CHAPTER 1

INTRODUCTION AND PURPOSE
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1.1 INTRODUCTION AND PURPOSE

The purpose of the New York State Department of Transportation’s (NYSDOT) Retaining Wall Inventory and Inspection Program is to provide a standardized program to inventory and inspect all retaining walls located on, or in proximity to, NYSDOT’s state highway system for use in the management of resources using a risk-based asset management approach.

The Retaining Wall Inventory and Inspection Program has been created to protect the safety and welfare of the public and public works by creating a comprehensive inventory, and continuing inspection of, retaining wall structures. The goal is to assess and report the condition of all wall assets throughout the State which could potentially impact NYSDOT-owned roadway or Right-of-Way (ROW). Reporting wall condition state and defects helps manage the wall assets, identify risk, and project where funding and maintenance need to be focused in an effort to increase the longevity of wall life by providing guidance on the asset management in accordance to MAP-21 requirements.

The Retaining Wall Inventory and Inspection Program will establish an inventory of retaining wall assets and the inspection program will:

- Establish a chronological record of periodic (and special) inspections, listing wall structure elements, and element condition at the time of each inspection, thus allowing detection of progressive changes.
- Determine the extent of any deficiency, critical or minor, resulting from deterioration, or any other cause.
- Enable maintenance, repair, and rehabilitation to be programmed more effectively through early detection of wall structure deficiencies by which the public investment in the highway system will be safeguarded and repair costs minimized.
- Collect data on frequently occurring deficiencies to support a change in design and/or construction practices to eliminate the cause of the deficiency.
- Collect, record, and store retaining wall inventory and inspection data to achieve State DOT targets for asset condition and system performance effectiveness.

1.1.1 Transformed Federal Policy

The Moving Ahead for Progress in the 21st Century Act (MAP-21) legislation (July 6, 2012) brought transformative changes to the Federal-aid highway program with its performance management and asset management requirements. MAP-21:

- adopted a requirement for States to develop and implement risk-based asset management plans for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system,
- requires FHWA to establish minimum standards for States to use in developing and operating bridge and pavement management systems, and
- mandates periodic evaluations to determine if reasonable alternatives exist to roads, highways, or bridges that repeatedly require repair and reconstruction activities.
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MAP-21 requires State DOT’s to develop and implement an asset management plan to include, at a minimum, NHS pavement and bridge assets. Furthermore, it encourages that State DOT’s to include all other NHS infrastructure assets within the ROW corridor and assets on other public roads. Noted examples of other NHS infrastructure assets include tunnels, ancillary structures, and signs. Within the Discussion of Comments section regarding the FHWA’s response to the Notice of Proposed Rule Making, it notes that AASHTO has defined “ancillary structures” as “lower-cost, higher-quantity assets that also play an important role in the overall success of transportation systems: Assets such as traffic signs, traffic signals, roadway lighting, guide rails, culverts (20 ft. or less), pavement markings, sidewalks and curbs, utilities and manholes, earth retaining structures and environmental mitigation features”.

1.2 Asset Management

The following terms are defined in the MAP-21 legislation:

**Asset:** all physical highway infrastructure located within the ROW corridor of a highway. The term asset includes all components necessary for the operation of a highway including pavements, highway bridges, tunnels, signs, ancillary structures, and other physical components of a highway.

**Asset Class:** assets with the same characteristics and function (e.g., bridges, culverts, tunnels, pavements, or guide rail) that are a subset of a group or collection of assets that serve a common function (e.g., roadway system, safety, Intelligent Transportation (IT), signs, or lighting).

**Asset Condition:** the actual physical condition of an asset.

**Asset Management:** a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost.

**Asset Management Plan:** a document that describes how a State DOT will carry out asset management. This includes how the State DOT will make risk-based decisions from a long-term assessment of the NHS, and other public roads included in the plan at the option of the State DOT, as it relates to managing its physical assets and laying out a set of investment strategies to address the condition and system performance gaps. The asset management plan describes how the highway network system will be managed to achieve State DOT targets for asset condition and system performance effectiveness while managing the risks, in a financially responsible manner, at a minimum practicable cost over the life cycle of its assets.

