State of Ohio

Department of Transportation

SPECIFICATION FOR

Design of Cantilever Soldier Pile Walls

January 30, 2023

**A. Definition**

A soldier pile wall consists of a row of drilled shaft foundations spaced at typically a 4-foot to 8-foot center-to-center spacing. HP-section or W-section steel beam sections (soldier piles) are inserted vertically into the shafts, with the webs of the steel sections placed parallel to the direction of the loading from the retained soil mass. Structural concrete is poured into the shafts up to the bottom of the proposed depth of lagging. Low-strength mortar (LSM), in accordance with C&MS Item 613 is often poured on top of the structural concrete to finish filling the holes. The soil and LSM is then excavated down to the top of the structural concrete. As excavation progresses, treated timber or precast concrete lagging panels are inserted in-between the steel soldier pile beams for temporary support, held in place by the flanges of the beams. In some cases, the precast concrete lagging panels are used for permanent support, and will constitute the final wall facing. However, a final cast-in-place facing is usually applied to the front of the steel soldier pile beams, attached by the use of welded shear studs. The final facing is considered structural, and is designed to resist the entire earth pressure load.

**B. p-y Method Analysis**

Once the load on the soldier pile is determined, calculate the reaction of the soldier pile to the load, the soldier pile head displacement, the shear and moment distributions, and check the factored resistance of the soldier pile beam versus the calculated factored maximum moment and maximum shear. Any capable p-y analysis software, such as PILE, or FBPIER may be used. ODOT currently uses the program LPILE, developed by Ensoft, Inc., therefore, the examples in this section refer to this program.

**1. Distributed Lateral Loading per Pile**

Represent active earth pressure (EH) loading on the wall as a triangular distributed load as per AASHTO LRFD Figures 3.11.5.6-1 and 3.11.5.6-2, between the top of the wall and the design grade. The actual load distribution is complex, and impossible to determine without direct measurement or back-calculation through measurement of displacements; however, a triangular load distribution is a close enough approximation of the actual condition to develop a realistic calculation of distributed shear, moment, and displacement in the soldier pile. Where the wall is within the influence zone of a live load, add a live load surcharge (LS) to the active earth pressure load between the top of the wall and the design grade. See Figure C.2-1.

The wall loading is represented solely as a horizontal distributed load, with no vertical component (δ = 0), as this is a more conservative assumption, providing the maximum lateral loading. Research has shown that the vertical load component is either insignificant, or tends to provide a small amount of compression to drilled shaft foundations, which marginally increases bending resistance. If using LPILE, convert the distributed load into units of pounds per inch (lb/in) of length along the soldier pile.

Model the soldier pile in the p-y analyses from proposed top of pile elevation to the estimated tip elevation. Do not represent the load on the soldier pile as a single resultant point load, and “cut off” the top of the pile at the point of application of this resultant load. This method does not realistically predict either the shape or magnitude of shear and moment distributions, and cannot predict the displacement at the soldier pile head.

**2. p-y Modification Factors for Group Action**

If drilled shaft foundations are placed at a center-to-center spacing closer than 3.75 diameters, use a p-multiplier reduction in the soil resistance p, for the p-y curve behavior of the soil. The loss in resistance is due to soil-structure-soil interaction, and an overlap in the region of the soil that provides passive resistance to the deflection of the drilled shaft foundations when placed in a closely-spaced group. This effect does not occur where drilled shafts are embedded in a relatively much stiffer material, such as bedrock, where the stress field effects are very limited, and the material does not deform substantially under the design loadings. Therefore, only apply the p-multiplier from the design grade to the top of bedrock or to the bottom of the drilled shaft foundations, whichever is shallower.

For determination of the p-multiplier, use the equation pm = 0.64(S/D)0.34, for 1 ≤ S/D < 3.75, where 0.640 ≤ pm ≤ 1.00, published by Reese, Isenhower, and Wang, “Analysis and Design of Shallow and Deep Foundations” (2006) for a single row of piles placed side by side. This is an empirical relationship based on testing by several researchers in multiple different soil types.

**3. Soil Layering and p-y Models**

Set the ground surface in LPILE equal to the design grade, and model all soil layers below the design grade as in the proposed condition.

