CHAPTER 2

RETIETING WALL APPRAISALS
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2.1 RETAINING WALLS

A Retaining Wall or Earth Retaining Structure (ERS) is any structure intended to stabilize an otherwise unstable soil mass by means of lateral support or reinforcement. Retaining walls which have a vertical, or near vertical face, are by far the most familiar type of ERS.

The following are terminology used to distinguish the particular situational status of a retaining wall.

Wall Project: a NYSDOT contract which includes the construction of a retaining wall.

Wall Site: a location within the contract limits of a NYSDOT contract where retaining walls are constructed (e.g. a structure spanning a roadway which includes wingwall extensions in each quadrant would be identified as a Wall Site).

Wall Structure: an individual retaining wall (e.g. a Mechanically Stabilized Earth System (MSES) founded structure with flared wingwalls over a railroad would contain six wall structures (four flared wingwalls and two abutment walls)).

2.1.1 Qualifying Retaining Walls

The retaining walls qualified to be included in the NYSDOT Retaining Wall Inventory & Inspection Program (RWIIP) shall meet the following requirements:

Wall Height: measure at least 4 ft. from the finished grade in height at the maximum point along the length of the wall

- The maximum wall height should be measured from the toe of the wall to the intended height of earth retention. For locations where the wall has been disturbed and/or retained materials have been eroded, the wall height should be measured to a projected height of retention.
- Although during the inspection program the condition assessment will only address that portion of the wall that can actually be seen, there may be walls which appear important to the stability of the roadway but may otherwise not qualify on exposed height alone. When determining whether a wall qualifies for the RWIIP, the inventory team should include walls where the elevation of the buried toe of the wall is known or verifiable.
- Parapets or integral jersey barrier structures extending above the intended retained earth height of the wall are not to be included in the maximum height determination. These features are evaluated as contributing “secondary wall elements” in the condition assessment, and will be further evaluated as traffic barriers.
- If any portion of the wall meets the height criterion, the entire wall length is included in the inventory – not just the segment meeting the criterion.
Wall Batter: display greater than 45 degree vertical batter.

- In general, a retaining wall is defined by the National Highway Institute (NHI) as wall which face makes an angle of 70 degrees or more with the horizontal and retains earth. This definition covers most conventional cut and fill wall designs. However, NYSDOT has broadened this criterion to structures with greater than a 1:1 face angle to include earth retention structures such as stacked & offset rockeries, stepped gabions, etc. that don’t directly meet the NHI design definition but are nonetheless critical earth retention assets.
- Tiered wall systems may be comprised of different wall types, possibly constructed at different times, and/or may have vertical or horizontal offsets between walls such that it may be more appropriate to consider the walls individually, rather than as an integrated earth retention system.

In addition, the RWIIP includes the following structures as noted herein:

**Noise Wall / Retaining Wall Combination:** A combination Noise Wall and Retaining Wall structure will be included in the Retaining Wall Inventory & Inspection Program provided that the qualifying retaining wall parameters are met.

**Wingwall Extensions:** As noted in the NYSDOT Bridge Inspection Manual, a Bridge Inspector assessing the condition of a very long wingwall will consider the length of the wingwall that can be associated with the bridge. Lacking any other logical criterion (such as a vertical construction joint), a Bridge Inspector will use twice the height of the abutment as the length of the wall to set their inspection limits. Wingwalls that exceed this limit will be included in the Retaining Wall Inventory & Inspection Program.

**Mechanically Stabilized Earth System (MSES) Walls:** All MSES walls will be included in the Retaining Wall Inventory & Inspection Program provided that the qualifying retaining wall parameters are met. As such, this will include MSES walls supporting a bridge. Although Bridge Inspectors will inspect these wall structures as part of their assessment (see National Bridge Element (NBE) 215 Reinforced Concrete Abutment identified in NY Figure 3.5-10 of the NYSDOT Bridge Inspection Manual), an MSES wall requires unique attention.

- Mechanically Stabilized Earth (MSE) retaining wall systems have three major components: soil reinforcement (mesh or strip), backfill, and precast facing elements. Neither the reinforcements nor the backfill can be completely accessed for visual inspection or quantitative analysis. This leaves the structural face and secondary and contiguous elements to decipher the systems condition. Therefore, a thorough visual inspection of the MSES wall and adjacent area is required. In addition to the facing panels, the Inspector will need to inspect the drainage facilities, roadway surface and attached barriers to gather sufficient informational keys regarding stability of the MSES wall.

