contractor shall conduct dynamic load testing and supply instruments, equipment, and measurement devices conforming to ASTM D 4945.

Furnish shelter to protect dynamic test equipment from the elements, with minimum floor size of 8 feet by 8 feet and minimum roof height of 7 feet. Maintain inside temperature of shelter above 45 degrees F. and below 90 degrees F. Locate shelter within 50 feet of test location.

Install anchors with pile in a horizontal position and not in contact with other piles. Support pile by level blocking at pick-up point locations. Do not rest pile directly on the ground.

Place and secure pile in driving lead only after pile has been prepared satisfactorily. Then drive the pile 5 feet. At this time, from a safety bucket, attach transducers, accelerometers, and terminal box to anchors near pile head.

After installing attachments, drive pile to depth in accordance with contract documents or as ordered by the Engineer. Monitor pile stresses during driving with dynamic test equipment. If necessary, reduce driving energy transmitted to pile by using additional cushions, or reduce hammer energy output. If dynamic test equipment measurements show non-axial driving, realign driving system immediately.

When pile head approaches the ground, stop driving to prevent damage to instruments and remove instruments from pile.

Wait at least 72 hours, reattach instruments for dynamic testing, and restrike pile. Ensure maximum restrike penetration is 3 inches or maximum total number of restrike hammer blows is 50 blows, whichever occurs first. After restrike, the Engineer will either provide pile tip elevation or order additional pile penetration and testing.

(H) Driving Piles.

(1) General. Drive production and test piles with impact hammer. Use only a single system. Drive test piles as specified in Subsection 505.03(G)(2) - Driving Test Piles. Use driving aids conforming to Subsection 505.03(E) - Pile Driving Aids.

Drive piles for a given foundation unit with the same hammer, under the same operating conditions, and with the same cushion material used to drive test piles.

(2) Installation Sequence. Place individual piles in pile groups in the order starting from the center of the group and proceeding outwards in both directions or starting at the outside row and proceeding progressively across the group.

(3) Pile, Hammer, and Lead Alignment. Commence pile driving with pile in vertical or batter position shown in the contract documents. Continue driving pile in specified position without inducing bending stresses on pile. If pile can no longer be brought back to specified position without inducing bending below ground and without forcing

pile back to specified position, maintain hammer and leads in alignment with longitudinal axis of the pile.

For vertical piles, the Engineer may require driving to be temporarily stopped so that hammer can be lifted completely off pile head. Release hammer without inducing bending stresses in pile. If necessary, align leads parallel to the natural pile inclination.

(4) Driving Near Fresh Concrete. Do not drive piles when fresh concrete is within 150 feet measured horizontally, or vibrations can be felt in the vicinity of the fresh concrete. Fresh concrete is defined as less than 72 hours old or having a compressive strength less than 2000 pounds per square inch.

(5) Accuracy of Driving. Pile tops at cut-off elevations shall be within 2 inches of the plan locations for trestle bent caps supported by piles. If as-driven load centroid of pile group at cut-off elevation varies by more than 3 inches from plan location, submit structural analysis signed by Hawaii Licensed Structural Engineer and construct modifications, if necessary, as ordered by the Engineer. No pile shall be nearer than 4 inches from edges of the cap. Increase size of cap to meet this edge distance requirement at no increase in contract price or contract time.

Install piles so that axial alignment of the top 10 feet of pile is within 4 percent of specified alignment. For piles that the Engineer cannot inspect internally after installation, perform alignment check before installing last 5 feet of pile, or after completing installation if exposed portion of pile is not less than 5 feet in length. The Engineer may require driving to be stopped to check pile alignment. Do not push or pull on piles, laterally, to correct misalignment, or splice a properly aligned section on a misaligned section.

If pile location or alignment exceeds specified tolerances, the Engineer will investigate extent of overloading within 10 working days and inform the Contractor of the decision in writing. If the Engineer determines that corrective measures are necessary, the Contractor shall redesign, submit for acceptance, and construct corrective measures at no increase in contract price or contract time.

