Specifications for the Construction of Secant and Tangent Pile Wall Systems using Drilled Shafts

1.0 GENERAL

This document establishes the recommended construction specifications for the installation of cantilevered, braced, and/or anchored secant and tangent pile retaining wall systems. Secant and/or tangent pile walls may be constructed using various technologies including drilled shaft construction, continuous flight auger (CFA), and deep soil mixing (DSM) systems. The work described hereinafter is limited to the installation of secant or tangent pile walls using drilled shaft construction methods.

Commentary: *It is recommended that a meeting shall be held early in the secant/tangent pile wall design process to discuss the construction requirements appropriate for the structure application, and for geotechnical and general site conditions. For state and local government projects, those involved should include representatives from the Bridge/Structures office, Geotechnical office, and Construction office, representatives from the local ADSC Chapter, and other appropriate designers and consultants assigned to the project. Arrangements for ADSC representation at such discussions or meetings can be made through the local ADSC Chapter or through the national office of the ADSC.*

Note: *This specification is subject to revision. Contact the national office of the ADSC at (469) 359-6000 for the latest version of this specification.*

2.0 DESCRIPTION

This item of work shall consist of furnishing all materials, labor, tools, equipment, services and incidentals necessary to construct the secant/tangent piles in accordance with the Plans, Standard Specifications, and these specific product specifications.

In the event that these specific specifications cause conflict or ambiguity with the project specifications, the Project Specifications shall take precedence unless otherwise accepted, in writing, by the Project Engineer.

3.0 DEFINITIONS

Acceptable or accepted	Received or admitted by the Owner's Representative as adequate or satisfactory.
Bearing Stratum	The soil or rock stratum that carries the load transferred to it by a secant/tangent pile.
Contract Documents	Documents covering the required Work, including the Project Drawings, Geotechnical Reports/Information, and Project Specifications.
Contractor	The specialty contractor who is responsible for satisfactorily performing the work described herein.
Casing Method	A method of construction in which a temporary casing is used to advance and support the sides of the borehole during the

	construction of the secant/tangent pile, including the placement of the reinforcing steel and the concrete. Natural mineral or polymer drilling fluid may or may not be used in conjunction with this method.
Designer	A qualified engineer who is responsible for designing the secant or tangent pile wall system in accordance with the appropriate design standards, specifications, and construction techniques.
Drilling Fluid	The drilling fluid can be composed of natural mineral materials (i.e., processed clay materials such as bentonite or attapulgite), can be composed of synthetic materials (e.g., polymers or acrylamides), or can be a blend. See also: Slurry.
Dry Method	A method of construction in which a borehole is advanced without the use of slurry or water (as a stabilizing fluid) during the construction of the secant/tangent pile, including the placement of the reinforcing steel and the concrete. A temporary steel casing may be used.
Engineer	On behalf of his/her employer or client (e.g., Owner, Contractor, Consultant, etc.), this is a qualified engineer specialized in geotechnical and structural characteristics of earth retention systems who is charged with serving as the representative on matters pertaining to the design, specifications, construction, quality assurance-quality control, and supervision of the project.
External bracing	A system of horizontal and/or inclined structural members connected to the vertical structural members (i.e., secant or tangent piles) used to increase lateral stability of the earth retention system.
Firm/Firm Secant Piles	Primary and secondary piles are backfilled with unreinforced, weak or lean concrete. Secondary piles can be reinforced as required by design.
Fully Cased	A method of construction that occurs when a temporary steel casing is used to support the borehole fully during the construction of a secant or tangent pile. The casing is installed (during, before, or after excavation depending on ground or other environmental conditions) and then is extracted after placement of the steel reinforcement and concrete.
Ground Anchor (Tieback)	A system used to transfer tensile loads to the ground (i.e., soil and/or rock) and to provide active lateral support to an earth retention system. The components of a ground anchor include the pre-stressing steel tendon, grout, centralizers, bond breaker, anchorage, and corrosion protection. Ground anchors are most often pre-stressed to limit the deformation of the earth retention system.
Ground Surface	The level at which the tooling for the construction of the secant or tangent pile wall first enters the ground. The ground surface is not necessarily the same elevation as the working platform and/or the

top of the guidewalls.

Guidewall — A reinforced concrete template that is formed in the ground prior to the start of the construction of the secant or tangent pile walls. The guidewall provides restraint to the position and verticality of the secant/tangent piles, and aids in the support of the reinforcing steel, casing extractors, etc. during the placement of concrete.

Hard/Firm Secant Piles — Primary piles are backfilled with unreinforced, weak or lean, concrete, and secondary piles are backfilled with higher strength structural grade concrete and are typically reinforced.

Hard/Hard Secant Piles — The concrete in each primary and secondary pile has the same compressive strength, which is a higher strength structural grade concrete. Secondary piles are typically reinforced, and primary piles typically unreinforced.

Hard/Soft Secant Piles — Primary piles are backfilled with a cement/bentonite mix and are typically unreinforced, and secondary piles are backfilled with higher strength structural grade concrete and are typically reinforced.

Inspection — The observation of construction, equipment, materials, and actual subsurface conditions that enables the Geotechnical Engineer to render a professional opinion on the expected performance of the constructed work and on the Contractor's conformance to the Contract Documents.

Mineral Slurry — Slurry in which the principal ingredient, by weight or activity, is finely divided clay and/or other minerals.

Obstruction — A naturally occurring or man-made object(s) in the ground that impedes or prevents the advancement of the borehole or the installation of the secant/tangent pile.

Pig — A device inserted into a tremie pipe that is used to separate fresh, fluid concrete from the fluid(s) within the borehole excavation.

Polymer — Water-dispersible or water-soluble water thickening compound formed from two or more polymeric compounds. Suitable polymers may potentially be synthetic, natural, modified natural, or combinations or grafts.