Accordingly, all MSES walls will be inspected by inspection teams from the Geotechnical Engineering Bureau.
Retaining Walls of Unknown Ownership: A retaining wall structure whose ownership is unknown will be included in the Retaining Wall Inventory & Inspection Program provided that the qualifying retaining wall parameters are met and, in the opinion of the inspector, the retaining wall is supporting the roadway facility.

2.2 TRAINING REQUIREMENTS

Retaining wall assessments are most commonly conducted by teams of two to three individuals knowledgeable in wall components and construction, and skilled in recognizing a wide range of element distresses and failure modes.

All inspection teams must include a Team Leader (TL) and Assistant Team Leader (ATL). The Team Leader is responsible for ensuring that the retaining wall structure is inspected completely and that the inspection reporting conforms with all requirements of the RWIIP. The Assistant Team Leader may inspect and measure components, if working under the Team Leader’s direct supervision. Additional personnel, such as laborers or Assistant Team Leader Trainees, may be added as needed.

A. A Team Leader shall be a licensed and registered NYS Professional Engineer and have at least three (3) years of experience in design, construction, or inspection of transportation structures. The Team Leader shall:

- be present at the wall inspection site throughout the inspection process,
- take part personally in the inspection of the wall,
- supervise other inspection team member(s) to ensure that each wall is properly inspected, and
- ensure that the inspection results are properly documented.

The team leader shall ensure that additional team members are appropriately qualified and trained for their required duties.

B. An Assistant Team Leader shall:

- possess a Bachelor of Science Degree in Civil Engineering from an Accreditation Board for Engineering and Technology (ABET) accredited program or an equivalent degree acceptable to the Department, or
- possess an Associate Degree in Civil Engineering Technology or an equivalent Associate Degree determined to be acceptable by the Department, and have one-and-one-half (1½) years of experience in the design, construction, or inspection of transportation structures, or
- have at least three (3) years of experience in design, construction, or inspection of transportation structures.

Quality Control review is a detailed process that includes careful examination of all parts of the retaining wall inspection documentation and field reviews of inspection teams and field procedures. The Quality Control Engineer (QCE) shall review and approve all field inspection reports and shall meet the same qualifications specified for a Team Leader. The QCE shall not be
the same individual responsible for performing the inspection or preparing related inspection reports.

The primary goals of the Team are to readily identify and consistently document the many factors contributing to a wall’s overall condition and performance state. Upon completion of the field inspection, Team members are also responsible for entering wall data into the AgileAsset Database System.

To prepare for field evaluations, Teams should be fully trained on the various components of the wall inspection program documented within this RWIIP Manual, including:

- Pre-field preparation, including acquisition of previous inspection information, associated bridge inspection information, and necessary field equipment, forms, etc.;
- Proper use of the inventory field forms, including a complete knowledge of the definition, intent, and application of each attribute and element within the form;
- Use of the AgileAsset Database System for entering/extracting field data and archiving wall photos; and
- Field safety regarding site inspection work.

The remaining chapters in this RWIIP Manual contain detailed information regarding the various processes and procedures to be followed throughout a retaining wall inspection effort, including definitions for each of the inventoried wall attributes and elements. Poor-quality field assessments, including incomplete forms, minimal or non-descriptive element condition narratives, or similar deficiencies, are a reflection of a lack of training on program requirements. Therefore, it is imperative that all team members are well-versed on the contents of the RWIIP Manual before undertaking field inspection.

It should be emphasized that, retaining walls, by their very nature, are often located in steep settings which may be extremely hazardous to investigate. Safely locating and accessing walls begins with roadway safety precautions (e.g., proper signage, flagging, vehicle pull-offs, etc.), and further includes proper personal safety gear and the use of personal protective equipment when evaluating the wall structure (e.g., ropes and harnesses). If necessary, the team should communicate their safety concerns and needs with Maintenance personnel to gain access to a potentially hazardous site.

### 2.3 INSPECTION FREQUENCY

There is currently no federal mandate for the inventory and inspection of retaining wall structures. It is the policy of NYSDOT Office of Technical Services that routine inspections for retaining walls be performed at a maximum interval of ten years (120 months). The maximum inspection interval for mechanically stabilized earth system walls should not exceed five years (60 months). Certain structures may be deemed higher risk and require shorter inspection intervals at the discretion of the Main Office Geotechnical Engineering Bureau or Main Office Structure Management Bureau. The inspection interval may deviate from the routine inspection cycle based on evaluation and consideration of several aspects:
- Reinspection Cycle Based on Wall Type: The total asset inventory is comprised of numerous wall types with different condition states and performance attributes (e.g. old stone masonry walls may still be performing well with little to no signs of significant deterioration, whereas younger corrugated metal bin walls may be indicating rapidly deteriorating metal facing elements). The inspection cycles for certain walls may need to be shorter than others to optimize life-cycle maintenance.