(6) Heaved Piles. Make level readings at start of pile driving operations. Continue making level readings until the Engineer decides that such readings are no longer required. Take level readings immediately after driving pile and again after driving piles within a radius of 15 feet. If pile heaving is observed, take accurate level readings on piles referenced to a fixed datum. Take readings immediately after installation, and periodically, as adjacent piles are driven, to determine pile heave range. Redrive piles that have heaved

more than 0.25 inches, to the required resistance or penetration, at no increase in contract price or contract time. If pile heave is detected for pipe piles filled with concrete, redrive piles to original position after concrete has attained sufficient strength, using hammer-pile cushion system acceptable to the Engineer.

(7) Retapping. After piles are driven and before driving equipment is removed from footing, the Engineer will select one pile in the footing for retapping. The Engineer will require pile to set up for at least 72 hours before retapping. Retap with same hammer used to drive piles. Stop retapping pile if penetration rate is less than or equal to initial refusal at the same hammer energy setting. During retapping, ensure not less than 50 blows are delivered or pile moves 3 inches, whichever occurs first.

If retapping penetration rate is greater than initial refusal rate, continue to drive pile until initial refusal rate is attained. The Engineer will select additional piles in the footing for retapping.

(8) Furnishing As-Driven Pile Locations. Furnish plan showing locations of as-driven piles of a pile group, including batter and direction of batter. Perform survey of the work under the supervision of the Engineer or the Engineer's representative. Notify the Engineer in advance of when surveying will be performed. Submit copy of survey notes locating piles immediately after survey has been completed. After submitting survey notes, submit plan of as-driven pile locations, drawn to scale.

The Engineer will use that plan to determine if redesign or added pile is necessary. Allow the Engineer 10 working days from date the Engineer receives as-driven pile location plans, to make this determination.

Do not proceed with footing form work before the Engineer accepts pile locations.

(9) Archive of Foundation Records. At completion of pile driving for each footing, submit one electronic file in Adobe Acrobat, version 4.0 or higher, containing all pile driving records for the footing. Submit separate and complete electronic file for each pile group. Include in first page of file for each footing, a footing layout showing actual pile locations and identifying each pile. Arrange pile driving reports in order as indexed in footing layout.

Ensure that information in pile driving reports is complete and accurate; piles are properly identified; and information in report is legible and fully readable when converted to Adobe Acrobat format.

Convert and submit corrected original tracings of foundation plans and "Log of Test Borings" plans. Submit all electronic files on CD-ROM. Include index prepared specifically for drawings for each structure, containing file names in the set of Adobe Acrobat files for each structure, in root of CD-ROM directory tree. Ensure that files for each pile group are organized in folders on CD-ROM.

Make edge of document image clearly visible with the frame and visually parallel with the edges of the frame. Provide a clear, legible symbol on the upper left side of each frame to show the amount of reduction. Provide horizontal and vertical scales that are photographed on each frame.

(I) Defective Piles. Use pile driving method that will not subject piles to excessive or undue abuse, resulting in concrete crushing or spalling; wood splitting, splintering, or brooming; or steel deforming. Correct piles that were damaged during driving due to internal defects or by improper driving; or were driven out of proper horizontal location or below designated cut-off elevation, at no increase in contract price or contract time.

Use the following methods, subject to acceptance by the Engineer, for correcting defective piles: extracting and replacing defective pile with new, and if necessary, longer pile; driving second pile next to defective pile; extending footing sufficiently to properly embed pile; or splicing or building up pile, in accordance with the contract documents. Do not splice timber piles without permission from the Engineer.

Dynamic testing may be utilized for pile acceptance. At the option of the Engineer, the State's pile driving analyzer may be used to evaluate structural condition of a driven pile, including integrity of pile splice connections. The Contractor shall conduct dynamic testing similar to testing procedure for load test pile in Subsection 505.03(G)(4) - Dynamic Load Test. The Engineer may use information obtained with dynamic analyzer as a basis for pile rejection. Compliance with requirements of contract documents does not relieve the Contractor of the responsibility to provide piles free of defects and within specified driving tolerances.

(J) Pile Bearing Capacity and Penetration.

(1) General. If refusal occurs before tip elevation shown in the contract documents is reached, penetration as specified in Subsection 505.03(J)(3) - Penetration shall apply.

If specified bearing capacity cannot be achieved when pile tips reach the given elevations, the Engineer will decide if piles need to be extended or if footing needs to be redesigned.