Polymer Slurry — Slurry, in which the principal ingredient, by weight or activity, is water-soluble or water-dispersible polymers.

Primary Pile — The initial vertical pile, usually unreinforced (but can be reinforced for some applications), typically constructed using rotary drilling methods (including oscillator methods), which serves as soil support between the secondary, reinforced piles.

Commentary: *Primary piles function as soil support between the secondary piles in both linear and circular shaft wall applications. They also serve to transfer compression loads in circular shaft applications. It's not uncommon for designs to include multiple unreinforced "primary" piles between each reinforced pile.*

Qualification	The Contractor intending to perform the construction of the Work must have had prior experience successfully installing secant or tangent wall systems. The requirements vary based on the difficulty of the specific project. The contractor qualification requirements are typically defined within the project specific specifications.
Quality Assurance	A system or program of procedures, methods, and/or evaluations that ensure the required level of quality of and performance from the constructed work is achieved.
Quality Control	A system for verifying and maintaining the required level of quality in and performance from the constructed work through planning, use of proper equipment, continued observation and inspection, and corrective action.
Seating	The act of installing a steel casing whereby its entire circumference is in complete contact with the underlying soil/rock formation.
Secant Pile Wall	An earth retention system consisting of contiguous, interlocking/overlapping vertical piles (e.g., drilled shafts, columns, etc.). A secant pile wall is constructed by installing concrete or cement/bentonite grout primary vertical piles (with or without steel reinforcement) at prescribed intervals. Secondary vertical piles are then installed in between and slightly overlapping the primary piles, wherein reinforcing steel is inserted and the secondary piles are filled with the appropriate concrete mix. The reinforcement may be composed of either a steel reinforcing cage or a steel beam section. Typically, the primary and secondary piles are of the same diameter. In non-water retaining designs, often the unreinforced piles (primary piles) are only drilled to 1-2 feet below the excavation level while the reinforced secondary piles have a deeper toe for wall stability.
Secondary Pile	A vertical reinforced concrete pile, typically constructed using rotary drilling methods (including oscillator methods), which serves as the support for the proposed earth retention system and can be used for vertical loading (e.g., when the secant wall is used as an abutment, as support for the superstructure, etc.).
Slurry	A drilling fluid used to stabilize and support sides and bottom of the borehole during the construction of the secant/tangent piles. The slurry mixture provides hydrostatic pressure that supports the sides and bottom of the borehole, lubricates and cools the drill tools, and aides in cleaning or removing the cuttings from the borehole. For this type of construction, the slurry is mainly comprised of water, clay materials (e.g., bentonite or attapulgite), polymeric materials, and/or acrylamides.
Slurry Displacement Method	Method of drilling and concreting, whereby controlled slurry consisting of water with or without additives such as bentonite, attapulgite, or polymer is used to stabilize the borehole. The slurry may be used to stabilize an uncased drilled borehole, or to

allow acceptable concrete placement when water seepage into the borehole is excessive.

Surface Casing Temporary casing that is installed to prevent the sloughing of soil near the surface of a borehole.

Tangent Pile Wall An earth retention system consisting of contiguous (i.e., abutting with small or no gap) vertical piles (e.g., drilled shafts, columns, etc.). A tangent pile wall is constructed by installing concrete or cement/bentonite grout primary vertical piles (with or without steel reinforcement) at prescribed intervals. Secondary vertical piles are then installed in between and typically abutting the primary piles, wherein reinforcing steel is inserted and the secondary piles are filled with the appropriate concrete mix. The reinforcement may be composed of either a steel reinforcement cage or a steel beam section. Typically, the primary and secondary piles are of the same diameter. Wall designs may allow small gaps (1-6 inches) occurring between tangent piles.

Temporary Casing This refers to a steel pipe that may be used to advance the borehole by supporting the sides of a borehole during the drilling and installation of the secant/tangent pile. The casing may be used to construct the primary and/or secondary piles, and typically provides a more consistent finished product. The casing is extracted during concreting.

Tremie Method A method used to place concrete by gravity into the borehole where water and/or slurry are typically present. Concrete is placed through a conduit (i.e., steel pipe or tube) into the bottom of the borehole, and the concreting operation continues until the borehole is completely filled from the bottom up. A significant head of fresh concrete (eg. 5 to 10 feet "above fluid level in the shaft") is constantly maintained, inside and above the tip of the tremie, ensuring upward displacement of slurry and water to prevent intermixing or dilution of fresh concrete with soil, water, and/or slurry. The tremie or tube is smooth and clean both inside and out, and typically has a minimum inside diameter (ID) of 10 inches. The pump tube typically has a minimum ID of 5 inches.

Wet Method A method of construction, in which a borehole is advanced with the use of slurry or water during the construction of the secant/tangent pile, including the placement of the reinforcing steel and the concrete. The slurry or water is used also as a stabilizing fluid to support the sides of the borehole and to counteract hydrostatic conditions. A temporary steel casing may be used also with this method.

Work This includes all of the activities associated with the installation of cantilevered, braced, and/or anchored secant and/or tangent pile earth retention systems.

Working platform A surface that safely supports the construction equipment and personnel. The working platform also includes any ramps, access paths, and roads.

4.0 MATERIALS

4.1 Water

Water shall be potable, and shall be in accordance with the slurry requirements provided herein.

4.2 Concrete

4.2.a Guidewalls

Concrete used in the construction of the guidewalls shall have a minimum 28-day compressive strength of 3,000 psi, and shall conform to the requirements of Section ____ of the Standard Specifications.

4.2.b Primary Piles

For hard/hard vertical piles, the concrete shall have a minimum 28-day compressive strength of _____ psi, and shall conform to the requirements of Section ____ of the Standard Specifications. For hard/firm vertical piles, the infill material shall be a pumpable lean concrete mix composed of 1.5 bags of cement per cubic yard of concrete. In water retention applications, the concrete mix design shall be such that its minimum 28-day compressive strength is 550 psi.