- Reinspection Cycle Based on Wall Location: Environmental factors can greatly impact wall performance (e.g. concrete and metal-faced walls subject to coastal marine environments). Areas subject to high annual precipitation, extreme freeze-thaw cycles, and/or heavy, rapid vegetation growth are also highly susceptible to accelerated wall deterioration.

- Reinspection Due to External Event: Emergency destructive events (e.g. floods, landslides), rapidly developing wall failures, etc. may also trigger the need for updated inspections.

- Reinspection Due to Flagging Procedure: Appendix 3E Inspection Flagging Procedure for Retaining Walls provides the procedure for timely notification of retaining wall structure deficiencies that require attention. A retaining wall flag or inactive flag may dictate a monitoring program or inspection cycle adjustment.

The proposed inspection interval, along with a justification, should be noted during the inspection. Any recommendation to adjust the inspection frequency shall be reviewed and approved by the Region. At times, there are circumstances that may impact scheduling of inspections. In such situations, the Region may adjust the inspection schedule, with appropriate justification. Documentation of this justification shall be placed in the WIN folder.

### 2.4 ROUTINE INSPECTION PROCEDURES

The following is a list of common inspection procedures when conducting a routine inspection on a retaining wall.

1. Arrive at site and set-up traffic control (if required).
2. Identify & Verify Structure.
3. Perform Inspection.

   - Check wall for signs of settlement, rotation, or bulging.
   - Inspect the vertical alignment of the wall with a plumb-bob. (Note: Most walls are constructed with a battered or sloped face, therefore this must be taken into account and noted).
   - Examine the opening of the construction joints between sections of the wall.
   - Inspect joints near ground line for any fill material washing out from between panels or joint.
   - Inspect panel joints for differential movement or rotation. Sight down panel face to note individual rotation or tipping out of plane.
   - Inspect for erosion of the embankment material in front of the wall.
Inspect for heaving of the embankment material in front of the wall.
Inspect for settlement of the fill material behind the wall.
Examine the wall for deterioration of the material, such as cracking, spalling, and/or corrosion, noting the width, length, depth, and/or orientation of the deterioration. Provide photographs of defects.
Some wall types (timber pile and lagging, for example) may require the inspector to randomly select a few posts and dig down 3’-6” below groundline to see if piling is deteriorating at the soil level.
Lagging or cribbing should be checked for excessive deflections. Excessive deflections may allow the soil behind to spill or wash out, causing settlement in the retained material above.
Examine previous areas of repair for soundness.
Check wall façade for evidence of water seepage, efflorescence or rust staining.
Examine anchorage systems if present. Fasteners and connections to the wall components should be checked for tightness and distress.
Examine and probe drains for signs of clogging. Examine drainage around ends of wall and note if embankments have been experiencing erosion.
Examine site grading for any locations that may prohibit proper drainage from behind the wall. Look for evidence of ponding above the wall, such as debris accumulation in the lower spots. Attempt to ascertain why water is not draining properly, and note in the inspection.
Inspect sidewalk or roadway components above wall for signs or joint separation, potholes and areas of settlement.
Examine vegetation growth along and above the wall. Root infiltration may create undesirable stresses on the wall and may induce cracking, bulging or failure.
Examine the wall system for vehicular damage. Document the location and degree of damage.

4. Determine if an underwater dive inspection or an in-depth inspection needs to be scheduled to supplement the routine inspection and provide more information on the condition and performance of the wall.
5. Review of inspection notes to ensure completeness and correctness.
6. Document all defects with a photo and/or a sketch.

Appendix 2A Noteworthy Inspection Features Based on Wall Types provides spotlights on some frequent trouble areas of some typical retaining walls, categorized by wall type.
2.5 REFERENCES


Appendix 2-A

Noteworthy Inspection Features Based on Wall Types

The following are outlines of the structure composition of some common retaining walls, categorized by wall types:
Steel Sheeting Wall

**Description:** Sheeting members of a shoring system are structural units which, when connected one to another, will form a continuous wall. Sheeting is driven to a depth sufficient for the passive pressure exerted on the embedded portion to resist the lateral active earth pressures acting on the cantilevered section.