**4. Drilled Shaft Length**

Embed the drilled shaft foundations in a solid stratum such that deflection at the soldier pile head is constrained to appropriate serviceability limits (see Section B.8 for details of the required serviceability limits). Also select a total drilled shaft length such that the drilled shaft is geotechnically stable (see Section B.9).

**5. Steel Soldier Pile Beam Section**

Analyze the pile structurally as a steel pile without concrete, although the steel beam section is actually embedded in a concrete shaft. We acknowledge that this is conservative, as it is generally recognized that the concrete stiffens the web and allows an increased shear and bending resistance due to tension field effects and composite action. However, at present there is little research into the shear resistance of concrete encased steel sections. The AISC code addresses concrete encased steel sections and specifies that the shear resistance be based on the steel section alone. In the case of steel beam section reinforced drilled shafts, the concrete exists primarily to transfer load to the steel member, and we are relying on the steel for shear and bending resistance. Although this produces a conservative design, we recommend this approach until more research is available into the behavior of composite sections. In the case of the un-encased section of the soldier pile, this approach is not overconservative, as the steel sections are exposed above the concrete to support the lagging.

**6. Section Type, Dimensions, and Cross-section Properties**

Typically analyze the portion of the soldier pile embedded in concrete as a “Round Shaft with Casing and Core/Insert” under “Section Type” in LPILE. Set the casing outside diameter to the nominal drilled shaft diameter, set the casing wall thickness to 0 inches, and set the number of bars to “0” for the rebars unless a supplemental reinforcing bar cage is used. For the core/insert type, typically choose “Steel H Section Strong Axis” or “Steel AISC Section Strong Axis.” This analysis method accounts for the additional stiffness from the composite action of the concrete contained within the web and flanges of the soldier pile section. It will also produce a non-linear non-elastic analysis that accounts for the loss of stiffness from a cracked section with deflections beyond the tensile strain limit for the concrete.

For the portion of the soldier pile above the drilled shaft concrete, or if a steel section other than a HP-section or W-section is used in the portion of the soldier pile embedded in concrete, analyze the soldier pile as an “Elastic Section (Non-yielding)” under “Section Type” in LPILE. This section type will result in an elastic analysis which uses a constant beam stiffness, which is unaffected by deflection of the beam. Select the structural shape “Circular without Void” under “Dimensions and Properties.” In order to develop the proper reaction from the soil in LPILE, set the “Elastic Section Diameter” equal to the nominal drilled shaft diameter. However, set the moment of inertia and area under “Elastic Section Properties” equal to the actual values of IX and AS for the steel soldier pile beam. Set the modulus of elasticity equal to that for a steel section alone (approximately 29,000,000 psi), not for a composite section.

Set the ground surface as level or inclined per the proposed slope of the design grade.

Unless there is a constructability concern which dictates a smaller rock socket diameter, specify the same diameter for the drilled shaft foundation over its entire length. Use 50 ksi or higher yield strength steel for the structural steel used in a steel soldier pile beam section. Assume a drilled shaft concrete strength for design purposes in accordance with BDM Section 304.2.1 and commentary C304.2.1. This means f′c = 3.5 ksi for Class QC1 concrete, f′c = 4.0 ksi for Class QC5 concrete, and typically, f′c = 3.5 ksi for Class QC4 Mass Concrete unless a higher strength is specified as per plan.

**7. Pile-Head Loading and Options**

At the head, a soldier pile is free to move both laterally and rotationally. In LPILE, there are multiple Pile-Head Loading Type options to define boundary conditions and loading at the pile head. Select the option “1 Shear [F] & 2 Moment [F-L]”, with a value of zero (0) input for both the shear and moment loading. This defines a pile which is free at the head, with a moment and shear which will start at zero at the pile head. All other options define rotational or displacement fixity of the pile head or define a known deformation at the pile head.

Set the option “Compute Top Y vs. L?” to “Yes,” as this will aid in determining the required length of the drilled shaft foundation to resist the lateral loading (see Sections B.8 and B.9.a below).