Jetting or other methods to ease pile penetration will not be allowed without written authorization from the Engineer. Base the pile bearing capacity of jetted piles on blow count of impact hammer after removal of jet pipes. Splice jetted piles that do not attain required pile bearing capacity at ordered length, as required, and at no increase in contract price or contract time. Drive jetted piles with impact hammer until required pile bearing capacity is achieved as specified in Subsection 505.03(J)(2) - Determination of Pile Bearing Capacity.

When followers are used, required pile bearing capacity of piles driven will be accepted only when follower-driven piles attain same tip elevation as full-length piles that attained required bearing capacity.

When non-impact hammers are used as specified in 505.03(D)(1)(d) - Non-Impact Hammers, determine pile bearing capacity as specified in the contract documents. Drive first pile of each group of 10 piles with vibratory hammer to tip elevation, in accordance with the contract documents. When tip elevation is attained with non-impact hammer, retap pile with impact hammer acceptable to the Engineer. Drive pile with impact hammer until required pile bearing capacity is attained, as specified in Subsection 505.03(J)(2) - Determination of Pile Bearing Capacity.

Splice piles not attaining required pile bearing capacity at tip elevation, as required. Drive such piles with impact hammer until required pile bearing capacity is achieved. When required pile bearing capacity is achieved, install remaining nine piles to the same tip elevation as the first pile. Use same vibratory hammer power consumption and rate of penetration used on first pile, on the remaining nine piles.

(2) Determination of Pile Bearing Capacity.

(a) Load Tests. When the contract documents specifies load tests, the Contractor shall determine pile bearing capacity based on results of static load tests. If the contract documents specifies only dynamic load tests, the Contractor shall determine pile bearing capacity based on results of dynamic load tests.

(b) Dynamic Analysis. When the contract documents does not specify load tests, the Contractor shall determine pile bearing capacities by dynamic analysis using the wave equation. Perform this analysis using the "WEAP87" (or later version) Computer Program, developed under sponsorship of the FHWA.

Drive piles with accepted driving equipment to ordered

length or other lengths necessary to achieve required pile bearing capacity. Adequate pile penetration is achieved when specified wave equation resistance criteria is attained within 5 feet of tip elevation, based on the ordered length. Drive piles that have not achieved specified resistance within these limits, to penetrations established by the Engineer.

(c) Dynamic Formula. When specified in the contract documents, the Contractor shall determine pile bearing capacity by dynamic formula. Drive piles to length necessary to achieve pile bearing capacity in accordance with the following:

TABLE 503.03-5 – PILE BEARING CAPACITY
$R_U = [(1.75)(E^{0.5})\text{Log}(10N)] - 100$
Where: R_U = Pile Bearing Capacity (kips) E = Manufacturer's rated hammer energy (foot pounds) at the ram stroke observed in the field N = Number of hammer blows per inch at final penetration (blows per inch) Log (10N) = Logarithm to the base 10 of the quantity 10 multiplied by N

(3) Penetration. When the contract documents do not specify tip elevation, ensure pile bearing value is not less than pile bearing capacity shown in the contract documents. Drive piles at least 10 feet below bottom of footing or finished grade, whichever is lower.

When the contract documents specifies tip elevation, drive piles to bearing value of not less than pile bearing capacity shown in the contract documents and to specified tip elevation, unless otherwise permitted by the Engineer in writing.

(K) Finishing of Satisfactorily Driven Piles

(1) Cutting Off and Capping Pile.

(a) General. Cut off tops of permanent piles and pile casings at elevation and plane shown in the contract documents or as ordered by the Engineer. Cut-off lengths shall become property of the Contractor and removed from the project site.

(b) Timber Piles. Saw tops of timber piling to a true plane, in accordance with the contract documents, and at elevation fixed by the Engineer. Saw piles that support timber caps or grillage to conform to the plane of the superimposed structure bottom. Provide pile of sufficient length so that length of pile above cut-off elevation is sufficient to permit complete removal of material damaged by driving. Adze or remove broomed, splintered, or otherwise damaged material from piles driven to very nearly the cut-off elevation.

Treat timber pile heads, not encased in concrete, as specified in Subsection 502.03(F) - Treatment of Pile Heads.

(c) Precast Concrete Piles. Extend pile reinforcing steel and prestressing strands at least 24 inches above tops of pile or as specified in the contract documents. Clean reinforcing steel and prestressing strands to ensure that a secure bond with the fresh concrete is obtained. The use of explosives to cut off piles will not be allowed.

Unless otherwise specified, after cut-off, pile tops shall be on plane normal to pile axis.