Commentary: *For hard/firm piles, other cementitious products commonly used in the lean mix include slag cement and fly ash.*

4.2.c Secondary Piles

Concrete used in the construction of the secondary piles shall have a minimum 28-day compressive strength of 4,000 psi, and shall conform to the requirements of Section ____ of the Standard Specifications.

4.3 Cement-Bentonite Grout

4.3.a Primary Piles

For hard/soft vertical piles, the infill material shall be a cement-bentonite grout mix with typical mix proportions of 27 gallons of water, 94 lbs. of cement, and 11 lbs. of bentonite. The addition of slag or fly ash is allowed in order to achieve similar low strength properties.

4.4 Steel Reinforcement

4.4.a Reinforcing Bars

Bar reinforcement shall conform to the requirements of Section ____ of the Standard Specification.

4.4.b Steel Beams

Steel beam reinforcement shall conform to the requirements of Section ____ of the Standard Specifications.

4.4.c Centralizers and Spacers

Non-corrosive centralizers and spacers that facilitate proper alignment of the steel reinforcement shall be used in the Work.

4.5 Casing

The temporary casing shall be steel, rigid, smooth, clean, and capable of withstanding all handling, installation, and extraction stresses. The temporary casing shall be capable of withstanding the pressures exerted by the infill concrete, groundwater, and the surrounding soil and/or rock. The outside diameter (OD) of the temporary casing shall be at least the required size of the vertical pile. The temporary casing shall be of sufficient length (partial or full length of pile) to provide temporary support to achieve the required length for each secant/tangent pile within the Work. If segmental casing is used, the segments shall be connected by using flush-bolted, reasonably watertight, casing joints.

4.6 Slurry

Slurry shall conform to one of the following:

4.6.a Mineral Slurry

Mineral slurries shall be used in conformance with the manufacturer's recommendations and the quality control plan specified in subsection 5.2.b.5 of this specification. The mineral slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	63 to 75
Viscosity (seconds/quart)	Marsh Funnel and Cup API 13B-1, Section 2.2	26 to 50
pH	Glass Electrode, pH Meter, or pH Paper	8 to 11
Sand Content (percent) 1. Prior to final cleaning 2. Immediately prior to placing concrete	Sand API 13B-1, Section 5	 4.0 (max) 4.0 (max)

The use of bentonite in salt-water installations shall not be allowed. At the time of testing, the temperature of the slurry shall be at least 40°F.

Commentary: *When it is necessary to use a mineral slurry in salt water applications, it is recommended that attapulgite or sepiolite be used in lieu of bentonite.*

4.6.b Synthetic Slurries

Synthetic slurries shall be used in conformance with the manufacturer's recommendations and the quality control plan specified in subsection 5.2.b.5 of this specification. The synthetic slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	64 (max)
Viscosity (seconds/quart)	Marsh Funnel and Cup API 13B-1, Section 2.2	32 to 135
pH	Glass Electrode, pH Meter, or pH Paper	6 to 11.5
Sand Content (percent) 3. Prior to final cleaning 4. Immediately prior to placing concrete	Sand API 13B-1, Section 5	 1.0 (max) 1.0 (max)

At the time of testing, the temperature of the slurry shall be at least 40°F.

4.6.c Water Slurry

Water, with or without site soils, may be used as slurry when casing is used along the entire length of the drilled hole. The use of water slurry without full-length casing may only be used with the approval of the Engineer. The water slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	65 (max)
Sand Content (percent)	Sand API 13B-1, Section 5	1.0 (max)

At the time of testing, the temperature of the slurry shall be at least 40°F.

4.7 External Bracing Steel

The components comprising the external bracing steel used in conjunction with the Work shall conform to Section _____ of the Project Specifications.

4.8 Ground Anchor Tendons

The components comprising the ground anchor tendons used in conjunction with the Work shall conform to Section _____ of the Project Specifications.

4.9 Grout

The grout to be used in conjunction with the Ground Anchor Work shall conform to Section _____ of the Project Specifications.

5.0 CONSTRUCTION

5.1 Quality Assurance

5.1.a Secant/Tangent Pile Construction Tolerances

5.1.a.1 Secant/Tangent Pile Diameter

The allowable tolerance for the minimum diameter of the drilled shaft is 1 inch smaller (-1") than the diameter shown on the plans. The allowable tolerance for the

maximum diameter of the drilled shaft is 6 inches larger (+6") than the diameter shown on the plans.

5.1.a.2 Horizontal Positioning

At cut-off level, the maximum permitted deviation from the center of shaft shown on the drawings shall be one-inch in any direction.

5.1.a.3 Verticality

The maximum permitted deviation of the finished drilled shaft from the vertical at any level is 1 in 100 (1%). The Contractor shall demonstrate to the satisfaction of Engineer the pile verticality is within the allowable tolerance.

Commentary: *A verticality tolerance for each drilled shaft of 1% is a very restrictive tolerance. A vertical tolerance of 2% is a more practically achievable tolerance. Designers and Specifiers must take the verticality tolerance into account in their secant pile overlap, tangent pile alignment design, and specifications to ensure proper wall design, water tightness (if required), and pile wall constructability.*

During drilling or excavation of the borehole, the Contractor shall make frequent checks on the plumbness, alignment, and dimensions of the borehole. Any deviation exceeding the allowable tolerances shall be corrected with a procedure approved by the Engineer.

5.1.a.4 Steel Reinforcement

Placement tolerances of the steel reinforcing shall conform to the stated tolerances.