Represent horizontal earth pressure (EH) loading on the soldier piles as a triangular distributed load (as noted in Section B.1) with a value of zero at the retained ground surface (pile head), and a maximum at the depth of the design grade. If the horizontal distance between the soldier piles and traffic loading is less than or equal to half the retained height (the depth between the pile head and design grade), also apply an (unfactored) vehicular live load surcharge (LS) to the soldier piles equal to two feet of soil with a unit weight γs = 125 pcf, in accordance with AASHTO LRFD Article 3.11.6.4. See Figure C.2-1.

Run LPILE twice for each loading case; running analyses with unfactored loading for the Service I Limit State, to determine soldier pile head deflection; and with factored loading for the Strength I Limit State, to check the structural and geotechnical resistance of the soldier pile. For the Strength I Limit State condition, use a load factor of γls = 1.75 for the vehicular live load surcharge (LS) and a load factor of γeh = 1.50 for the horizontal earth pressure (EH), in accordance with AASHTO LRFD Article 3.4.1.

**8. LPILE Output**

After the p-y analysis calculations are completed, inspect several items immediately. LPILE can produce a plot of “Top Deflection versus Length” (see Section B.7). For both the Service I Limit State analysis and the Strength I Limit State analysis, the length(s) at which either of these plots climbs to infinity or becomes indeterminate is the point at which the soldier pile length becomes too short; choose a length beyond this point. If it appears that several iterations may be required to determine the optimal soldier pile length through incremental increases, it may be more efficient to analyze a soldier pile which is known to be too long, and then cut down the soldier pile length to the optimal point. Note that we do not recommend an embedment of less than 10 feet below the design grade, regardless of the results of the deflection plots.

LPILE also generates a plot of Lateral Deflection versus Depth and calculates a (maximum) Pile-head deflection. For the Service I Limit State analysis, limit the maximum Pile-head deflection to 1% or less of the retained height (the depth between the pile head and design grade); however, if the soldier pile wall is to be installed within 10 feet of the edge of pavement, and the pavement is not to be replaced along with the same project, additionally limit the Pile-head deflection to 2” or less. In this case, use whichever serviceability limit requires the least deflection. If the soldier pile deflects more than the required serviceability limit, we consider this to represent failure, and a stiffer soldier pile beam section or larger diameter drilled shaft foundation must be selected and re-analyzed.

LPILE also provides maximum values for shear and moment in the soldier pile. Use these values from the Strength I Limit State analysis, in the structural analysis of the soldier pile, to check if it is has adequate structural resistance without failing in either bending or shear.

**9. Geotechnical Resistance**

Perform a Strength I Limit State check of geotechnical resistance against overturning of the soldier pile. The check of geotechnical resistance is not a check of the structural resistance of the soldier pile, but of the geotechnical resistance of the soil and bedrock to resist excessive overturning movement of the soldier pile. Two options are available for performing this check:

**a. LPILE Deflection Analysis**

This is by far the simpler method to check geotechnical resistance. Consider the Pile-head deflection calculated by LPILE from the Strength I Limit State analysis. If the deflection does not indicate failure – either failure of the program to converge at a solution, an infinite deflection, or a very large deflection (typically around 100 inches) – then the soldier pile is considered to be stable, with adequate geotechnical resistance against overturning. It is acceptable for the Strength I Limit State analysis deflection to be quite large, as long as the Service I Limit State analysis deflection meets the required serviceability limits (see Section B.8). The LPILE plot of Top Deflection versus Length can be helpful to find the point of optimized soldier pile length.

If the Strength I Limit State loading results in LPILE result in a large deflection that creates a plastic hinge in the pile (see Section C.2), then this analysis cannot be completed conventionally. We would be showing a failure of structural resistance in the pile, and not a failure of geotechnical resistance against overturning. In this case, magnify the stiffness of the beam section in the Strength I Limit State p-y analysis by multiplying the moment of inertia (IX) by a factor of 2 and re-run the analysis. This should make the beam stiff enough to not buckle internally due to the load, and result in most of the deflection coming from the soil p-y reaction.

