LOW ACTIVITY WASTE PRETREATMENT SYSTEM

Project No. 31269 (T5L01)

Document No. 31269-13-RPT-0004

Safety Related □ Non-Safety Related □

Evaluation of Excavation Retaining Methods

Prepared for
Washington River Protection Solutions, LLC

Revision: A  Status: Preliminary
## Revision Page

**Project Name:** LAWPS  
**Discipline:** Structural  
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### Safety Related

- Yes □  
- No ☒  

### Quality Level

- FQA □  
- EQA □  
- CQA ☒
EXECUTIVE SUMMARY

A soldier pile and lagging earth retaining system (ERS) with tie-backs is selected as an option for LAWPS vault excavation in lieu of a full excavation with sloping sides at a constant slope. This system was selected based on cost, schedule, and feasibility considering site conditions. Calculations were performed to provide a preliminary design shown in Attachment D, Figure D-2. The study also produced a shoring excavation plan that is shown in Attachment D, Figure D-1. The excavation plan has an operating pad for an excavator to remove soil from excavation and place it in a dump truck on the access road. The access road runs south and east of the excavation allowing other LAWPS facilities to be constructed while the vault is constructed. Pending is a decision whether the ERS may be used as a form for the vault exterior concrete walls.

An advantage of using the shoring excavation approach is that less area would be dedicated to the excavation. This would allow construction of other LAWPS facilities while the vault is under construction. Also, less soil removal, storage, and compaction would be required for the shoring excavation versus a cut only excavation.
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ABBREVIATIONS AND ACRONYMS

CQA Commerical Quality Assurance
DBD Design Basis Document
ERS Earth Retaining System
QA Quality Assurance
SDE Supervising Discipline Engineer
SGH Simpson Gumpertz & Heger
SSI Soil-Structure Interaction
WRPS Washington River Protection Solutions, LLC
1.0 INTRODUCTION

Conceptual design for LAWPS shows a cut and fill excavation from grade elevation to an elevation at the lowest vault basemat elevation (see Attachment E, Figure E-1). This requires removal, storage, and compaction of a substantial amount of soil. Also, this approach requires a large area dedicated to the excavation until the vault exterior walls are constructed and the area is backfilled. This has led to the consideration of an alternate approach where a shoring system is installed around the vault area and soil is excavated only within the area bounded by the shoring walls. This would allow work to be performed on other parts of the LAWPS facility that would otherwise be inaccessible if the cut and fill excavation approach was used.

2.0 PURPOSE AND SCOPE

This study identifies excavation and earth retaining systems (ERS) and provides recommendations for the LAWPS vault structure per the Prejob Brief Meeting (31269-02-PJB-0193). Considerations for selection of method include:

1. Technical adequacy
2. Impact on concrete design
3. Excavation area/volume
4. Schedule
5. Cost

This study documents coordination meetings with Washington River Protection Solutions (WRPS) and geotechnical consultant Shannon and Wilson held to evaluate construction impacts and coordinate development of estimates as necessary to determine relative costs associated with this study.

3.0 ASSUMPTIONS AND OPEN ITEMS

3.1 Assumptions

1. Design of the earth retaining system for seismic forces is not required due to period of construction.
2. The soldier piles will be driven and not installed in drilled holes.

3.2 Open Items

1. Discussion with SGH regarding the impact of the ERS on the soil-structure interaction analysis. This may determine whether the ERS is permanent or temporary.
2. Costs of the designed soldier pile wall have not been estimated. Tom Goedjen, WRPS, said that he has estimators who can estimate costs for the selected ERS.
3. The schedule and estimated duration for installing the ERS has not been determined.
4. Drawing H-16-000201 shows waste transfer piping routed to the south end of the LAWPS vaults. Although the specific routing of the lines is on hold, penetrations in the lagging for these lines are necessary.