**Classification:** Externally Stabilized Cut Structure
Generic Construction Detail:

Cantilever Steel Sheeting Wall
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Anchored Steel Sheeting Wall
### Noteworthy Inspection Features:

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Horizontal or vertical deviation from the design alignment. May be caused by several factors including structural failure of sheet, wale, or anchor; soil failure at toe or backfill slope; horizontal sliding, or seepage.</td>
</tr>
<tr>
<td>Corrosion</td>
<td>Loss of steel section due to interaction with environment. The rate of corrosion is dependent upon the oxygen concentration and moisture in contact with the steel.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Vertical movement of material behind sheeting. May be caused by consolidation of the soil; loss of backfill; or wall movement.</td>
</tr>
<tr>
<td>Sinkhole (cavity) Formation</td>
<td>Loss of fill material behind sheeting. Associated settlement may or may not occur, but the potential exists.</td>
</tr>
<tr>
<td>Interlock Separation; Holes; Dents; or Cracks</td>
<td>Interlock separation is the failure of sheeting interlocks; Holes are broad openings in a sheet; Dents are depressions in sheet (without rupture); and Cracks are narrow breaks in sheet. These defects represent openings in a sheeting wall and are typically caused by corrosion or impact.</td>
</tr>
</tbody>
</table>
□ Soldier Pile and Lagging Wall □

**Description**: Soldier piles used as part of a shoring system are vertical structural units, or members, which are spaced at set intervals. A lagging material is placed between the soldier piles to complete the shoring system. A soldier pile and lagging wall derives its resistance from the embedded portion of the wall. The lagging material is usually selected based upon the design life of the wall.

**Classification**: Externally Stabilized Cut Structure
Generic Construction Detail:

Cantilever Soldier Pile and Lagging Wall
Anchored Soldier Pile and Lagging Wall
## Noteworthy Inspection Features:

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Horizontal or vertical deviation from the design alignment. May be caused by several factors including structural failure of soldier pile, wale, or anchor; soil failure at toe or backfill slope; horizontal sliding, or seepage.</td>
</tr>
<tr>
<td>Corrosion</td>
<td>Loss of steel section due to interaction with environment. The rate of corrosion is dependent upon the oxygen concentration and moisture in contact with the steel.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Vertical movement of material behind soldier pile and lagging. May be caused by consolidation of the soil; loss of backfill; or wall movement.</td>
</tr>
<tr>
<td>Sinkhole (cavity) Formation</td>
<td>Loss of fill material behind soldier pile and lagging. Associated settlement may or may not occur, but the potential exists.</td>
</tr>
<tr>
<td>Interlock Separation; Holes; Dents; or Cracks</td>
<td>Interlock separation is the failure of lagging to soldier pile interlocks; Holes are broad openings in the lagging; Dents are depressions in the lagging (without rupture); and Cracks are narrow breaks in the lagging. These defects represent openings in a soldier pile and lagging wall and are typically caused by corrosion or impact.</td>
</tr>
</tbody>
</table>
□ Concrete Cantilever Wall □

**Description:** A cast-in-place (or precast) cantilever wall is comprised of reinforced concrete formed to yield a thin, reinforced stem cantilevered from a base slab. Stability of the cantilever wall is achieved by the weight of the wall system and the weight of the backfill above the heel projection of the base slab to resist lateral soil pressure.

**Classification:** Externally Stabilized Fill Structure
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Generic Construction Detail:

Precast Concrete Cantilever Wall
 CHAPTER 2
Retaining Wall Appraisals

Noteworthy Inspection Features:

**General:**

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Horizontal or vertical deviation from the design alignment. May be caused by several factors including structural failure of the precast unit; soil failure at toe or backfill slope; horizontal sliding, or seepage.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Vertical movement of material behind the precast unit. May be caused by consolidation of the soil; loss of backfill; or wall movement.</td>
</tr>
<tr>
<td>Sinkhole (cavity) Formation</td>
<td>Loss of fill material behind the precast unit. Associated settlement may or may not occur, but the potential exists.</td>
</tr>
</tbody>
</table>