**b. Moment Equilibrium Analysis**

Demonstrate moment equilibrium about the toe of the soldier pile, in accordance with AASHTO LRFD Articles 3.11.5.6, 11.6.3.5, and 11.8.4.1, with reference to AASHTO LRFD Figures 3.11.5.6-1 and 3.11.5.6-2, and utilizing the methodology as outlined in AASHTO LRFD Commentary C11.8.4.1. Please note that Figures 3.11.5.6-1 and 3.11.5.6-2 do not include the effects of vehicular live load surcharge (LS), which will have to be added by the engineer. Also note that the figures do not utilize load or resistance factors (all loads and resistances shown are nominal); apply appropriate load and resistance factors as described by AASHTO LRFD Commentary C11.8.4.1.

If the soldier pile exhibits excessive deflection or cannot achieve moment equilibrium at the analyzed length, this is considered failure. In this case, deeper embedment of the soldier pile or a larger diameter drilled shaft foundation may be required to meet the requirements of geotechnical resistance against overturning.

Do not utilize the Geotechnical Strength Limit State check per FHWA Geotechnical Engineering Circular No. 10 (GEC 10), Publication FHWA-NHI-18-024, Drilled Shafts: Construction Procedures and Design Methods, Section 9.3.3.3.1. We consider this check to produce overly conservative results.

**C. Steel Beam Section Design**

After determining the Service I Limit State lateral deflection of the pile and the Strength I Limit State moment and shear distributions for the pile by analysis with an appropriate p-y analysis software package, check the factored structural resistance of the soldier pile versus the calculated factored maximum moment and maximum shear.

Specify ASTM A572 Grade 50 (50 ksi) or higher yield strength steel for the structural steel used in a steel soldier pile beam section.

**1. Concrete and Minimum Cover**

Ensure that the steel soldier pile can fit within the drilled shaft foundation with the minimum required concrete cover in accordance with BDM Section 305.4.4.2 and C&MS 509.04.B for steel reinforcements. The increase in concrete cover for larger diameter drilled shafts is due to allowance for placement tolerance given potential misalignment or “wander” in the drilled shaft tooling. If a supplemental reinforcing bar cage is used, the minimum spacing between the inside of the cage and the outside corners of the steel soldier pile beam section is 2 inches.

For a soldier pile drilled shaft foundation, Class QC 1 concrete may be used if there is no supplemental reinforcing bar cage; if a supplemental reinforcing bar cage is used, specify Class QC 5 concrete in accordance with C&MS Item 524 Drilled shafts. If the drilled shafts are of 7 feet or greater in nominal diameter, specify Class QC 4 Mass Concrete instead.

**2. Strength I Limit State Analysis**

Use a load factor of γls = 1.75 for the vehicular live load surcharge (LS) and a load factor of γeh = 1.50 for the horizontal earth pressure (EH), in accordance with AASHTO LRFD Article 3.4.1. Check the factored structural resistance of the steel soldier pile beam section versus the calculated factored maximum moment and maximum shear. Use a resistance factor φf = 0.90 for flexural resistance in accordance with AASHTO LRFD Table 11.5.7-1 and a resistance factor φv = 1.00 for shear resistance in accordance with AASHTO LRFD Article 6.5.4.2. Check the flexure resistance of the steel beam section according to AASHTO LRFD Article 6.10.8. Check the shear resistance of the steel beam section according to AASHTO LRFD Article 6.10.9. For the portion of the steel section embedded in the concrete drilled shaft foundation, assume that it has continuous lateral bracing and transverse stiffening and is restrained from both local and lateral buckling by the concrete embedment. For the portion of the steel soldier pile beam section that extends above the drilled shaft foundation, assume it is unbraced and is not restrained against buckling, therefore, check the steel section for both lateral torsional bucking and flange local buckling with an unbraced length equal to the exposed length, in accordance with AASHTO LRFD Article 6.9.4.1.2.

