Earth Retaining System (ERS) Type Selection

This module provides guidance on the selection of an appropriate ERS for given project conditions and requirements by discussing the advantages and disadvantages of various ERS.

The process for selecting an ERS type is iterative that requires collaboration with Bridge Design, Structures Construction, District Design, Environmental, and other stakeholders. When selecting the ERS type, the GP should assess the site and subsurface conditions, construction methods such as bottom-up method, top-down method, or their combination, and right of way (ROW)/environmental restrictions. It is important to discuss potential ERS types with the Project Development Team (PDT) to ensure the most suitable ERS type is selected, and applicable information be included in the risk register.

Every effort should be made to select a standard plan ERS since they are typically less expensive to engineer and construct. If a special design is the only alternative, contact the PDT so that adequate adjustments are made to the project resourcing and schedule.

In addition to this module, refer to the following documents for the ERS selection.

- Caltrans Highway Design Manual (2023), Topic 210 – Reinforced Earth Slopes and Earth Retaining Systems
- Caltrans Bridge Design Practices 11.2 (2022), Earth Retaining Systems

Investigations

The purpose of the geotechnical investigation for an ERS is to determine the properties of soil and/or rock and the groundwater conditions that can affect the wall design and construction. Specific investigative requirements are presented in the ERS-specific modules.

ERS Selection – Bottom-up and Top-down Walls

Some wall types are best suited for fill situations whereas others are best suited for cut situations. The key considerations in selecting a wall type are the amount of excavation or shoring required during construction and the overall height. ERS are categorized by construction method: bottom-up wall or top-down wall.

- Bottom-up wall construction is typically for fill situations and starts at the lowest elevation along the wall bottom. The wall face is then formed or constructed vertically upward followed by placement of backfill, and reinforcements if required.

- Top-down walls are typically constructed as a cut, or in a series of cuts, and involve placement of reinforcing elements, discrete elements, and facing as construction moves downward.

Bottom-up walls typically require some excavation before construction, while top-down walls typically require some fill or grading to establish the finished grade before or after construction.

The following tables present ERS types used.

Table 1: Bottom-up/Fill-section Wall

<table>
<tr><th>Externally Stabilized[1]</th><th>Internally Stabilized[2]</th></tr>
<tr><td>Conventional Wall:
• Gravity Wall
• Standard Plan Cantilever Wall
• Modified/Special Design Wall</td><td rowspan="2">• Mechanically Stabilized Embankment Wall (MSE)
• Alternative ERS
• Gabion (Faced) MSE</td></tr>
<tr><td>Prefabricated Modular-Gravity Wall:
• Gabion Wall</td></tr>
</table>

1. Externally Stabilized: rely on the integrity of wall elements (with or without braces, struts, walers and/or tiebacks or anchors) to resist lateral loads.
2. Internally Stabilized: rely on friction developed between closely spaced reinforcing elements and the backfill to resist lateral soil pressure.

Table 2: Top-down/Cut-section Wall

<table>
<tr><th>Externally Stabilized[1]</th><th>Internally Stabilized[2]</th></tr>
<tr><td>Non-Gravity Cantilever Wall:
• Sheet Pile Wall
• Soldier Pile and Lagging Wall
• Secant/tangent Pile Wall</td><td rowspan="2">• Soil Nail Wall</td></tr>
<tr><td>Anchored Wall:
• Ground Anchor Wall
• Deadman Anchor Wall</td></tr>
</table>

1. Externally Stabilized[1]: rely on the integrity of wall elements (with or without braces, struts, walers and/or tiebacks or anchors) to resist lateral loads.
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ERS Selection Procedure

Use the following steps in conjunction with Tables 1 and 2 when type-selecting an ERS.

1. Identify how the proposed wall can be built more economically: Bottom-up or Top-down.

   Favorable Top-down Wall Situations:

   - Requires a cut.
   - Difficult to procure structure backfill due to haul distance or cost.
   - Adequate right-of-way or easements to accommodate anchors or nails.
   - Soil can stand up for limited durations without support.
   - Landslide Stabilization

   Favorable Bottom-up Wall Situations:

   - Structural backfill is cost-effective.
   - Limited excavation or wall height.
   - Sufficient distance and right-of-way for temporary slopes (otherwise shoring may be required).
   - Construction sequence may be difficult for the top-down wall (e.g., anchor installation and testing).

2. If the bottom-up wall is selected,

   - Identify if Standard Plan Walls can be used.
   - If Special design walls are needed, select the most appropriate wall among the specially designed conventional wall, gabion wall, and MSE wall (see Tables 3 and 4).