5.1.a.5 Overpours, Cavities, and Overbreaks

To account for potential voids, cavities, overbreaks, obstructions, soft soil layers, etc., an additional tolerance of plus __ inches (+__") shall be allowed for concrete protrusions beyond the intended face of the secant or tangent pile wall. The Contractor shall be responsible to remove, by means accepted by the Engineer, concrete protrusions beyond the acceptable limits specified herein.

5.1.b. Secant/Tangent Pile Pre-Construction Conference

At least five working days prior to the Contractor beginning any secant/tangent pile related construction work at the site, a pre-construction conference shall be held to discuss construction procedures, personnel, and equipment to be used, and other details of the approved secant/tangent pile installation plan as specified in subsection 5.2.b of this specification. Those attending shall include:

1. *Contractor Representatives* - The superintendent, on site supervisors, and all foremen responsible for excavating the boreholes, placing the casing and slurry (as applicable), placing the steel reinforcement, and placing the concrete. If synthetic slurry is used to construct the secant/tangent piles, the slurry manufacturer's representative or approved Contractor employees trained in the use of the synthetic slurry shall attend also.

   Commentary: *If the Secant/Tangent Pile system is designed by the Contractor, the Contractor's Design Engineer shall attend.*

2. *Contracting Agency Representatives* - The Project Engineer, designer, key inspection personnel, and representatives from the Contracting Agency Construction Office and Materials Laboratory Geotechnical Branch.

If the Contractor proposes a significant revision to the approved secant/tangent pile installation plan, as determined by the Engineer, an additional conference shall be held before any additional secant/tangent pile construction operations are performed.

5.2 Submittals

5.2.a Construction Experience

The proposed Work shall be accomplished by Contractors and skilled workers thoroughly experienced in the necessary crafts and having relevant experience with the anticipated subsurface materials, water conditions, installation equipment, drilled shaft dimensions, and any special techniques required. In some cases, pre-qualification may be required to ensure that qualified, experienced contractors perform the work. Approval of the Contractor, its personnel, equipment, methods, etc. is subject to satisfactory field performance. Documentation containing satisfactory proof of compliance shall be submitted by the Contractor to the Engineer for his/her approval, and shall include:

1. Not less than three successfully completed and documented projects within the past five years where the Contractor performing the work has successfully installed a secant or tangent wall system with drilled shafts similar to the size, length, and type to be installed on the project. The Contractor shall provide relevant details describing the equipment and methods used, details pertaining to any difficulties encountered, and how the difficulties were overcome. The Contractor shall include the complete contact information for at least one reference for each project cited.
2. The name and experience record for the Contractor's on-site supervisor for this work. The experience record shall include, at a minimum, a record of successful installation of a secant or tangent pile wall system on at least two projects in the most recent 5 to 10 years.
3. The name and experience record for the Contractor's drilling operator for this work. The experience record shall include, at a minimum, two years of experience installing secant and/or tangent pile wall systems, or drilled shaft foundations with similar diameters and lengths, and in similar ground conditions using a technology similar to that proposed for this work. The experience record shall include a record of successful installation of a secant or tangent pile wall system on at least two projects in the most recent 5 to 10 years.

The Engineer shall approve or reject the Contractor's qualifications and field personnel within 10 working days after receipt of the submission. Work shall not be started on any secant/tangent pile until the Contractor's qualifications and field personnel qualifications are approved by the Engineer. The Engineer may suspend the secant/tangent pile construction if the Contractor substitutes unapproved personnel. The Contractor shall be fully liable for the additional costs resulting from the suspension of work, and no adjustments in contract time resulting from the suspension of work shall be allowed.

5.2.b Secant/Tangent Pile Installation Plan

The Contractor shall submit a secant/tangent pile installation narrative for approval by the Engineer. The Engineer shall evaluate the secant/tangent pile installation plan for conformance with the Plans and Specifications, within the review time specified in Section _____ of the Standard Specifications.

In preparing the narrative, the Contractor shall reference the available subsurface data provided in the contract geotechnical report(s) prepared for this project. This narrative shall provide at least the following information:

1. Proposed overall construction operation sequence including procedures and methods to be used to ensure the adjacent or nearby structures and utilities are protected during the execution of the Work.

2. Procedures and methods to be used to safeguard against loss of slurry, concrete, and/or grout into waterways, sewers, project areas, and protected areas. The proposed procedures shall be in full compliance with all local, state, and federal environmental regulations.

3. The proposed construction procedures, sequencing and methods for installing any ground anchors and/or bracing, including the procedures for anchor drilling; reinforcement and grout placement; anchor testing or pre-loading; and inspection.

4. Drawings (e.g., plans, elevations, section views, etc.) and/or methods to describe the various activities required to complete the guidewall templates including dimensions, concrete strength, reinforcement, and formwork in accordance with the specifications.

5. Description, size, and capacities of proposed equipment, including but not limited to cranes, drills, oscillators, rotators, augers, bailing buckets, final cleaning equipment, and slurry handling equipment. The narrative shall describe why the equipment was selected, and describe equipment suitability to the anticipated site conditions and work methods. The narrative shall include a project history of the drilling equipment demonstrating the successful use of the equipment on drilled shafts of equal or greater size/length in similar soil/rock conditions. The narrative shall also include details of borehole excavation and cleanout methods.

6. Details of the method(s) to be used to ensure stability (e.g., prevention of caving, bottom heave, etc. using temporary casing, slurry, or other means) of the drilled shaft during excavation (including pauses and stoppages during excavation) and during concrete placement.

7. Detailed procedures for mixing, using, and maintaining the slurry shall be provided. A detailed mix design (including all additives and their specific purpose in the slurry mix) and a discussion of its suitability to the anticipated subsurface conditions shall be provided for the proposed slurry.