Although the above Strength I Limit State analysis will work in most instances, it should be noted that, strictly speaking, p-y analyses are load-deflection analyses that are intended to use unfactored service loads. While it is possible to factor the load going into the soldier pile, it is not possible to accordingly factor the stiffness of the pile or the soil response. In some instances, due to lack of stiffness in the system, factored loads will result in excessive soil deflection that transmits through the p-y response into a much higher load in the pile or in the pile deflecting beyond the elastic range of the pile materials and developing a plastic hinge. In this case, it will appear that a much larger and stiffer section will be needed to resist the load. In other words, while the beam should be able to take the applied factored loads according to the section modulus and shear area of the section, the factored load is causing enough deflection to induce buckling in the section or to produce an artificially-magnified resultant moment and shear (often by a factor of from 2 to 10 times what would be calculated from a purely static beam analysis or moment equilibrium analysis). In this event, for the Strength I Limit State structural resistance checks, use only unfactored service loads in the p-y analysis, but then factor the ***resulting*** maximum shear and moment by the composite Strength I Limit State load factors to check the bending and shear resistance of the soldier pile beam.

To determine the composite Strength I Limit State load factors for both shear an moment, use the following procedure.

1. Construct a load diagram with the triangular EH load distribution and the rectangular LS load distribution (see Figure C.2-1).

Figure C.2-1: Soldier Pile Load Diagram



1. Calculate the unfactored Service I Limit State resultant loads:

EH = ½kaγsH2

LS = ka(2.0’)(125 pcf)H

where:

ka = Coulomb earth pressure coefficient

γs = unit weight of retained soil (typically γs = 120 pcf)

H = retained height (the depth between the pile head and design grade).

1. Multiply the unfactored Service I Limit State resultant EH and LS loads by the Strength I Limit State load factors, to arrive at the Strength I Limit State factored resultants:

γEHEH and γLSLS.

1. The composite Strength I Limit State load factor for shear is:

γshear = (γEHEH + γLSLS)/(EH + LS) ≥ 1.50.

1. Examine the Service I Limit State p-y analysis results, and determine the location of the maximum value of the internal distributed moment in the soldier pile beam, Mmax.
2. The location of the EH and γEHEH resultant loads will be ⅓H up from the design grade; the location of the LS and γLSLS resultant loads will be ½H up from the design grade. Calculate the moment arms for both sets of resultant loads, as the distance between these resultant loads and Mmax. These will be:

MAEH = moment arm from Mmax to the resultant loads EH and γEHEH

MALS = moment arm from Mmax to the resultant loads LS and γLSLS

1. The composite Strength I Limit State load factor for moment flexure is:

γmoment = (MAEHγEHEH + MALSγLSLS)/(MAEHEH + MALSLS) ≥ 1.50.

**3. Iterative Design Process**

Use an assumed steel section for the p-y analysis to determine the Service I Limit State head deflection and Strength I Limit State distributed and maximum moment and shear for the soldier pile beam. Check that the soldier pile head deflection is less than the required serviceability limit (see Section B.8) and check the factored resistance of the selected steel section versus the calculated factored maximum moment and maximum shear (see Section C.2). If these requirements are not met, select a steel section with greater resistance. If the steel soldier pile beam with the minimum section properties will not fit within the selected nominal drilled shaft foundation diameter with the minimum required concrete cover, specify a larger diameter drilled shaft. If the deflection, flexure, and shear requirements are exceeded, consider selecting a lighter steel section (and possibly a smaller diameter drilled shaft) to save cost. Decreasing or increasing the center-to-center spacing of the soldier pile drilled shafts in order to reduce or increase the applied load per pile is another option for optimization of the wall.

Every time a new steel section, a new nominal drilled shaft diameter, or a new drilled shaft center-to-center spacing are selected, recalculate the soldier pile reaction with a new p-y analysis, and recheck the deflection and the flexure and shear resistance of the steel section.

**D. Plan Notes**

The following plan notes are provided for inclusion in the plans for soldier pile walls. Most of the plan notes are applicable to all soldier pile walls. However, choose the appropriate lagging note depending on whether timber or precast concrete lagging is to be used.

If the soldier pile wall will be permanent, and if a permanent CIP face is placed over the lagging, provide drainage in the plans in accordance with Item 518 consisting of either prefabricated geocomposite drain (PGD) strips attached to the face of the lagging, or drainage backfill behind the lagging. Also provide plan note Item 513 - Welded Stud Shear Connectors, As Per Plan for attachment of the final CIP face.