Currently, the NYSDOT has implemented a deliberate and strategic approach to manage both bridge and pavement assets in an efficient and cost-effective manner, where system safety is a central tenet of the approach. The asset management efforts to preserve, maintain, operate, and
enhance the safety and condition of the transportation system utilize sound engineering based asset management principles and practices. Within the framework of this approach pertaining to bridges, the NYSDOT has implemented a Comprehensive Asset Management program. The program has identified short-term objectives by establishing a hierarchy of priorities: (1) Demand Response; (2) Preventive and Corrective Maintenance; (3) Enhance Safety; (4) System Renewal; and (5) Strategic Enhancement. Demand Response activities address, in an expedited time frame, repair of the condition of critical elements discovered during scheduled bridge inspections.

The *Retaining Wall Inventory and Inspection Program* is a direct effort to address an ancillary structure (earth retaining structures) which, when managed as an asset, the need for emergency stabilization of a failure is significantly reduced whereby the NYSDOT can benefit from a more efficient use of resources and long-term cost savings.

### 1.2.1 Enterprise Asset Management Program (EAMP)

NYSDOT’s Transportation Asset Management Plan (TAMP) provides an outline of its asset management practices and establishes a blueprint that includes considerations of: risk, life cycle management, performance management, service levels, strategic alignment, and customer outreach.

NYSDOT is integrating risk management into the asset management process via the evolving Enterprise Asset Management System. Enterprise asset management is the lifecycle management of the physical assets of an organization. To support the endeavor, in January, 2012 the NYSDOT contracted with AgileAssets Inc. to implement the AgileAssets® Bridge Inspector™ software system. In addition to supporting the primary asset structures (Figure 1), AgileAssets can support all future asset classes comprising the NYSDOT Enterprise Asset Management Program (EAMP).

![Figure 1.1 Structure Assets](image-url)
With the continuing evolution of the EAMP, it is envisioned that the NYSDOT will be able to capture and report on the condition of additional structural assets, such as Retaining Walls (a secondary asset structure).

1.3 Risk Management

The following terms are defined in the MAP-21 legislation:

**Risk:** the positive or negative effects of uncertainty or variability upon agency objectives.

**Risk Management:** the processes and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance.

MAP-21 requires a State DOT to establish a process for developing a risk management plan. This process shall, at a minimum, produce the following information:

- Identification of risks that can affect condition of NHS pavements and bridges and the performance of the NHS, including risks associated with current and future environmental conditions, such as extreme weather events, climate change, seismic activity, and risks related to recurring damage and costs as identified through the evaluation of facilities repeatedly damaged by emergency events. Examples of other risk categories include financial risks such as budget uncertainty; operational risks such as asset failure; and strategic risks such as environmental compliance.
- An assessment of the identified risks in terms of the likelihood of their occurrence and their impact and consequence if they do occur;
- An evaluation and prioritization of the identified risks;
- A mitigation plan for addressing the top priority risks;
- An approach for monitoring the top priority risks; and
- A summary of the evaluations of facilities repeatedly damaged by emergency events that discusses, at a minimum, the results relating to the State's NHS pavements and bridges.

1.4 Retaining Wall Classifications

The classification of retaining wall systems is based on the basic geotechnical mechanism used to resist lateral loads and the construction method used for the installation of the wall. The following are definitions used to classify retaining wall systems:

**Externally Stabilized Structures:** rely on the integrity of wall elements (with or without braces, struts, walers and/or tiebacks or anchors) to both resist lateral loads and also prevent raveling or erosion of the retained soil.

**Internally Stabilized Structures:** rely on friction developed between closely-spaced reinforcing elements and the backfill to resist lateral soil pressure. A separate, non-structural element (facing, erosion control mat and/or vegetation) is attached to prevent raveling or erosion of the retained soil.
**Cut Type Retaining Walls:** retaining structures constructed from the top of the wall to the base (i.e. “top-down” construction).