5. The effect of surcharge loading on the ERS due to adjacent structures has not been evaluated.

4.0 SELECTION OF EARTH RETAINING SYSTEMS

4.1 Earth Retaining Systems Considered

The following earth retaining systems were initially considered:

1. Sheet pile wall with tie backs.
2. Soldier pile and lagging wall with tie backs.
3. Slurry (diaphragm) wall with tie backs
4. Tangent pile/secant pile wall with tie backs
5. Soil mixed wall with tie-backs.
6. Soil-nailed wall

Descriptions of these systems are shown in Attachment A, which contains excerpts from FHWA-SA-96-038.

4.2 Earth Retaining Systems Costs

Table 1. Earth Retaining System Relative Costs

<table>
<thead>
<tr>
<th>Earth Retaining System</th>
<th>Cost</th>
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<tr>
<td></td>
<td>(1995 dollars/square meter)</td>
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<tr>
<td>Sheet Pile Wall</td>
<td>$160-$430</td>
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<tr>
<td>Soldier Pile and Lagging Wall</td>
<td>$110-$380</td>
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<tr>
<td>Slurry (Diaphragm) Wall</td>
<td>$650-$930</td>
</tr>
<tr>
<td>Tangent Pile/Secant Pile Wall</td>
<td>$430-$810</td>
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<td>Soil Mixed Wall</td>
<td>$430-$590</td>
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<tr>
<td>Anchored Wall</td>
<td>$160-$810</td>
</tr>
<tr>
<td>Soil Nailed Wall</td>
<td>$160-$600</td>
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Costs for ERS’s shown in Table 1 as 1995 costs per square meter are taken from FHWA-SA-96-038. They provide a rough guide as to relative costs of the various ERS.
4.3 Selection of Earth Retaining System for LAWPS

During the first meeting (see 5/19/16 meeting notes in Attachment B) it was decided that the feasible ERS’s for the LAWPS site are:

1. Sheet pile wall with tie backs.
2. Soldier pile and lagging wall with tie backs.
3. Soil-nailed wall

Table 1 shows that these are the least cost ERS’s.

In subsequent meetings, Clint Wilson from Shannon and Wilson recommended that the in situ cohesionless soil would make the soil-nailed wall infeasible (see 5/24/16 meeting notes in Attachment B). Also, in situ soil conditions would allow sheet piles to be driven to a maximum depth of 20 ft (see 5/26/16 meeting notes in Attachment B) while the vault excavation would require driving piles to a depth greater than 46 ft.

Therefore, it was concluded that soldier pile and lagging wall with tie backs would be feasible and the preferred ERS.

5.0 DESIGN OF THE EARTH RETAINING SYSTEM

5.1 Design of Soldier Pile and Lagging ERS

Preliminary design of the soldier piles, tie-backs, and walers is shown in Figure D-2 in Attachment D. Structural calculations showing adequacy of the design are shown in Attachment G. These calculations were performed using preliminary soil information provided by Shannon and Wilson (see email dated 6/7/16 in Attachment C) and in accordance with the Design Basis Document.

Construction of the soldier pile and lagging wall begins with driving soldier piles down to their final depth. Alternately, soldier piles may be placed in drilled holes, which are then backfilled with soil or concrete. For this study it was assumed that soldier piles would be driven. Also, steel HP sections are used for the soldier piles for this study. These steel sections are similar to wide flange (I-shaped) sections except that the flange width exceeds the depth. Excavation begins after installation of the soldier piles. Lagging is installed between the soldier piles as the excavation proceeds. The lagging can be wood timbers as shown in Figure 1 if the wall is temporary or using concrete panels as shown in Figure 2 if the wall is permanent. Tie-backs and walers are installed when the excavation reaches about 3 ft. below the tie-back elevation (see Figure 1). Tie-backs are soil anchors which may consist of a single steel rod or steel tendons. As shown in Attachment D, Figure D-2, the anchors are grouted for length of the anchor called the bond zone a certain distance behind the potential failure plane.
Calculations shown in Attachment G show that HP16x88 soldier piles spaced at 8'-0” o.c. are adequate for the vault excavation. Three rows of tie-back anchors are required each with a 145 kip design. These tie-backs would not require unusually heavy or specialized equipment according to FHWA-IF-99-015, Sect. 5.3. In addition, the anchor bond length of 34'-0” does not exceed the maximum 40'-0” recommended by FHWA-IF-99-015. The horizontal tie-back spacing is 8’-0” o.c. Since the horizontal tie-back spacing is the same as the soldier pile spacing, tie-backs could be installed through the soldier piles. A steel circular tube stiffener or other type of stiffener would be welded to the soldier pile as shown in Figure 3.