These notes are for soldier pile and lagging walls with the soldier pile placed into a hole drilled in accordance with C&MS Item 524. These notes are not appropriate for walls with tiebacks.

**Item 507, Steel Piles, Misc.: Soldier Piles**

This work consists of furnishing and placing steel soldier piles into drilled holes. Furnish soldier piles consisting of structural steel members that meet the plan requirements and conform to ASTM A572, Grade 50 in accordance with C&MS 711.01. Galvanize soldier piles as shown on the plans and in accordance with C&MS 711.02. Do not field weld or splice steel soldier piles.

The Department will measure soldier piles along the axis of the soldier pile from the top of wall elevation to the bottom of the drilled shaft, as determined by the Engineer. The Department will pay for Soldier Piles at the contract unit price per foot for Item 507, Steel Piles, Misc.: Soldier Piles.

***Designer Notes:***

*Indicate on the plans the steel section required for the soldier pile (e.g. HP 10x42) and the length of the soldier pile that will be galvanized (if any).*

*Also provide the following line in the General Notes, under Design Data:*

Steel soldier piles - ASTM A572 - yield strength 50 ksi

*If a different grade of steel is used in the design for the soldier piles, modify the plan note and Design Data entry accordingly.*

**Item 524, Drilled Shafts, \_\_" Diameter, Above Bedrock, As Per Plan**

**Item 524, Drilled Shafts, \_\_" Diameter, Into Bedrock, As Per Plan**

This work consists of furnishing and installing drilled shafts for soldier pile and lagging walls. The drilled shafts are reinforced with soldier piles instead of reinforcing steel cages. The soldier piles extend above the top of the drilled shaft. Furnish and install the drilled shafts in accordance with C&MS 524 except as modified and supplemented below.

A maximum depth to bedrock of \_\_ feet is assumed for the design of the soldier pile wall from station \_\_ to \_\_. If bedrock is encountered at a deeper depth, inform the Engineer immediately.

Excavate the hole for the drilled shaft within 3 inches of the plan location. Place the soldier pile within the hole so it is vertical and not inclined more than 1 inch between top to bottom. Place the soldier pile so that the flanges are parallel to the centerline of the row of drilled shafts. Do not allow the orientation of the flanges to vary by more than 10 degrees. Support the soldier pile so that it does not move during concrete placement.

Use Class QC 1 concrete according to C&MS 511. Place concrete to the elevation for the top of the drilled shaft. The Contractor may place concrete using the free fall method provided the depth of water is less than 6 inches and the concrete falls without striking the sides of the hole. Pouring concrete along the web of the soldier pile is acceptable.

Check the position, the vertical alignment and orientation of the soldier pile immediately after concrete placement. Make corrections as necessary to meet the above tolerances. If shown on the plans, fill the hole above the bottom of the lagging to the existing ground surface with Item C&MS 613 Low Strength Mortar Backfill (LSM).

Remove concrete and LSM as necessary from around the soldier pile in order to place the lagging. Place lagging so that the soldier pile flange overlaps the ends of the lagging by at least \_\_ inches at both ends of the lagging. Wait at least 12 hours after placing concrete in the drilled shafts before placing lagging.

Sequence of Installation: Install the drilled shafts in a sequence such that no drilled shaft is installed adjacent to either an open drilled shaft excavation or a drilled shaft in which the concrete has less than a 48-hour cure. Installing the shafts in an alternating sequence or any other sequence that meets these criteria is permissible.

Protection of Unattended Open Shafts: Cover unattended open shafts. Use temporary covers of adequate strength to prevent a person or animal from falling in. Leave no drilled shaft excavation un-poured overnight.

The Contractor is responsible for the means and methods used to construct the drilled shafts and place lagging. Any temporary grading, excavation, embankment, aggregate, drainage, sheeting, etc. needed to complete the work is included in the bid price for the drilled shafts. The cost of any excavation and subsequent replacement of embankment (in accordance with Item 203 Embankment) is included in the various bid items for the drilled shafts and lagging, unless separately itemized. No separate payment will be made.