The submittal shall include a detailed plan for quality control of the selected slurry to ensure conformance with the slurry manufacturer's recommendations and these specifications. The quality control narrative shall include the test methods to be performed and the minimum and/or maximum property requirements, which must be met to ensure the slurry functions as intended for the anticipated subsurface conditions and drilled shaft construction methods,. At a minimum, the slurry quality control plan shall include the following tests:

Property	Test
Density	Mud Weight (Density) API 13B-1, Section 1
Viscosity	Marsh Funnel and Cup API 13B-1, Section 2.2
pH	Glass Electrode, pH Meter, or pH Paper
Sand Content	Sand API 13B-1, Section 5

8. Details of the concrete placement, including proposed operational procedures for pumping methods shall be provided. For a drilled shaft, the Contractor shall provide a sample uniform yield form to be used for plotting the approximate volume of concrete placed versus the depth of secant/tangent pile (except for concrete placement in the dry).

9. When drilled shafts are constructed in the wet, the submittal shall include descriptions of provisions for dewatering and flooding.

10. Description and details of the storage and disposal plan for excavated material, and drilling slurry (if applicable).

11. Reinforcing steel shop drawings, details of reinforcement placement, including bracing, centering, lifting methods, and the method to assure the reinforcement position is maintained during construction. The plan for the reinforcing steel cage assembly and installation shall include:

a. Procedure and sequence for the assembly of the steel reinforcing bar cage.

b. The tie pattern, tie types, and tie wire gages for all ties on permanent reinforcing and temporary bracing.

c. Number and location of primary handling steel reinforcing bars to be used during lifting operations.

d. Type and location of all steel reinforcing bar splices.

e. Cage weight and location of the center of gravity.

f. Quantity and location of pick points used for lifting for installation and for transport (if assembled off-site).

g. Crane charts and a description and/or catalog cuts for all spreaders, blocks, sheaves, and chokers used to equalize or control lifting loads.

h. The sequence and minimum inclination angle at which intermediate belly rigging lines (if used) are released.

i. Pick point loads at 0, 45, 60, and 90 degrees, and at all intermediate stages of inclination where rigging lines are engaged or slackened.

12. Remediation and/or corrective measures to be implemented for secant/tangent piles that may be out of tolerance (vertical, horizontal, and/or rotational). Provide a mitigation procedure for concrete segregation, tremie pipe breaks, etc. In addition, if used, provide remediation and/or corrective measures to be implemented for ground anchors that fail to sustain the required design and test loading.

5.2.c Slurry Technical Assistance

If slurry other than water slurry is used to construct the secant/tangent piles, the Contractor shall provide or arrange for technical assistance to ensure the slurry is properly stored, prepared, and used according to the manufacturer's recommendations.

The Contractor shall submit the following to the Engineer for informational purposes only:

a. The name and current phone number of the slurry manufacturer's technical representative assigned to the project and the frequency of scheduled visits to the project site by the slurry manufacturer's representative. At a minimum, the slurry manufacturer's technical representative shall be on site for the installation of the first three secant/tangent piles.

b. The name(s) of the Contractor's personnel assigned to the project and trained by the slurry manufacturer in the proper use of the slurry. The submittal shall include a signed training certification letter from the slurry manufacturer for each trained Contractor's employee listed, including the date of the training.

Work shall not begin until all of the required submittals have been approved in writing by the Engineer. All procedural approvals given by the Engineer shall be subject to trial in the field, and shall not relieve the Contractor of the responsibility to complete satisfactorily the work.

5.3 Records, Inspections and Documentation

5.3.a Work Records

A copy of the work record of all activities performed during each work day shall be submitted to the Engineer within 24 hours of that day's work being completed. All unanticipated drilling and/or installation conditions encountered shall be included in the work record.

5.3.b Inspection

Quality control (QC) shall be performed by the Contractor performing the work. Quality assurance (QA), including observation and testing, shall be performed by the Engineer or by one of his/her subcontractors.

5.4 Drilled Shaft Installation Methods

5.4.a General

Only the method(s) submitted to, reviewed by, and accepted by the Engineer may be used to construct the Work. In addition, depending upon the subsurface conditions encountered and/or Contractor performance during installation, the construction methods, equipment, personnel, etc. detailed in the Contractor's installation plan may need to be revised, as determined during consultation with the Engineer, at any time during the installation of the Work.

The design and construction of the guidewalls shall be the responsibility of the Contractor, and shall take into account the actual site and ground conditions and equipment to be used on site to ensure stability and avoid under-cutting as appropriate. Guidewalls shall be constructed using reinforced concrete or of other suitable materials. The minimum depth of the guidewall shall be three feet and the minimum shoulder width shall be 12 inches.

In all cases, the Contractor shall demonstrate by experience, calculation, and monitoring on site that adjacent piles shall remain interlocked to the final excavation depth.

The use of full-length temporary casing may be necessary for the installation of the secant/tangent piles on the project. The use of permanent casing in conjunction with this work is not permitted. The Contractor must ensure that the installation/extraction of the

temporary casing, if applicable, and the placement of the concrete produce durable secant or tangent pile walls free of defects.

The Contractor shall maintain a daily log of the construction of the secant/tangent pile wall system. The construction log shall include information pertaining to the method of installation, secant/tangent pile installation sequence and designation, borehole diameter and depth, equipment, machinery, tooling, drilling fluids, ground surface elevation, groundwater elevation, description of soil/rock/materials removed from borehole, obstructions, difficulties encountered, etc. The Contractor shall submit the construction logs to the Engineer for review, as stated in Section 5.3.a, "Work Records," within these specifications.

5.4.b Dry Method

The Dry Method refers to the installation of drilled shafts using open borehole drilling or excavation where the borehole stability is ensured and is not suspect, the existing groundwater table can be controlled, and stability against bottom heave and/or blowout in the bottom of the excavation is not an issue. This method is only applicable at sites in which all of the following apply:

1. The groundwater table and subsurface conditions are suitable to permit construction of the drilled shafts in a relatively dry excavation. A "relatively dry" excavation is one in which the infiltration rate of the groundwater does not exceed 12 inches of water in one hour. Construction operations shall be performed to ensure less than 3 inches of water is present at the bottom of the borehole excavation at the time of the concrete is placed.