**Concrete Cracks:**

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insignificant Cracks / (cracks &lt; 0.012 inches wide)</td>
<td>Map cracks are typically associated with AAR, Alkali-Aggregate Reaction. A chemical reaction takes place between the aggregate and potassium, sodium, or calcium hydroxide present in the cement. This causes an expansive gel which induces cracking.</td>
</tr>
<tr>
<td><strong>Map Cracks</strong></td>
<td></td>
</tr>
<tr>
<td>Moderate Cracks / (0.012 – 0.05 inches wide)</td>
<td>Structural cracks may be shear or flexural induced. Flexural cracks would occur on the back side of the wall and would not be visible to an Inspector. Non-structural reasons include temperature (expansion/contraction), thermal gradient (solid/hollow section transition) and shrinkage (contraction at cure).</td>
</tr>
<tr>
<td><strong>Wide Cracks</strong> (cracks &gt; 0.05 inches wide)</td>
<td></td>
</tr>
</tbody>
</table>

The inspector should use judgement when investigating concrete cracking. The inspector should consider width, spacing, location, orientation of the cracking and determine whether the cracking is structural or nonstructural in nature.

**Additional Concrete Distress:**

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spalling / Delamination</td>
<td>Delaminated or spalled concrete is when a piece of concrete detaches from the structure. Causes include improper handling during production / construction; inadequate joint material performance / closely spaced joints; impact of edges during handling; and/or expansion of corroding steel commonly caused by intrusion of chlorides or roadway deicers</td>
</tr>
<tr>
<td>Staining</td>
<td>• Efflorescence is a crystalline deposit, usually white, that may develop on the surfaces of masonry construction. This is usually a sign that moisture is slowly migrating through the wall.</td>
</tr>
</tbody>
</table>
Generally, efflorescence is looked upon as cosmetic in nature; however, it may be a warning sign that there is a structural issue or that some form of preventive maintenance is needed.
- Rusty stains on the wall may be a sign of iron ochre infiltration. Iron ochre is common wherever there are high levels of iron in the soil. Just like efflorescence, iron ochre is carried through with the migrating moisture.
- Rusty stains on the wall may be a more detrimental indicator, where reinforcement corrosion is showing as rust staining through cracks and thus a loss in strength.

| Exposed rebar | When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination, and spalling. This condition usually is the result of a crack in the concrete that allows water to travel through and reach the rebar. The force of the expanding rebar causes more damage to the concrete around it, which creates greater access for water and more corrosion in this compounding cycle. |
Description: A cast-in-place (or precast) gravity wall is comprised of a mass of concrete formed to produce an immense structure, usually economical only for small heights. Stability of the gravity wall is achieved by the weight of the wall system to resist lateral soil pressure. Other materials utilized to construct a gravity wall include stone, stone and mortar, and gabions.

Classification: Externally Stabilized Fill Structure
Generic Construction Detail:

**Gravity Wall**

**Gabions:** A gabion wall is a subset of the gravity wall category. Gabions are comprised of twisted or welded wire baskets that are divided by diaphragms into cells, including basket infill consisting of stone fill. Stability of these systems is achieved by the weight of the stone-filled baskets resisting the overturning and sliding forces generated by the lateral stresses from the retained soil.

**Classification:** Externally Stabilized Fill Structure
Generic Construction Detail:

Gabion Wall
Dry Laid Stone Wall: A dry laid stone wall is a subset of the gravity wall category. The wall is comprised of stone situated in compression with gravity, with friction binding them together. A dry laid stone wall is flexible (i.e. behaves like a woven basket and will tighten up internally while maintaining integrity). Water drains through it naturally, and any minor settling or shifting that occurs is absorbed by the wall and goes largely unnoticed.

Classification: Externally Stabilized Fill Structure
Generic Construction Detail:

Dry Laid Stone Wall

**Stone Masonry Wall:** A stone masonry wall evolved out of the dry laid stone wall with the emergence of cement mortars. It is designed as a rigid structure which will hold its form when external forces are exerted on the wall (e.g. ground settling, frost heaving). With the use of mortar, it is possible to build a taller stone wall that does not taper inward like a dry laid stone wall.

**Classification:** Externally Stabilized Fill Structure
Generic Construction Detail:

**Stone Masonry Wall**

**Rockery Wall:** A rockery wall is a subset of the gravity wall category. The wall is defined as an engineered system of stacked angular rocks placed, without mortar, in an approximate “running bond” pattern. Rock dimensions are generally greater than 18 in. and rock weights generally greater than 200 lb. Stability of the system is achieved through the mass of the rocks and inter-rock friction. Dry laid stone walls are not considered rockeries (as defined herein) as dry laid stone walls are generally constructed of 2 to 45 lb. hand-placed stones, stacked like bricks by masons.