**Fill Type Retaining Walls:** retaining structures constructed from the base of the wall to the top (i.e. “bottom-up” construction).

The following table provides a Retaining Wall Classification System:
<table>
<thead>
<tr>
<th>Wall Class</th>
<th>Wall Type</th>
<th>Construction Type</th>
<th>Wall Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Externally Stabilized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut Structures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sheeting</td>
<td>Cut Wall</td>
<td>Cantilever</td>
</tr>
<tr>
<td></td>
<td>Soldier Pile &amp; Lagging</td>
<td>Cut Wall</td>
<td>Cantilever</td>
</tr>
<tr>
<td></td>
<td>Anchored Walls (Sheeting or Soldier</td>
<td>Cut Wall</td>
<td>Deadman Anchors</td>
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<td></td>
<td>Pile &amp; Lagging Walls)</td>
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<td>Grouted Tiebacks</td>
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<td></td>
<td>Braced Walls</td>
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<tr>
<td>Externally Stabilized</td>
<td></td>
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<tr>
<td>Fill Structures</td>
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</tr>
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<td></td>
<td>Cantilever Wall</td>
<td>Primarily Fill Wall. May be installed as a Cut wall.</td>
<td>Precast Cantilever Wall</td>
</tr>
<tr>
<td></td>
<td>Gravity Wall</td>
<td>Primarily Fill Wall. May be installed as a Cut wall.</td>
<td>CIP Cantilever Wall</td>
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<td>Gabion</td>
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<td></td>
<td>Fill Type Retaining Wall</td>
<td>Fill Wall</td>
<td>Mechanically Stabilized Earth System (MSES)</td>
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<td>Mechanically Stabilized Wall System (MSWS)</td>
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<tr>
<td>Geosynthetically Reinforced Soil</td>
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<td>Fill Wall</td>
<td>Reinforced Soil System</td>
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<td>System (GRSS)</td>
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<tr>
<td>Cut Structures</td>
<td>Soil Nail Wall System</td>
<td>Cut Wall</td>
<td>Reinforced Soil System</td>
</tr>
</tbody>
</table>

**Table 1.1 Retaining Wall Classification System**

The following figures provide some typical examples of retaining wall systems categorized by wall groups:
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Figure 1.2 Mass Gravity / Semi-Gravity Retaining Walls
(modified, WisDOT)

Figure 1.3 Mechanically Stabilized Earth System / Mechanically Stabilized Wall System Retaining Walls
(modified, WisDOT)
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Figure 1.4 Prefabricated Wall System Retaining Walls (modified, WisDOT)

Figure 1.5 Reinforced Soil System (modified, WisDOT)

Figure 1.6 Cantilevered Flexible Retaining Walls (modified, WisDOT)
1.5 Retaining Wall Failure Modes and Failure Causes

The standard job of a forensic engineer is to investigate the damage, deterioration, or collapse of a structure, determine the cause of the problem, and in many cases, develop repair recommendations (Day, R.W., 2011). This too is true for forensic investigations of failed geotechnical works. A retaining wall collapse can jeopardize the safety and welfare of the traveling public and have a major impact to the transportation systems operation. Therefore, any failure needs to be investigated to determine what happened and why in order to:

- develop repair recommendations,
- address design-flaw issues,
- terminate improper construction techniques, and/or
- assure the stability of other similar assets in comparable circumstances.

There are a series of steps that lead to the failure of an engineered device (Daley, D.T.). The steps are:

- **Cause**
  - Lack of protection against a Failure Mechanism (or lack of prevention)
  - Failure Mechanism at work
  - Measurable Deterioration
  - Defect – Potential For Failure (deterioration to the point the device is unable to handle the intended load)
- **Failure Mode**
- **Failure**

By understanding failure modes and failure causes, the retaining wall inspection process can interrupt the steps leading to failure. As the retaining wall inspection process identifies measurable deterioration, or a defect(s), failure modes may be reviewed as possible consequences to the deterioration while failure causes may be reviewed to formulate potential corrective maintenance. Both maintenance and inspection are vital to ensuring the longevity and performance of retaining walls.
1.5.1 Failure Modes

A failure mode is a failure mechanism relating to external stability, internal stability, movement and overall stability. Most failure mechanisms are physical degradation of components due to destructive forces or simply age related. However, as noted above, a failure mechanism can be inherent in the design or accidently or unknowingly imposed during the construction of the wall system.