Alternately, tie-backs could be anchored by walers running horizontally across the soldier piles as shown in Figure 1. Structural calculations indicate that back-to-back MC18x51.9 steel sections would be required for the walers.

The ERS has been designed to support the heaviest equipment that may be used near the wall. The maximum equipment loads are shown in the email dated 6/8/16 shown in Attachment C. The maximum load is due to an excavator. The excavator used to design the wall is a Caterpillar 325 F with an operating weight of 116,600 lbf. Specifications for the excavator are shown in Attachment F. The track hoe is allowed to be placed a minimum 5 ft. distance from the track centerline to the wall. This minimum distance also applies to other equipment listed in the email dated 6/8/16.

Figure 1. Soldier Pile Wall with Timber Lagging and Walers
Figure 2. Soldier Pile Wall with Concrete Panel Lagging

Figure 3. Soldier Pile Wall with Tie-backs Installed Through Piles
5.2 One-Sided or Two-Sided Forms for the Vault Exterior Walls

The possibility of using the excavation support system as a form for the vault exterior walls was discussed (see Attachment B, 5/24/16 Minutes of Meeting). This could speed-up construction of the exterior walls and save forming costs. However, this is an open item pending discussions with SGH about the impact of the ERS on the soil-structure interaction (SSI) analysis. The SSI analysis may require the ERS to be temporary so that the ERS would not be used as a form. This would require 1) detensioning the tie-backs and 2) removal of the timber lagging as backfill is placed after which the ERS would no longer function.

Using the earth retaining system as a permanent form would require design of the tie-backs to resist seismic earth pressure loads and seismic forces due to the exterior vault concrete wall self-weight. The ERS shown in Figure D-2 has not been designed for seismic loads. Also, as discussed previously a permanent ERS may require concrete lagging as opposed to degradable timbers, which would increase costs.

6.0 PROPOSED EXCAVATION PLAN

The proposed shoring excavation plan and section is shown in Attachment D, Figure D-1. This plan was developed assuming that the ERS would be used as a form for the exterior vault concrete walls. If the ERS is not used as a form for the vault walls, then the excavation area would be widened by about 5 ft.

The excavation plan (Figure D-1) shows two bottom of excavation elevations levels since the vault has two basemat elevations. An excavator operation pad is provided. An excavator will operate off this pad to remove soil from the inside the excavation and place the soil in a dump truck adjacent to it on the access road.

Two scaffold stairs are shown in the main excavation area at diametrically opposed corners. The stairs would be increased in height as the excavation proceeded to deeper elevations. Having the stairs inside the excavation could require placing the basemat in two pours. For the first pour, the stairs would be placed in an area where concrete is not placed. For the second pour, the stairs would be moved to the area of the basemat already placed and ready to accept construction loads. Alternately, legs of stairs could be supported on embeds in the basemat. This would allow the basemat to be placed in one pour. These embed would have to be carefully planned so as not to interfere with embeds required to support equipment. Stairs would also be required at the bottom of the shallower excavation area. They are not shown on Figure D-1.

The access road is shown running south and then east of the excavation. This road alignment allows construction of other LAWPS facilities to proceed, while the vault is constructed. The access road is shown on Figure D-1 as running northward to the existing WTP Loop Road. However, this road may be adjusted to run slightly east of straight northward to provide better access to areas where other LAWPS facilities will be constructed.
7.0 COST AND SCHEDULE FOR SELECTED ERS

Cost and impact on the project baseline for this activity are TBD pending closure of open items identified in section 3.2.

