Contents

Introduction

Retaining structures are essential elements of every highway design. Retaining structures are used not only for bridge abutments and wing walls but also for slope stabilization and to minimize right-of-way for embankments. For many years, retaining structures were almost exclusively made of reinforced concrete and were designed as gravity or cantilever walls which are essentially rigid structures and cannot accommodate significant differential settlements unless founded on deep foundations. With increasing height of soil to be retained and poor subsoil conditions, the cost of reinforced concrete retaining walls increases rapidly.

Mechanically Stabilized Earth Walls (MSEW) and Reinforced Soil Slopes (RSS) are cost-effective soil-retaining structures that can tolerate much larger settlements than reinforced concrete walls. By placing tensile reinforcing elements (inclusions) in the soil, the strength of the soil can be improved significantly such that the vertical face of the soil/reinforcement system is essentially self-supporting. Use of a facing system to prevent soil raveling between the reinforcing elements allows very steep slopes and vertical walls to be constructed safely. In some cases, the inclusions can also withstand bending from shear stresses, providing additional stability to the system.

Inclusions have been used since prehistoric times to improve soil. The use of straw to improve the quality of adobe bricks dates back to earliest human history. Many primitive people used sticks and branches to reinforce mud dwellings. During the 17th and 18th centuries, French settlers along the Bay of Fundy in Canada used sticks to reinforce mud dikes. Some other early examples of manmade soil reinforcement include dikes of earth and tree branches, which have been used in China for at least 1,000 years and along the Mississippi River in the 1880s. Other examples include wooden pegs used for erosion and landslide control in England, and bamboo or wire mesh, used universally for revetment erosion control. Soil reinforcing can also be achieved by using plant roots.

The modern methods of soil reinforcement for retaining wall construction were pioneered by the French architect and engineer Henri Vidal in the early 1960s. His research led to the invention and development of Reinforced Earth®, a system in which steel strip reinforcement is used. The first wall to use this technology in the United States was built in 1972 on California State Highway 39, northeast of Los Angeles. In the last 25 years, more than 23,000 Reinforced Earth structures representing over 70 million m^2 (750 million ft^2) of wall facing have been completed in 37 countries. More than 8,000 walls have been built in the United States since 1972. The highest wall constructed in the United States was on the order of 30 meters (98 feet).

In this assignment we study MSE walls. We will see different types of MSE walls, comparing them to other types of retaining walls (Segmental and geotextile walls) and providing an example of designing an MSE wall.

1. MSE walls: Main concept

Mechanically stabilized earth (MSE) wall systems are essential elements of many highway designs, and they represent the retention system of choice more frequently than in the past. For many years, retaining structures were almost exclusively cast-in-place (CIP) concrete structures that cannot accommodate significant differential settlement, specifically with tall walls and poor subgrade conditions.

MSE wall systems are generally used for slope stabilization and to minimize right-of way embankment requirements, and are also used for bridge abutments and wing walls on a more limited basis. A typical MSE wall section is depicted in **Figure 1.1**.