(d) Steel Piles and Steel Shells. Cut off steel shells for cast-in-place piles before shells are filled with concrete. If the contract documents require capping, make connection in accordance with details shown in the contract documents.

(2) Build-ups of Piles. When requested and accepted by the Engineer in writing, extend, splice, or build-up piles.

(a) Timber and Steel Piles. Extend timber and steel piles in accordance with details shown in the contract documents or furnished by the Engineer.

(b) Precast Concrete Piles. After driving has been completed, cut off concrete in accordance with the contract documents. Leave reinforcing steel exposed for a length of 40

bar diameters. Make final concrete cut perpendicular to pile axis. Fasten reinforcement, identical in type, size, and grade to reinforcement that is used in the pile, securely to projecting steel. Place required formwork, taking care to prevent leakage along pile. Just prior to placing concrete, wet and cover pile top with thin coating of neat cement, retempered mortar, or other bond material acceptable to the Engineer.

Leave forms in place for not less than 7 days. Water cure for 30 days before driving is continued.

(3) Painting Steel Piles. Protect steel piles that extend above ground with three coats of paint, as specified for painting of metals in Section 501 - Steel Structures. Paint shall extend to one foot below finished grade.

(4) Backfilling Around Piles. Backfill space around pile caused by drilling or driving operations with fine aggregate conforming to Subsection 703.01 - Fine Aggregate for Concrete. Backfill, if required, after driving each pile so that vibrations caused by driving adjacent piles will further compact backfill.

505.04 Measurement.

(A) The Engineer will measure piles furnished, piles driven, cast-in-place concrete piles cast in shells, and drilled holes for piling per linear foot in accordance with the contract documents.

(B) The Engineer will measure pile driving shoe, pile load test, and splicing per each in accordance with the contract documents.

(C) The Engineer will measure retapping of additional piles and build-ups of piles on a force account basis in accordance with Subsection 109.06 - Force Account Provisions and Compensation and as ordered by the Engineer.

505.05 Payment. The Engineer will pay for the accepted pay items listed below at the contract price per pay unit, as shown in the proposal schedule. Payment will be full compensation for the work prescribed in this section and the contract documents.

The Engineer will pay for each of the following pay items when included in the proposal schedule:

Pay Item	**Pay Unit**
_____ Piles Furnished	Linear Foot

The Engineer will pay for:

(A) 80 percent of the contract bid price upon completion of manufacturing piles at plant site.

(B) 20 percent of the contract bid price upon completion of delivering piles to project site.

_____ Piles Driven — Linear Foot

The Engineer will pay for:

(A) 80 percent of the contract bid price upon completion of driving piles including installing pile splices, pile driving shoe, and pile collars.

(B) 20 percent of the contract bid price upon completion of cutting off piles.

Cast-In-Place Concrete Piles Cast in Shells — Linear Foot

The Engineer will pay for:

(A) 40 percent of the contract bid price upon completion of furnishing cast-in-place concrete piles cast in shells.

(B) 60 percent of the contract bid price upon completion of installing cast-in-place concrete piles cast in shells.

Drilled Holes for Piling — Linear Foot

The Engineer will pay for:

(A) 80 percent of the contract bid price upon completion of drilling.

(B) 20 percent of the contract bid price upon completion of disposing of material resulting from drilling holes.

Pile Driving Shoe Each

The Engineer will pay for:

(A) 100 percent of the contract bid price upon completion of furnishing pile driving shoe.

_____ Pile Load Test Each

The Engineer will pay for:

(A) 70 percent of the contract bid price upon completion of driving test pile

(B) 10 percent of the contract bid price upon completion of performing static and dynamic pile load tests, when required.

(C) 10 percent of the contract bid price upon completion of removing test piles that are not part of the completed structure.

(D) 10 percent of the contract bid price upon completion of cutting piles.

Splices Each

The Engineer will pay for:

(A) 100 percent of the contract bid price upon completion of furnishing splices.

Archiving of Pile Driving Records Lump Sum

Retapping of Additional Piles Force Account

Build-Ups of Piles Force Account

An estimated amounts for the force account pay items listed above may be allocated in the proposal schedule, but the actual amounts to be paid will be the sums shown on the accepted force account records, whether these sums are more or less than the estimated amounts allocated in the proposal schedule

END OF SECTION 505