8.0 RESULTS

A soldier pile and lagging earth retaining system (ERS) has been selected for the LAWPS vault excavation. This system was selected based on cost and technical adequacy. A soil nailed ERS was not selected due poor capacity in the cohesionless in situ soils at the site. Also, a sheet pile wall ERS was not selected since sheet piling can only be driven to a maximum 20 ft. depth, while the vault excavation would require driving the sheet piling to greater than 46 ft. in depth.

Calculations shown in Attachment G were performed to determine the required soldier piles, tie-backs, and walers. Details for the soldier pile wall are shown in Figure D-2 in Attachment D. HP16x88 soldier piles spaced at 8’-0” o.c. are adequate for vault excavation shown in Figure D-1. Three rows of tie-back anchors are required with a design capacity of 145 kip each. In addition, the required 34’-0” anchor bond length does not exceed the maximum 40’-0” recommended by FHWA-IF-99-015. Tie-backs could be installed through the soldier pile section or they could be anchored to walers running horizontally outside of the soldier piles. Structural calculations indicate that back-to-back MC18x51.9 steel section walers are required. The maximum equipment load allowed near the wall is a 116,600 lb excavator shown in Attachment F with the track centerline located a minimum 5 ft from the wall.

The ERS could be used as a form for the vault exterior concrete walls. This would reduce forming costs and eliminate bracing of the walls during backfilling operations. The ERS would be permanent and may require concrete panel lagging. This configuration would require that tie-backs resist seismic earth pressures and seismic loads due the wall self-weight. In addition, it may pose problems for the SSI analysis.

A shoring excavation plan using the selected ERS is shown in Figure D-1, Attachment D. This plan assumes that the ERS will be used as a form for the vault exterior walls. Two scaffold stairs are required in the excavation area. The plan shows a operation pad for an excavator. The excavator would remove soil from the excavation area and place it in a dump truck on the access road. The access road runs south and east of the excavation area. This allows access to most of the LAWPS site so other LAWPS facilities can be constructed while excavation and construction of the vault proceeds.

9.0 CONCLUSION AND RECOMMENDATIONS

This study selected an earth retaining system (ERS) based on feasibility due to site soil conditions and cost. The ERS selected is a soldier pile and lagging wall with tie-backs. Calculations were performed to determine the required steel soldier pile section and spacing. Also, the required vertical spacing of the tie-backs and design capacities were determined. The steel section for the walers was determined.
It is recommended to discuss the proposed system with SGH who will be performing the SSI analysis. Also, if the selected ERS is to be permanent and provide a form for the exterior vault concrete walls, then further calculations would be required to determine the effect of seismic forces on the ERS.

10.0 REFERENCES


4.3. 31269-22-DBD-001, Design Basis Document, Rev. 0 (Pending 06/16/16).

4.4. 31269-02-PJB-0193, Rev. 0, Develop White Paper Documenting Recommended Excavation Approach.

ATTACHMENT A. SHORING SYSTEM DESCRIPTIONS
ERS SUMMARY NO. 10: Sheet-pile Wall

Category of Wall: Non-gravity Cantilevered Wall
Classification of Wall: Externally Stabilized Cut Wall

Description
A sheet-pile wall consists of driven, vibrated, or pushed, interlocking steel or concrete sheet-pile sections. The required depth of embedment (i.e., length of sheet-pile below final excavated grade) is evaluated based on the assumption that the passive resistance of the soil in front of the wall plus the flexural strength of the sheet-pile can resist the lateral forces from the soil behind the wall. Sheet-pile walls can be constructed with anchors (see ERS Summary No. 15).

General
Typical applications: Retaining walls, slope stabilization, excavation support
Special applications: Marine walls, docks
Unit cost range: $160-$430 per square meter of wall face
Unit cost includes: Steel or concrete sheet-piles, labor, equipment, and construction of wall
Size requirements: N/A
Typical height range: 2-5 m

Advantages
- Conventional wall system with well-established design procedures and performance characteristics.
- Wall system can be used for applications in which the wall penetrates below the groundwater table.
- Work area inside wall face is not required.
- Wall system is suitable for temporary applications.