3. If the top-down wall is selected,

   - Identify if the cut face will be stable during excavation without supports. If the cut face is not stable, exclude soil nail walls.
   - Identify if ground anchors or soil reinforcements are needed (as a rule of thumb, the ground anchors would be needed if excavation/wall height is greater than 15 feet).
     - If the ground anchors/soil reinforcements are not needed, consider non-gravity cantilever retaining walls.
   - If the ground anchors/soil reinforcements are needed, select the most appropriate wall among the ground anchor walls and soil nail walls (see Tables 3 and 4).

Based on the selected ERS construction category following the steps above, consider the specific ERS type based on the information presented in Tables 3 and 4.

Table 3: Type Selection Chart for Bottom-up/Fill-Section Wall

Wall Type	Cost Effective Height (ft)	Required R/W	Feasible Site Condition	Advantage	Disadvantage
Gravity	3 - 5	0.5 – 0.7H	Granular soils, stiff to hard clays (not expansive), IGM soils, rock.	• Durable	• Requires relatively long construction time
Semi-gravity Cantilever	5 - 30	0.4 – 0.7H	Granular soils, stiff to hard clays (not expansive), IGM soils, and rock	• Standard construction that is commonly used • Can be integrated with the concrete barrier • Durable	• Requires temporary slope or shoring • High seismicity requires a special design or exception • May require pile foundation in poor soils • Longer construction time • Low tolerance to differential settlement
Gabion	5 - 25	0.5 - 0.7 H	Granular soils, soft to hard clays, IGM soils, and rock	• Can be built by general contractors capable of labor and earthwork • Can accommodate high differential settlement • Free draining • Erosion Resistant	• Susceptible to corrosion (baskets and ties) • Relies on a short distance to the source of infill • Requires significant manual labor
Gabion MSE	5 - 25	0.7 - 1.5 H	Granular soils, soft to hard clays, IGM soils, and rock	• Can be built by general contractors capable of labor and earthwork • Can accommodate high differential settlement • Free draining • Erosion Resistant	• Susceptible to corrosion (baskets and ties) • Relies on a short distance to the source of infill • Requires significant manual labor
MSE	5 - 65	0.7 – 1.5H	Granular soils, soft to hard clays, IGM soils, and rock	• Does not require skilled labor • Flexibility in choice of facing • Inexpensive • Adaptable to wall profile changes	• A larger area is required for soil reinforcement behind the wall • Requires selected fill • Subject to corrosion in an aggressive environment for steel reinforcements

Table 4: Type Selection Chart for Top-down/Cut-section Wall

Wall Type	Cost Effective Height (ft)	Required R/W	Feasible Site Condition	Advantage	Disadvantage
Sheet Pile	Up to 15	N/A	Granular soils, and soft to stiff clays	• Rapid construction • Readily available and easy transportation • Good water tightness	• Difficult to construct on hard ground or through obstructions • Susceptible to corrosion
Solider Pile	Up to 15	N/A	Granular soils with cohesion, soft to hard clays, IGM soils, and weathered rock	• Rapid construction • Readily available • Piles can be drilled through most subsurface	• Susceptible to corrosion • Requires larger laydown area for equipment (cranes/excavators) • Potential for ground loss at excavated face • Difficult to excavate pile foundations in loose caving materials (soil/decomposed rock with gravels, cobbles, or boulders) • No water tightness
Tangent/Secant Pile	Project-Specific	N/A	Granular soils, soft to hard clays, IGM soils, and weathered rock	• Piles can be drilled through most subsurface • Reduce lateral displacement of retained zone compared to the sheet pile wall • Good water tightness	• Expensive compared to the sheet pile wall • Reduce lateral displacement of retained zone • Difficult to keep vertical alignment for deep piles • Difficult to excavate pile foundations in loose caving materials (soil/decomposed rock with gravels, cobbles, or boulders)
Ground Anchor	15 - 65	Project-Specific	Granular soils with cohesion, medium stiff to hard clays (not expansive), IGM soils, and weathered rock	• Reduces lateral displacement of retained zone • Can sustain high lateral loads	• Relatively expensive • Anchors may require significant easement • May require specialized equipment • No water tightness
Soil Nail	10 – 65	0.7 – 2.0H	Granular soils with cohesion, medium stiff to hard clays (not expansive), IGM soils, and weathered rock	• Rapid construction • Adaptable to irregular wall alignment	• Susceptible to corrosion • Potential for ground loss at excavated face • Creep for clay soils • No water tightness

Wall Type	Cost Effective Height (ft)	Required R/W	Feasible Site Condition	Advantage	Disadvantage
Ground Anchor Diaphragm	Project-Specific	Project-Specific	Granular soils with cohesion, stiff to hard clays (not expansive), IGM soils, and weathered rock	• Reduces lateral displacement of retained zone • Adaptable to irregular wall alignment	• Susceptible to corrosion • Potential for ground loss at excavated face • Creep for clay soils