Method of Measurement: The Department will measure Drilled Shafts Above Bedrock, As Per Plan, along the axis of the drilled shaft from the existing ground surface to the top of bedrock, as determined by the Engineer. The Department will measure Drilled Shafts Into Bedrock, As Per Plan, along the axis of the drilled shaft from top of bedrock to the bottom of the drilled shaft, as determined by the Engineer.

Payment is full compensation for constructing the drilled shafts, including furnishing and placing concrete and LSM, removal of concrete or LSM from around the soldier pile in order to place lagging.

***Designer Notes:***

*Edit the note title to indicate the nominal drilled shaft diameter. Provide a separate line for each diameter specified, both Above Bedrock and Into Bedrock.*

*If a supplemental reinforcing bar cage is to be used, replace* “instead of reinforcing steel cages” *with* “and reinforcing steel cages.” *In this case, also replace* Class QC 1 *concrete with* Class QC 5 *concrete.*

*Edit the note to indicate the maximum depth to bedrock assumed for the design and the station limits to which this applies. If the wall is designed without bedrock embedment, remove all references to bedrock from the plan note.*

*Edit the note to indicate the overlap of the flanges with the lagging. See BDM Section 307.6.3 and notes “Item 530 Special - Retaining Wall, Timber Lagging” and “Item 530 Special - Retaining Wall, Precast Concrete Lagging” for details.*

*Detail the LSM filling the drilled hole above the concrete in the plans. It may not be necessary in all situations; if it is unnecessary, edit the note to remove references to LSM.*

**Item 530 Special - Retaining Wall, Timber Lagging**

This work consists of furnishing and placing timber lagging between the soldier piles as temporary support for the retained soil. Furnish timber lagging consisting of construction grade, untreated hardwood with a minimum thickness of \_\_ inches. To permit drainage, provide 1/4 to 1/2-inch spaces between lagging boards using 3/8-inch thick spacer blocks or other means acceptable to the Engineer. Place the lagging boards between the flanges of the soldier piles and bearing against the flanges on the exposed side of the wall so that the soldier pile flange overlaps the end of the lagging by at least 2 inches at both ends of the lagging boards. Perform excavation for placement of the lagging in such a manner that the lagging is tight against the excavation cut face. Backfill any voids behind the lagging with a suitable compacted Granular Material conforming to C&MS 703.16.C acceptable to the Engineer. The cost of any such backfilling required, including material, placement and compaction, is incidental to the cost of the lagging.

The Department will pay for Timber Lagging at the contract unit price per square foot for Item 530 Special - Retaining Wall, Timber Lagging.

***Designer Notes:***

*Edit the note to indicate the thickness of the timber lagging. Design timber lagging in accordance with BDM Section 307.6.3. The minimum thickness is 3 inches.*

**Item 530 Special - Retaining Wall, Precast Concrete Lagging**

This work consists of furnishing and placing precast reinforced concrete panels between the soldier piles to function as lagging for the retaining wall. Provide precast concrete lagging from a precast concrete manufacturer certified according to Supplement 1073. Provide Class QC 1 concrete according to C&MS 499. Provide epoxy coated reinforcing steel according to C&MS 709.00. In lieu of epoxy coating, a corrosion inhibiting concrete admixture may be used at the specified dosage rate. A qualified product list of corrosion inhibiting admixtures is on file at the Laboratory. Manufacturers should recognize that the corrosion inhibitor may affect the strength, entrained air content, workability, etc. of their concrete mixes. The manufacturer’s choice to use one of these corrosion inhibitors does not alleviate meeting all design requirements. Do not allow the dimensions of the lagging or location of the reinforcing steel to vary by more than 1/4-inch. Cast threaded inserts into the top of each panel for lifting and placing.

Fill all cavities produced by form ties and other single defects or defected areas and with a prequalified trowelable mortar in accordance with Supplemental Specification 843.02 and 843.06. Likewise fill cavities for lifting inserts in the top row of precast concrete lagging panels. Provide a broom/brush finish to all trowelable mortar patches. Cure the trowelable mortar according to Supplemental Specification 843.07. Air dry for at least 10 days after completion of the manufacturer’s recommended cure time for trowelable mortar. Brush abrasive blast, followed by air brooming or power sweeping, to remove dust and sand from the surface and opened pores.