Disadvantages
- Construction of wall system requires specialized equipment.
- Driving sheet-pile is noisy and it can induce vibrations which may be detrimental to nearby structures.
- Sheet-pile interlocks may be lost during driving which will allow water (for walls constructed in areas of high ground water) to advance into the excavation.
- Difficult to drive sheeting in hard or dense soils; also difficult to drive in gravelly soils.
- Wall height is limited based on required structural section.
- Wall system may undergo relatively large lateral movements which may be detrimental to nearby structures.

**Primary System Components**
- Steel or concrete sheet-pile

**Additional Comments**
- Proper selection of pile hammer and cushioning is necessary to avoid tearing of pile interlock and excessive damage at the top of the sheet-pile.
- Wall system is typically used in potentially squeezing or running soils such as soft clays and cohesionless silt or loose sand below the water table.

Temporary sheet-pile wall

Completed sheet-pile wall
ERS SUMMARY NO. 11: Soldier Pile and Lagging Wall

Description
A soldier pile and lagging wall is a non-gravity cantilevered wall which derives lateral resistance and moment capacity through embedment of vertical wall elements (soldier piles). The soil behind the wall is retained by lagging. The vertical elements may be drilled or driven steel or concrete piles. These vertical elements are spanned by lagging which may be wood, reinforced concrete, precast or CIP concrete panels, or reinforced shotcrete. The spacing of the lagging varies from 2 to 3 m with a common spacing of 2.4 m. A portion of the load from the retained soil is transferred to the vertical elements through arching; (i.e., load is redistributed away from the lagging to the much stiffer soldier piles). The purpose of the lagging is to prevent the retained soil from eroding, which would destroy the arching effect. Soldier pile and lagging walls can be constructed with anchors (see ERS Summary No. 15).

General
Typical applications: Slope stabilization, temporary excavation support, retaining walls
Unit cost range: $110-$380 per square meter of wall face
Unit cost includes: Soldier piles (steel or concrete), lagging (wood, reinforced concrete, precast or CIP concrete panels, or reinforced shotcrete), facing panels (if required), drainage elements, labor, equipment, and construction of wall
Size requirements: N/A
Typical height range: 2-5 m

Advantages
- Conventional wall system with well-established design procedures and performance characteristics.
- Less soldier piles are driven than for the construction of a sheet-pile wall.
- Soldier piles can be drilled or driven.
- Wall system requires minimal work area inside wall face.
- Wall system is suitable for temporary applications.

Disadvantages
- Construction of wall system requires skilled labor and specialized equipment.
- Driving piles is noisy and it can induce vibrations that may be detrimental to nearby structures.
- Difficult to drive piles in hard or dense soils; also difficult to drive in soils with large cobbles and boulders.
- Pre-drilling of soldier piles, if required, is a significant cost component.
- Vibration may induce settlement in loose ground.
- Wall height is limited based on required structural section.
- Wall system may undergo relatively large lateral movements which may be detrimental to nearby structures.

Primary System Components
- Soldier piles (vertical wall elements)
- Lagging
- Facing panels (if required)
- Drainage system(s)

Additional Comments
- Construction of wall system in hard clays, shales, or cemented materials enables temporary lagging to be widely spaced or omitted provided soldier piles are sufficiently close.
- Wall system is highly pervious.
- Wall stiffness can be controlled by increasing or decreasing number of soldier piles.
- Wall system develops passive resistance only at the soldier pile locations.
Figure A-3. Slurry (Diaphragm) Wall Excerpt from FHWA-SA-96-038

ERS SUMMARY NO. 12: Slurry (Diaphragm) Wall

Category of Wall: Non-gravity Cantilevered Wall
Classification of Wall: Externally Stabilized Cut Wall

Description
A slurry (diaphragm) wall is a continuous concrete wall consisting of either steel-reinforced CIP concrete or precast concrete panels that are constructed within an excavated trench. A temporary concrete guidewall is built to maintain the alignment. The trench is constructed from the surface and is stabilized with a mineral or polymer slurry as the excavation proceeds. As an individual section of wall (panel) is excavated, the slurry is cleared of sediments so that subsequently placed tremie concrete will fully displace the slurry. For a CIP panel, a reinforcing cage is inserted into the trench and a high slump concrete is then tremied into the trench. Following a specified set time, the next panel is constructed. After construction, the ground in front of the wall is excavated to final grade. Slurry walls develop earth pressure and moment resistance through embedment. Slurry walls are typically constructed using anchors (see ERS Summary No. 15). Precast or CIP concrete panels may be constructed for permanent applications.