2. Where the sides and bottom of the borehole remain stable without any caving, sloughing, or swelling.

3. Where the sides and bottom of the borehole can be visually inspected prior to placing the reinforcing steel and concrete.

5.4.c Cased Method

The Cased Method refers to the installation of drilled shafts using temporary casing where the stability of the excavated borehole may be suspect and/or the effects of the existing groundwater cannot be controlled. The temporary casing shall be installed and extracted using overhead, rotary drive equipment, or hydraulic oscillating equipment. The installation or removal of the temporary casing by impact driving or vibratory means is not permitted.

Commentary: *Vibratory methods may be used in limited applications where allowed by ground conditions, no sensitive structures/utilities occur, and proper pile sequencing is specified.*

If water is present in the borehole in excess of three inches and cannot be pumped down, placement of concrete using the free fall method is not permitted, and concrete placement using tremie methods shall be used. The temporary casing shall be removed while the concrete is still workable (i.e., before the concrete sets). As the casing is extracted, a minimum head of 5 to 10 feet of fresh concrete shall be maintained within the casing, which balances all external hydraulic pressures and allows all water and fluids within the casing to be displaced upward without contaminating the fresh concrete. The temporary casing shall be extracted at a slow, uniform rate along the centerline or longitudinal axis of the casing and drilled shaft.

5.4.d Wet Method

The Wet Method refers to the installation of drilled shafts using slurry, other drilling fluid(s), or water to ensure sidewall stability of the borehole and/or to prevent bottom heave. If required, temporary casing may be used in conjunction with the wet method. A minimum positive head of 10 feet of fluid (i.e., slurry, other drilling fluid, or water) shall be maintained above the highest level of the groundwater table to avoid bottom heave and/or blowout in the bottom of the excavation.

During excavation and concrete placement, the slurry within the borehole shall conform to the requirements detailed herein. The slurry shall be pre-mixed and allowed to hydrate prior to being placed into the borehole excavation. Any method in which slurry is to be prepared and mixed within the borehole excavation is not permitted. An adequate quantity of slurry tanks shall be provided by the Contractor to ensure an ample supply of slurry is prepared and available during the construction and installation of each drilled shaft. Slurry pits are not permitted without prior written approval from the Engineer.

When applicable, a slurry circulation system composed of shakers, de-silters, de-sanders, centrifuges, pumps, etc. shall be provided to maintain adequate slurry operations. The Contractor shall provide appropriate means to ensure adequate agitation and circulation of the slurry while it is within the borehole. The slurry mix and properties shall be adjusted to ensure proper use and intended function of the slurry. To ensure proper slurry performance, the slurry shall not remain un-agitated for more than 4 hours. For drilled shafts designed to resist axial loading in side shear, the sides of the borehole shall be scraped to remove any filter cake that may have formed when using mineral slurry that has not been agitated or circulated for more than 4 hours.

The wet method dictates cleaning and/or circulation (or complete replacement) of the slurry, and a final cleaning of the borehole excavation by means of a bailing bucket, air lift, submersible pump, or other devices prior to the placement of the reinforcement and concrete. Immediately prior to the placement of the reinforcement and/or concrete, samples of the slurry shall be taken from the bottom, a distance of 2 shaft diameters from the bottom, at quarter points along the length, and at a depth of 10 feet from the top of the borehole using an approved slurry sampling tool. If the slurry does not conform to the specifications, the borehole must be cleaned and the slurry must be re-circulated and/or flushed with clean, fresh slurry until subsequent tests reveal that the slurry is within the tolerances contained in the specification.

5.4.e Placement of Steel Reinforcement and Spacers

Steel reinforcement, including rebar cages or steel beam sections, shall be prepared and fabricated to the dimensioning and layout detailed in the contract documents. The steel reinforcement shall be fabricated, lifted, and installed in accordance with the approved Contractor fabrication and lifting plan submittal(s). Reinforcing steel cages shall be wire tied (50% minimum), as required, to prevent any distortion or racking during lifting and placement. The Contractor shall perform the lifting and placement of the reinforcing in such a manner to ensure the safety of all persons and equipment on and adjacent to the project site.

As detailed on the contract plans, the Contractor shall use the appropriate methods to ensure the reinforcing steel is centered, has the proper cover, and is properly oriented (i.e., has not distorted). Spacers and centralizers shall be used at sufficient intervals not exceeding 10 feet along the length of the reinforcement cage or the steel beam section. A minimum of 4 spacers shall be evenly spaced around the circumference of any

reinforcement cage or steel beam section such that the maximum distance between adjacent spacers around the circumference is 30 inches. The first spacers shall be placed 1.5 feet from the bottom of the drilled shaft with successive spacers at maximum intervals of 10 feet along the length of the drilled shaft. The spacers shall be sized to ensure conformance with the minimum clearance required between the borehole wall and the steel reinforcement, as shown on the contract plans.

5.4.f Placement of Concrete

Concrete shall be placed within 3 hours after excavation to ensure proper depth, cleanliness, etc. unless otherwise directed by the Engineer. If the concrete cannot be (or is not) placed within the allotted time, the borehole must be re-inspected and reapproved by the Engineer prior to the placement of concrete. Immediately prior to the placement of the concrete, a check of bottom cleanliness and depth measurements shall be made using a weighted tape or other methods approved by the Engineer. If it is shown that more than three inches of debris or loose soil has accumulated on the bottom of the borehole, the borehole shall be cleaned using appropriate and approved means.