**Classification:** Externally Stabilized Fill Structure
Generic Construction Detail:

Rockery Wall
Noteworthy Inspection Features:

**General:**

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Horizontal or vertical deviation from the design alignment. May be caused by several factors including structural failure of the concrete mass; soil failure at toe or backfill slope; horizontal sliding, or seepage.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Vertical movement of material behind the concrete mass. May be caused by consolidation of the soil; loss of backfill; or wall movement.</td>
</tr>
<tr>
<td>Sinkhole (cavity) Formation</td>
<td>Loss of fill material behind the concrete mass. Associated settlement may or may not occur, but the potential exists.</td>
</tr>
</tbody>
</table>

**Gabions:**

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion</td>
<td>Loss of welded wire section due to interaction with environment. The rate of corrosion is dependent upon the oxygen concentration and moisture in contact with the wire.</td>
</tr>
<tr>
<td>Bulging or Leaning</td>
<td>Distinct areas of deviation from the design alignment. May be caused by several factors including disruption to the internal drainage system and/or re-direction of surface drainage system; additional loads imposed on the wall; or soil failure at toe or backfill slope. Bulging may also be a result of the original installation. Gabions are to be filled with stone carefully placed by hand or machine to assure alignment and minimize voids. Dumping stone into the gabion unit with minimal care may speed construction but introduces a high potential for internal flexing, as the stone backfill settles into place.</td>
</tr>
<tr>
<td>Dislocation or loose stones</td>
<td>Loss of welded wire connections. May be caused by corrosion; rupture from ice or debris flow against wall face; or vandalism.</td>
</tr>
</tbody>
</table>
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Retaining Wall Appraisals

### Dry laid, Stone masonry, Rockery:

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulging or Leaning</td>
<td>Distinct areas of deviation from the design alignment. May be caused by several factors including disruption to the internal drainage system and/or re-direction of surface drainage system, additional loads imposed on the wall, or soil failure at toe or backfill slope. Leaning walls may also be a result of the original installation. If the front part of the wall was constructed with tightly fitting joints, the consequence may be that the back face is extremely uneven (not providing for the maximum resistance to overturning). Pinnings (small wedges of stone) are typically used to address this situation. Pinnings may deteriorate more quickly than the wall stone if they are made by breaking up weak stone.</td>
</tr>
<tr>
<td>Dislocation or loose stones</td>
<td>Loss of internal interlock (friction) or failure of mortared joints. During construction, the backfill material near the wall backface may receive minimal compaction. With subsequent imposed loading and passage of time the fill will have settled, possibly inducing bulging of the wall. In sheltered sites walls are often damp, thereby encouraging the growth of vegetation. Roots can cause direct disturbance to the wall structure. Climbing plants can inhibit free water drainage and further encourage moisture build up within the walls.</td>
</tr>
<tr>
<td>Weathering, Fracturing, or Disintegration of stone, Cracked / Loss of Mortar</td>
<td>Poor selection of blocks during construction can result in high voids ratio and high contact stresses between adjacent blocks, leading to fracture and encouraging weathering. Stone in sheltered sites and/or covered in vegetation may remain damp throughout the year. Deterioration of stone by salt attack, both from road treatment and percolation from the backfill, may also attribute to wall deterioration.</td>
</tr>
</tbody>
</table>
Description: There are multiple subsets of a Fill Type Retaining Wall:

Prefabricated Wall System (PWS): A PWS is comprised of prefabricated face units, which may either be (1) a series of open face units assembled to form bins, which are connected in unbroken sequence or (2) a combination of solid face units with a characteristic alignment and connection method. Stability of the PWS is achieved by the weight of the wall system elements and the weight of the infill to resist lateral soil pressure.

Classification: Externally Stabilized Fill Structure
Generic Construction Detail:

Prefabricated Wall – Precast Concrete Unit

Prefabricated Wall – Drycast Concrete Unit
Concrete Crib Walls (aka Concrete Header & Stretcher Walls): A concrete crib wall is comprised of precast “logs” that are assembled like a mini log cabin. Stretchers run parallel with the wall face (forming the face of the retaining wall), while Headers run perpendicular to the wall face. The ends of the precast logs are overlapped to create hollow cells, which are then filled with granular material. Together, the backfill and the precast logs form a composite gravity wall.