General
Typical applications: Retaining walls, slope stabilization, excavation support
Special applications: Cut and cover tunnels, building foundations
Unit cost range: $650-$930 per square meter of wall face
Unit cost includes: Slurry, concrete and reinforcing steel or precast concrete panels, facing panels (if required), anchors, labor, equipment, and construction of wall
Size requirements: Wall width is typically 0.4 to 1.0 m
Typical height range: 6-24 m

Advantages
- Wall system is relatively impermeable.
- Lateral movements are relatively small compared to more flexible wall systems.
- Wall system is suitable for construction in all soil types.
- Unobstructed working space can be achieved on-site.
- Wall system construction does not produce significant noise or vibrations.
- Wall system may be used for permanent support of vertical loads.
Disadvantages

- Construction of this system requires specialty contractor and equipment.
- Difficult to obtain a smooth finished wall face.
- Disposal of slurry may be costly due to environmental restrictions.

Primary System Components

- Slurry
- Precast or CIP reinforced concrete panels
- Facing panels (if required)
- Anchors

Additional Comments

- Slurry should be tested periodically to ensure that the required specific gravity and viscosity are maintained.
- Concrete placement records should be kept to determine concrete overpours and underpours that would indicate trench collapse.
- Panel connections should be inspected to ensure continuity.
- Panel width is determined by size of excavation tool.

Excavation of trench

Top of wall panel

Completed slurry (diaphragm) wall
Figure A-4. Tangent Pile/Secant Wall Excerpt from FHWA-SA-96-038

ERS SUMMARY NO. 13: Tangent Pile/Secant Pile Wall

Category of Wall: Non-gravity Cantilevered Wall
Classification of Wall: Externally Stabilized Cut Wall

Description
A tangent pile wall consists of a single row of tangentially touching drilled, reinforced-concrete piles. The reinforcement of each pile may consist of a steel beam, a single reinforcing bar, or a reinforcing bar cage. A secant pile wall consists of a single line of alternating drilled, reinforced and unreinforced concrete piles. Alternating unreinforced piles are constructed and allowed to set for a short period of specified time. Subsequently, a reinforced concrete pile is constructed between the previously drilled piles by cutting through a section of the previously constructed concrete piles. Tangent pile and secant pile walls can be constructed with anchors (see ERS Summary No. 15). Precast or CIP concrete panels may be constructed for permanent applications.

General
Typical applications: Retaining walls, excavation support
Unit cost: $430-$810 per square meter of wall face
Unit cost includes: Concrete, reinforcing steel, facing panels (prefabricated or CIP), anchors (if required), labor, equipment, and construction of wall
Size requirements: Pile diameter is typically 0.5 to 1.0 m
Typical height range: 3-9 m without anchors; 6-24 m with anchors

Advantages
- Lateral movements of these wall systems are relatively small compared to more flexible wall systems.
- Wall system is adaptable to an irregular installation arrangement and is also well-suited for wall alignments with significant horizontal curves.

Disadvantages
- Construction of wall system requires specialty contractor and equipment.
- Difficult to construct watertight tangent pile wall because small gaps can exist between piles.

Primary System Components
- CIP reinforced concrete piles
- Facing panels (if required)
- Anchors (if required)
ERS SUMMARY NO 14: Soil Mixed Wall (SMW)

Category of Wall: Non-gravity Cantilevered Wall
Classification of Wall: Externally Stabilized Cut Wall

Description
A soil mixed wall consists of overlapped soil-cement columns in which in-situ soils are mixed with a cement slurry or other hardening agent. A multiple axis auger and mixing paddles are used to construct overlapping soil-cement columns without soil removal or unmixed zones between columns. Steel structural members are typically used for reinforcement and are placed into alternating columns before substantial hardening of the soil-cement takes place. The unreinforced soil-cement columns are designed to resist and redistribute horizontal stress to adjacent reinforced members. Soil mix walls are typically constructed using anchors (see ERS Summary No. 15). Precast panels or CIP concrete may be constructed for permanent applications.