The placement of concrete shall be performed such that the elapsed time from the beginning to completion of concrete placement is kept as short as possible. The duration of concrete placement is dependent upon several variables (e.g., diameter and depth of borehole, distance to concrete plant, etc.); therefore, the duration can be estimated only on a per job basis. For drilled shafts constructed using the Wet Method, it is advisable to use a retarding agent in the concrete mix, with the contractor determining the specific dosage rates for each pour. The placement of concrete shall continue in such a manner to ensure the concrete mix remains in a workable, plastic state throughout the entire concrete placement.

For drilled shafts constructed using the Dry Method, or where temporary casing results in a dry shaft, concrete may be placed using tremie, pumping, or free-fall methods. When being placed into the borehole using the free-fall method, the concrete shall be directed such that it does not strike the sides of the excavation or the reinforcement cage.

For drilled shafts constructed using the Casing or Wet Method, concrete shall be placed using the tremie, pumping, or another method approved by the Engineer. Placement of concrete using the free-fall method is not permitted in conjunction with the Wet Method. At the lowermost end of the tremie pipe, a plug or similar device (e.g., a one-way flap valve, a pig, etc.) shall be required to separate the fresh concrete from the fluid in the hole until pumping begins.

In conjunction with the Dry, Cased, or Wet Method, concrete pumps and tremie lines may be used for the placement of concrete under self-weight pressure. The steel tremie lines shall have a minimum ID of 10 inches for a gravity system, and a minimum ID of 5 inches ID for a pumped tremie system, and must guide the concrete to the discharge point at the center of the borehole excavation. The pump lines may be flexible, but the segments and joints of the pump lines shall be connected together using watertight fittings and connections. Concrete placement shall not commence until the discharge orifice of the tremie line is located at the base of the borehole excavation.

To maintain a proper seal and to avoid the sudden jumping of the pump line out of the poured concrete, the discharge orifice of the tremie line shall be maintained at least 10 feet below the uppermost surface of the fluid concrete already placed. The concrete shall be placed from the bottom of the borehole to the top surface in one continuous operation. The placement of concrete shall continue until over pouring is visible at the top of the

drilled shaft, and until fresh, dark grey colored concrete is easily discernible from the slurry or drilling fluid. The use of cold joints within the secant/tangent pile is not permitted.

5.5 Secant and Tangent Pile Wall Installation

5.5.a Guidewalls

Unless explicitly stated otherwise in the contract documents, the use, design, and construction of guidewalls is a contractor means-and-methods constructability issue. The design and construction of the guidewalls is the responsibility of the Contractor. During the construction of the drilled shafts, guidewalls may be utilized to aid in the proper positioning and alignment of the tangent and/or secant pile wall system to ensure conformance with the specified tolerances.

5.5.b Drilled Shafts

The drilled shafts shall be constructed using Dry Method, Cased Method, or Wet Method, as described above, to the depths and dimensions indicated on the contract plans. The boreholes shall be advanced in accordance with the construction method used and to the depths and dimensions indicated in the contract plans. In addition, the drilling of the borehole shall be performed in such a manner not to cause excessive disturbance or settlement to the surrounding ground surface and/or not to cause distress to any adjacent structures. During the drilling of the borehole, placement of the reinforcement, and placement of the concrete, the Contractor shall ensure the specified tolerances are maintained. The Contractor shall correct all deviations exceeding the allowable tolerances using the procedures approved by the Engineer. Handling and disposal of drill spoil and waste materials shall be performed in accordance with the methods and procedures approved by the Engineer.

5.5.b Obstructions

An obstruction is defined as a natural or man-made object(s) encountered within the ground, which impedes or prevents the advancement of the borehole or the installation of the casing. The construction activities associated with advancing past or through any obstructions, as used herein, include drilling, excavating, coring through, or otherwise removing, breaking up, or pushing aside any objects preventing or impeding the construction of the boreholes for the secant or tangent pile walls.

The removal of natural and/or man-made obstructions shall be measured by the hour for each actual hour the Contractor spends drilling, excavating, coring through, breaking up, pushing aside, or otherwise removing the obstruction. The recordable time, to be used in conjunction with the applicable pay item, shall be defined as the total time (in fractions of an hour) expended by the Contractor to advance past or remove the obstruction. The recordable time commences when downward progress of the borehole excavation using conventional earth/soil augers and/or the installation of the temporary casing either has ceased or has been significantly impeded.

Commentary: *To minimize ambiguity and potential misunderstandings during construction, it is highly recommended that the conditions and provisions describing an obstructions condition be explicitly detailed within the bid documents and payment item(s). In addition, it is advisable to review the provisions of the obstructions clause and the protocol for reporting such conditions during the pre-construction meeting.*

Upon encountering an obstruction condition, the Contractor shall notify the Engineer of such a condition where the Contractor is required to utilize tooling necessary to advance past the obstruction. The tooling includes, but is not limited to, conventional rock augers, core barrels, chisels, breakers, and/or air rotary percussive tools operating at normal power, torque, and down thrust. Additionally, the need for increasing the diameter of the drilled shaft may be required to advance past the obstruction(s) if other conventional methods are not successful. The Contractor shall utilize whatever equipment, tooling, and methods he/she deems necessary whenever obstructions are encountered. The method(s) to be utilized by the Contractor shall be submitted to the Engineer for review and approval.

5.5.c Sequencing and Construction of Primary and Secondary Secant/Tangent Piles

The installation of the primary and secondary secant/tangent piles shall be sequenced and constructed in accordance with the following:

1. To prevent communication between boreholes and/or to prevent flow of freshly placed concrete, concrete set must be verified prior to drilling within ten feet or three shaft diameters (3D), whichever is less, from an adjacent drilled shaft.
2. For secant pile walls, the drilling of a secondary drilled shaft shall be performed before the concrete/grout in the primary drilled shaft has achieved full strength. That is, the secondary secant/tangent pile should be drilled and excavated as soon as the concrete/grout within the adjacent primary secant/tangent piles achieves ample strength to resist damage and deformation, but has not achieved too much strength to prevent or hinder the drilling of the secondary secant/tangent pile.
3. For secant pile walls, the secondary drilled shafts shall be constructed within the allowable tolerances to provide the required overlap between adjacent secant piles, as shown on the contract plans.