Classification: Externally Stabilized Fill Structure
Generic Construction Detail:

**Precast Concrete Crib Wall**
Metal Bin Walls: Metal bin walls are a system of adjoining closed-faced bins, approximately 10 ft. wide, comprised of sturdy, lightweight steel members. The overlapping steel members are bolted together to form an integral structure. The closed bins are then backfilled with granular material. Together, the backfill and the closed-faced bins form a composite gravity wall.

Classification: Externally Stabilized Fill Structure
Generic Construction Detail:
Mechanically Stabilized Earth System (MSES): An MSES is comprised of natural select granular backfill (reinforced backfill), precast concrete panels (facing), subsurface drainage system, and high-strength, metallic or polymeric inclusions (reinforcement) to create a reinforced soil mass. The reinforcement is placed in horizontal layers between successive layers of granular soil backfill. Each layer of backfill consists of one or more compacted lifts. Each reinforcement is connected to the facing with a mechanical connection. Load is transferred from the backfill soil to the metallic or polymeric inclusion by shear along the interface and/or through the passive resistance on the transverse members of the inclusion. Stability of these systems is achieved by the weight of the reinforced soil mass resisting the overturning and sliding forces generated by the lateral stresses from the retained soil behind the reinforced mass.

**Classification:** Internally Stabilized Fill Structure
Generic Construction Detail:

Mechanically Stabilized Earth System (MSES) Wall
Mechanically Stabilized Wall System (MSWS): An MSWS are PWS which, when constructed beyond wall heights exceeding the maximum allowable unreinforced height, relies on reinforcing elements within the backfill to provide stability. The reinforcement is connected to the facing either with a mechanical or friction connection, depending on the system. Systems like these are similar in function and construction to a permanent GRSS system, however they utilize the PWS face units as a permanent facing.

Classification: Internally Stabilized Fill Structure
Generic Construction Detail:

Mechanically Stabilized Wall System (MSWS) Wall

Noteworthy Inspection Features:

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Horizontal or vertical deviation from the design alignment. May be caused by several factors including structural failure of the precast unit; soil failure at toe or backfill slope; horizontal sliding, or seepage.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Vertical movement of material behind the precast unit. May be caused by consolidation of the soil; loss of backfill; or wall movement.</td>
</tr>
<tr>
<td>Sinkhole (cavity) Formation</td>
<td>Loss of fill material behind the precast unit. Associated settlement may or may not occur, but the potential exists.</td>
</tr>
</tbody>
</table>
# CHAPTER 2
## Retaining Wall Appraisals

### Concrete Cracks:

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insignificant Cracks / (cracks &lt; 0.012 inches wide)</td>
<td>Map cracks are typically associated with AAR, Alkali-Aggregate Reaction. A chemical reaction takes place between the aggregate and potassium, sodium, or calcium hydroxide present in the cement. This causes an expansive gel which induces cracking</td>
</tr>
<tr>
<td>Map Cracks</td>
<td></td>
</tr>
<tr>
<td>Moderate Cracks (0.012 – 0.05 inches wide)</td>
<td>Structural cracks may be shear or flexural induced. Non-structural reasons include temperature (expansion/contraction), thermal gradient (solid/hollow section transition) and shrinkage (contraction at cure)</td>
</tr>
<tr>
<td>Wide Cracks (cracks &gt; 0.05 inches wide)</td>
<td></td>
</tr>
</tbody>
</table>

The inspector should use judgement when investigating concrete cracking. The inspector should consider width, spacing, location, orientation of the cracking and determine whether the cracking is structural or nonstructural in nature.

### Additional Concrete Distress:

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Spalling / Delamination</td>
<td>Delaminated or spalled concrete is when a piece of concrete detaches from the structure. Causes include improper handling during production / construction; inadequate joint material performance / closely spaced joints; impact of edges during handling; and/or expansion of corroding steel commonly caused by intrusion of chlorides or roadway deicers</td>
</tr>
</tbody>
</table>
| Staining                | • Efflorescence is a crystalline deposit, usually white, that may develop on the surfaces of masonry construction. This is usually a sign that moisture is slowly migrating through the wall. Generally, efflorescence is looked upon as cosmetic in nature; however, it may be a warning sign that there is a structural issue or that some form of preventive maintenance is needed.  
  • Rusty stains on the wall may be a sign of iron ochre infiltration. Iron ochre is common wherever there are high levels of iron in the soil. Just like efflorescence, iron ochre is carried through with the migrating moisture.  
  • Rusty stains on the wall may be a more detrimental indicator, where reinforcement corrosion is showing as rust staining through cracks and thus a loss in strength. |
| Exposed rebar           | When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination, and spalling. This condition usually is the result |
of a crack in the concrete that allows water to travel through and reach the rebar. The force of the expanding rebar causes more damage to the concrete around it, which creates greater access for water and more corrosion in this compounding cycle.