General
Typical applications: Retaining walls, excavation support
Unit cost range: $430-$590 per square meter of wall face
Unit cost includes: Cement slurry or other hardening agent, reinforcing steel, facing panels (if required), anchors, labor, equipment, and construction of wall
Size requirements: Soil-cement column diameter is typically 1.0 m
Typical height range: 6-24 m with anchors

Advantages
- Reduced excavated spoil is produced as compared to slurry (diaphragm) walls.
- Wall system is adaptable to an irregular installation arrangement.

Disadvantages
- Design procedures are not well-established.
- Construction of wall system requires specialty contractor and equipment.
- When exposed to freeze-thaw cycles, soil-cement surface may form layers that flake away from the surface.
- Quality control/quality assurance protocol is not well-documented for this wall system.
- Disposal of excavated spoil resulting from the soil mixing process may be costly due to environmental restrictions.
- Special anchor details are required to maintain water-tightness.
Primary System Components
- Cement slurry or other hardening agent
- CIP unreinforced and reinforced soil-cement columns
- Facing panels (if required)
- Anchors

Additional Comments
- Samples of soil-cement should be obtained for laboratory strength testing.
- Continuity of soil-cement requires careful quality assurance and quality control during construction.
- Wall system can be designed to be relatively impermeable.
- Required engineering properties can be achieved through proper mix design of soil-cement.

Mixing augers

Completed soil mixed wall
Figure A-6. Anchored Wall Excerpt from FHWA-SA-96-038

ERS SUMMARY NO. 15: Anchored Wall

**Category of Wall:** Non-gravity Cantilevered Wall

**Classification of Wall:** Externally Stabilized Cut Wall

**Description**
An anchored wall is any non-gravity cantilevered wall (i.e., sheet-pile wall, soldier pile and lagging wall, slurry (diaphragm) wall, tangent pile/secant pile wall, or soil mixed wall (SMW)) which relies on one or more levels of ground anchors (tiebacks) or deadman anchors for additional lateral support. The use of anchors enables these walls to be higher and deflect less than walls without anchors, (i.e., cantilever walls). An anchor is a structural system designed to transmit tensile loads to the retained soil behind a potential slip surface. Construction of the vertical wall elements and lagging (if required) for an anchored wall proceeds from the top-down as for all non-gravity cantilevered walls. When the elevation of the excavation in front of the wall reaches approximately 1 m below the specified elevation of an anchor, the process of excavation is temporarily suspended and anchors are installed at the specified elevation. An anchor is installed using drilling and grouting procedures consistent with the anchor type and prevailing soil conditions. Each anchor is tested following its installation. Typical permanent facing panels include CIP or precast concrete with natural, textured, or architectural finishes.

**General**
- **Typical applications:** Bridge abutments, retaining walls, slope stabilization, excavation support
- **Unit cost range:** $160-$810 per square meter of wall face
- **Unit cost includes:** Soldier piles (steel or concrete), lagging (wood, reinforced concrete, precast or CIP concrete panels, or reinforced shotcrete), facing panels (if required), drainage elements, anchors, grout, labor, equipment, construction of wall, and installation, proof testing, and stressing of anchors

**Size requirements:** Unbonded anchor length is typically 0.6 of wall height; actual length depends on minimum specified total anchor length and distance to a bearing strata

**Typical height range:** 5-20 m

**Advantages**
- Design procedures for anchors are well-established.
- Unlike internally braced excavations, an unobstructed working space can be achieved on the excavation side of the wall for an anchored wall.
- Relatively large horizontal earth pressures can be resisted by an anchored wall.
- Quality assurance is achieved through