5.5.d Placement of Steel Reinforcement and Concrete

The steel reinforcement, where required, and concrete shall be placed in accordance with the approved methods, as detailed within Section 5.4, "Drilled Shaft Installation Methods."

5.6 Quality Control (QC) - Inspection and Monitoring

5.6.a Dimensions and Alignment of Borehole

The Contractor shall verify and log the dimensions and alignment of each borehole excavation. Prior to the start of construction, the Contractor shall submit to the Engineer, for informational purposes, the procedures (including any equipment and tooling) that shall be followed to verify the dimensions and alignment of each borehole excavation. If requested, the Contractor shall provide the Engineer with a copy of each verification log.

5.6.b Depth of Borehole Excavation

With the Engineer present, the Contractor shall verify and log the final depth of each borehole excavation.

5.6.c Cleanliness of Bottom of Borehole

The Contractor shall ensure that the bottom of each borehole excavation has less than 3-inches of sediment or debris present immediately prior to the placement of the steel reinforcement and prior to the placement of concrete.

Commentary; *If the secant/tangent pile wall system is to be loaded axially with permanent loads, the Contractor shall limit the average thickness of sediments on the bottom of the borehole to one-half inch, and shall limit the maximum thickness of sediments to one-and-one-half inches if the drilled shaft is designed to support these axial loads in end bearing.*

5.6.d Slurry Testing

Throughout the construction of the drilled shafts, testing of the slurry shall be performed in accordance with the approved submittals.

5.6.e Steel Reinforcement

The steel reinforcement, including rebar cages and steel beam sections, shall be fabricated, lifted, and installed in accordance with the approved Contractor fabrication and lifting plan submittal(s) and in such a manner to ensure the safety of all persons, structures, and equipment on and adjacent to the project site. The Contractor shall ensure and verify that the reinforcing steel is centered, has the proper cover, and is properly oriented (i.e., has not distorted).

5.7 Allowable Thru Wall Seepage for Cut-Off Wall Systems

In addition to their earth retention function, secant pile walls may also serve as groundwater cut-off walls that retain and prevent the seepage of subsurface groundwater from behind the wall from entering the excavation through the joints between adjacent vertical pile elements. Groundwater seepage through the joints or exposed face of the secant pile wall shall be limited to be less than visible and measurable flow, or as specified by the Engineer.

Slight moisture on the exposed face of the secant pile wall, as evidenced by damp and darker colored concrete, shall be acceptable. Unacceptable seepage is defined as a regular steady drip or accumulated wetness observed running down the exposed face of the secant pile wall.

As the face of the secant pile wall is excavated and exposed, the Contractor shall repair any cracks, joints, or other defects in the exposed wall face where seepage exceeds the allowable limits, as defined above. All exposed secant pile wall areas that exhibit unacceptable seepage, as determined by the Engineer, shall be repaired by the Contractor to seal or lower the seepage through the wall to conform to the acceptable limits specified herein.

The Contractor shall submit the method of repair to the Engineer for review and approval prior to commencing repairs. All repairs shall be made prior to the installation of any additional temporary or permanent facing, including shotcrete, cast-in-place reinforced concrete, and/or precast concrete panels. Out of tolerance repairs to the secant pile wall, if necessary and/or required by the Engineer, shall be made by the Contractor, and shall not be measured for payment.

5.8 Remediation and Repair

Repairs to the secant/tangent pile wall system due to out of tolerance, if necessary and/or required by the Engineer, shall be made by the Contractor in accordance with approved submittals, and shall not be measured for payment.

6.0 MEASUREMENT

6.1 Plan Quantity and Length

The construction of the secant/tangent pile wall shall be measured as the number of linear feet (LF) of secant or tangent piles satisfactorily completed (i.e., furnished, installed, and accepted at the specified minimum OD), as shown on the contract documents. Permanent wall facing shall be measured and paid for separately. Repairs to the secant or tangent pile wall performed by the Contractor due to oversizing, over pouring, out of tolerance issues, excessive seepage, etc., as required by the Engineer, shall not be measured for payment.

7.0 PAYMENT

7.1 Plan Quantity and Length

The pay items shall include full compensation ($/LF) for furnishing all labor, equipment, tooling, materials, and incidentals necessary to complete the installation of the primary and secondary piles of the secant/tangent pile wall system. These pay items shall include full compensation for the installation and/or removal of guidewalls, full depth temporary casing, and temporary working surfaces; for slurry and/or other drilling fluids; for the clearing and/or removal of known surface obstructions; for the removal of out of tolerance concrete due to oversizing, over pouring, blowouts, and/or protrusions from the face of the drilled piles; drilling the boreholes for the drilled piles; for the handling and disposal of drill spoil, slurry, other drilling fluids, and waste concrete; for the fabrication, spacers and centralizers, lifting, positioning, and placement of the pile reinforcement; for the furnishing and placement of all necessary concrete and grout; for performing and providing monitoring and quality control services; and for providing all required documentation. The contract unit price shall be reflected as follows:

Item Number	Description	Unit	Unit Price
XX	Primary Piles	LF	$ XX /LF
XX	Secondary Piles	LF	$ XX/LF

7.2 Obstructions

All costs incurred by the Contractor to remove obstructions shall be compensated on a force account basis for the total time for all labor and equipment including all necessary consumables. Should equipment be idled and cannot be reasonably reassigned within the project, then standby payment shall be added to the payment calculations. Should labor be idled and cannot be reasonably reassigned within the project, then proper payment for all idled labor shall be added to the payment calculations.