### Metal Bin Wall:

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion</td>
<td>Loss of steel member section due to interaction with environment. The rate of corrosion is dependent upon the oxygen concentration and moisture in contact with the metal bin wall elements.</td>
</tr>
<tr>
<td>Bulging or Leaning</td>
<td>Distinct areas of deviation from the design alignment. May be caused by several factors including disruption to the internal drainage system and/or re-direction of surface drainage system; additional loads imposed on the wall; or soil failure at toe or backfill slope.</td>
</tr>
</tbody>
</table>
□ Geosynthetically Reinforced Soil System (GRSS) Wall □

**Description**: A GRSS is comprised of natural select granular backfill (reinforced backfill), facing element (geocells, timbers, welded wire baskets), subsurface drainage system, and high-strength polymeric inclusions (reinforcement) to create a reinforced soil mass. The reinforcement is placed in horizontal layers between successive layers of granular soil backfill. Each layer of backfill consists of one or more compacted lifts. Each reinforcement is connected to the facing either with a mechanical or friction connection, depending on the facing. Load is transferred from the backfill soil to the polymeric inclusion by shear along the interface and/or through the passive resistance on the transverse members of the inclusion. Stability of these systems is achieved by the weight of the reinforced soil mass resisting the overturning and sliding forces generated by the lateral stresses from the retained soil behind the reinforced mass.

**Classification**: Internally Stabilized Fill Structure
CHAPTER 2
Retaining Wall Appraisals

Generic Construction Detail:

**Geocell Faced Geosynthetically Reinforced Soil System (GRSS) Wall**

**Timber Faced Geosynthetically Reinforced Soil System (GRSS) Wall**
### Noteworthy Inspection Features:

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Horizontal or vertical deviation from the design alignment. May be caused by several factors including rupture/ pullout failure; soil failure at toe or backfill slope; horizontal sliding, or seepage.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Vertical movement of material behind the GRSS reinforced mass. May be caused by consolidation of the soil or wall movement.</td>
</tr>
<tr>
<td>Sinkhole (cavity) Formation</td>
<td>Loss of fill material behind the GRSS reinforced mass. Associated settlement may or may not occur, but the potential exists.</td>
</tr>
<tr>
<td>Bulging or Leaning</td>
<td>Distinct areas of deviation from the design alignment. May be caused by several factors including deterioration of GRSS facing connection; disruption to the internal drainage system and/or re-direction of surface drainage system; additional loads imposed on the wall; or soil failure at toe or backfill slope.</td>
</tr>
</tbody>
</table>
Soil Nail Wall

**Description:** Soil nails are steel bars or tendons installed to reinforce or strengthen the existing ground. Soil nails are installed into a slope or excavation as construction proceeds from the existing ground surface to the proposed bottom of excavation. The soil nailing process creates a reinforced section that is itself stable and able to retain the ground behind it. Soil nail walls are typically covered by a temporary shotcrete finish which allows a variety of options for the final wall facing. Typically, final wall facing is either a permanent shotcrete finish or a concrete stem wall, which can then be faced with aesthetically pleasing elements.

**Classification:** Internally Stabilized Cut Structure
Generic Construction Detail:

Soil Nail Wall
### Noteworthy Inspection Features:

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Horizontal or vertical deviation from the design alignment. May be caused by several factors including soil failure at toe or backfill slope; horizontal sliding, or seepage.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Vertical movement of material behind the reinforced mass. May be caused by consolidation of the soil or wall movement.</td>
</tr>
<tr>
<td>Sinkhole (cavity) Formation</td>
<td>Loss of fill material behind the reinforced mass. Associated settlement may or may not occur, but the potential exists.</td>
</tr>
<tr>
<td>Bulging or Leaning</td>
<td>Distinct areas of deviation from the design alignment. May be caused by several factors including disruption to the internal drainage system and/or re-direction of surface drainage system; additional loads imposed on the wall; or soil failure at toe or backfill slope.</td>
</tr>
</tbody>
</table>

Typical wall facing is either a permanent shotcrete finish or a concrete stem wall (faced with any variation of aesthetically pleasing elements). Inspection features are material dependent.