Finish the faces of the precast concrete lagging panels that will not be exposed to a uniform surface, free of open pockets of aggregate. Finish the exposed face of the panels to a smooth surface. \*Seal the front (exposed) face, sides, top, bottom, and 3” minimum of the back face of the concrete panel with Item 512, Sealing of Concrete Surfaces (Epoxy-urethane). The color of the urethane shall be Federal Color Number 17778 (Light Neutral). Cost of sealing shall be incidental and included with the precast concrete lagging panels for payment.

Permanently mark each precast concrete lagging panel to indicate which face will be placed against the soil. Place the panel between the flanges of the soldier piles and bearing against the flanges on the exposed side of the wall so that the soldier pile flange overlaps the end of the lagging by at least one inch more than the concrete cover over the reinforcing steel at both ends of the lagging.

Handle, store, and ship the precast concrete lagging panels to avoid chipping, cracking and fracturing the panels. Support the panels on firm blocking while storing and shipping. Do not ship panels until concrete has attained a minimum 3000 psi compressive strength. Submit shipment documentation to the Engineer as the panels are delivered to the project, including the Precaster’s record of final inspection, the measurements and tolerances, strength, and dimensions of each panel, along with the TE-24 shipping document.

Inspect all precast concrete lagging panels and reject panels having any of the following:

1. Defects that indicate imperfect molding.
2. Defects that indicate honeycombed or open texture concrete.
3. Defects in the physical characteristics of the concrete, or damage to the sealing of concrete surface treatment or to aesthetic surface treatments.
4. Concrete chips or spalls that are larger than 4 inches wide or 2 inches deep. Repair all chips and spalls that are smaller.
5. Stained form faces, due to form oil, curing, or other contaminants.
6. Signs of aggregate segregation.
7. Cracks wider than 0.01 inches, penetrating more than 1 inch or longer than 20 percent of the length of the face containing the crack. Repair all cracks that are smaller.
8. Panels that do not meet the specified dimensional tolerances.
9. Unusable lifting inserts.
10. Exposed reinforcing steel.
11. Insufficient concrete compressive strength.

Either replace damaged precast concrete lagging panels or document the damage and propose to the Engineer a repair method for the damaged panel; perform repairs with the acceptance of the Engineer. Provide acceptable replacement panels for any that are rejected.

When installing the precast concrete lagging panels, place hardwood wedges near the top and bottom on each side to hold the lagging panels against the front inside flange of the steel piles.

Payment for all labor, equipment, and material required to fabricate, transport, and install the precast concrete lagging panels shall be made at the contract unit price per square foot for Item 530 Special - Retaining Wall, Precast Concrete Lagging.

***Designer Notes:***

*When precast concrete lagging is to be used, show the design of the precast lagging in the plans, including dimensions, rebar sizes, and locations. Modify the required concrete strength for the lagging if necessary. Design precast concrete lagging in accordance with BDM Section 307.6.3. A minimum of 3 inches at each end of the lagging must be supported by the soldier pile flange.*

*If an aesthetic surface treatment is to be applied to the precast concrete lagging panels, specify to* “cast the aesthetic surface treatment into the front (exposed) face of the panels.” *For panels that will be covered over with a permanent cast-in-place concrete facing,* “finish **all** faces to a uniform surface, free of open pockets of aggregate.”

*\* For panels that will be covered over with a permanent cast-in-place concrete facing, eliminate sealing with epoxy-urethane. Federal Color Light Neutral may be replaced with any other color according to the aesthetics of the project.*

**Item 513 - Welded Stud Shear Connectors, As Per Plan**

Weld headed steel studs to the flanges of the soldier pile in order to connect the cast-in-place concrete wall facing to the soldier pile. Attach headed studs according to C&MS 513.22 and as shown in the plans. The contractor may attach the studs either before placing the soldier pile in the drilled hole or after excavating in front of the wall. Protect the headed studs from damage until the concrete wall facing is poured. Repair or replace damaged headed studs at no expense to the department.

***Designer Notes:***

*Welded stud shear connectors are used only when the solder pile wall will be covered over with a permanent cast-in-place concrete facing. Detail the locations of the studs in the plans.*