The following figures give some examples of common geotechnical failure modes, with a brief description following:

![Figure 1.8 Sliding (WisDOT)](image)

**Sliding** – Sliding of the wall away from the backfill when there is shearing failure at the base.

![Figure 1.9 Overturning (WisDOT)](image)

**Overturning** - Rotation of the wall about its toe due to the exceeding of the overturning moment in relation to the resisting moment.
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**Figure 1.10 Crushing**

*Crushing* - is possible under high overturning loads.

**Figure 1.11 Bearing**

*Bearing* – Pressure exerted by resultant vertical force at the toe must not exceed the allowable bearing capacity of the soil.

**Figure 1.12 Global**

*Global* – Excessive shear stressed along a critical cylindrical failure surface.
- Shallow Shear Failure: This type of failure occurs along a cylindrical surface passing through the heel of the retaining wall.
- Deep shear failure: This type of shear failure occurs along a cylindrical surface, when there is a weak layer of soil underneath the wall a depth of about 1.5 times the height of the wall.
**Rupture (Tension)** - Reinforcement failure occurs when the tensile forces in the reinforcement cause excess elongation or rupture, which would lead to large movements and possible collapse of the structure.

**Pullout** – Reinforcement pullout occurs when tensile forces in the reinforcements become larger than the pullout resistance (the force required to pull the reinforcement out of the soil mass).

**Structural** – Failure of the wall itself, i.e. development of a plastic hinge in the wall (or failure of the anchor or strut).
Soil – Two mechanisms
- Deep-Seated Circular Failure – wall penetration too short.
- Wedge-Shaped Failure zone behind the wall, combined with a rotational failure in the subsoil – Top bends over.

1.5.2 Failure Causes

A failure cause (i.e. reason for failure) is something without which the failure would not happen. A cause can be a distinct activity or a decision that resulted in an act detrimental to the wall system. An example of a distinct activity would be improper reinforcement placement within a reinforced fill of a mechanically stabilized earth system (MSES) wall. The incorrect placement would be the cause of the failure. An example of a decision that resulted in an act detrimental to the wall system would be the use of a backfill material specification for an MSES wall that does not address corrosion potential for metallic reinforcements. The cause of the failure would be the designer’s decision, not the contractor who supplied and placed the material for a wall system that included metallic reinforcements. However, if the designer’s specification distinguished between metallic and non-metallic reinforcement situations and provided additional requirements to address corrosion potential within the metallic scenario, the designer’s plan would not be the cause of the failure.

The principal causes of in-service retaining wall failures may be categorized into the following groupings:

Design Related Failures – where the retaining wall fails to function as designed. Examples of design related failures include a total lack of design, the use of broad assumptions, misinterpretation of test results, unintended need for special construction considerations without specifying such, or omitting specifications or requirements to address specific needs of the completed design.
Construction Related Failures – where the retaining wall fails to function due to construction defects. Examples of construction related failures include grade elevation discrepancies, improper reinforcement placement, use of substandard material, fabrication issues, or surcharging the adjacent area with a temporary fill not accounted for in design.

Destructive Force Related Failures – where the retaining wall fails to function due to a destructive force. Examples of destructive force related failures include flood water, rockfall impact, scour, pore water pressure buildup in the retained soil mass, chain reaction to a failed linked structure, or vandalism.

Age Related Failures – where the retaining wall fails due to age (i.e. the retaining wall has surpassed its service life and no longer provides the desired level of performance).
1.6 REFERENCES