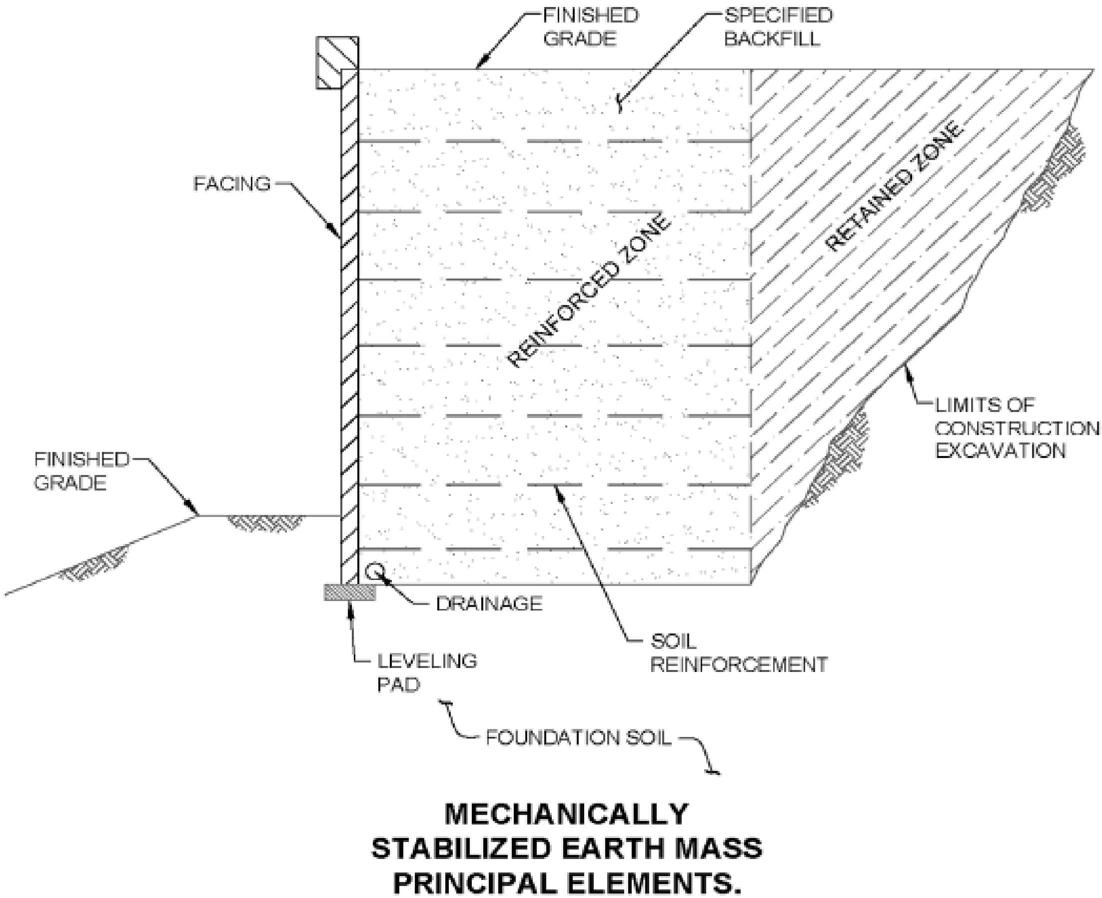

Fig. 1.1 : Typical MSE wall section
(source : MSE Wall Engineering – A New Look at Contracting, Design, and Construction)

MSE wall systems are cost-effective earth-retaining structures that can tolerate larger settlements than conventional retaining wall systems, such as CIP walls. By placing tensile reinforcing elements (inclusions) in the soil, the strength of the soil can be improved significantly such that the near-vertical face of the soil/reinforcement system is self-supporting. Use of a facing system (such as modular blocks or concrete panels) to prevent soil raveling between the reinforcing elements allows near-vertical walls to be constructed safely.

The construction sequence is typically as follows:

- First, the site is cut to grade and all unsuitable material is removed.

- The site is proof rolled to delineate any loose and/or unsuitable materials. Compacting any loose material and remove and replacing any unsuitable material found. The proof rolling is accomplished by at least 5 passes of a vibratory roller.

- The leveling pad excavation is dug (see **Figure 1.2**).

Fig. 1.2 : Preparing site, Proof roll and excavate Footing
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- The leveling pad is placed (see **Figure 1.3**). The concrete is allowed to cure a minimum of 12 hours before any panels are placed.

Fig. 1.3 : Place concrete leveling pad
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- The first row of panels are placed on the leveling pad and braced (see **Figure 1.4**). If ½ panels are used they are placed at the correct spacing using a spacing guide; then the second row is set and braced. The panels should be set with a backward batter, typically +1/8 inch per foot. This may allow the panel to be vertical once fill is placed against it. The batter is adjusted for the site conditions e.g. backfill properties, the finer sand may require a larger batter.

Fig. 1.4 : Install and brace 1st row of pannels
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- An adhesive is used to hold the filter fabric across all of the panel joints. The adhesive should be applied on the panel next to the joints then the filter fabric is placed over the joint (see **Figure 1.5**), because applying adhesive on the filter fabric tends to clog the filter fabric.

Fig. 1.5 : Attach filter fabric
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- The select backfill is then placed and compacted to the level of the first row of connections. The compacted fill should be at or slightly higher than the panel connections (see **Figure 1.6**). On the initial row of panels (and only the initial row of panels) the backfill is not placed against the panel until the first row of reinforcement have been connected and the initial 6 inch layer of compacted fill is placed on the reinforcement. This is to keep the bottom of the panels from "kicking out". From that point, the backfill is brought up uniformly from the back of the panels to the end of the reinforcement.

Fig. 1.6 : Fill in 6" lifts to reinforcement
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- The reinforcement is then placed typically perpendicular to the wall panel and the connection (see **Figure 1.7**). Any slack in the reinforcement should be removed to avoid excessive panel movement. With polymer reinforcement some tension should be applied to the reinforcement by means of a kicker tension device or a rod.

Fig. 1.7 : Connect and tighten Reinforcement
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- Then another row of wall panels is placed with the proper batter.

- The select backfill is then placed (see **Figure 1.8**) in 6 inch compacted lifts until the fill is at or slightly above the next set of connections. Any additional water needed for compaction must meet the specification requirements. The backfill is placed parallel to the wall starting approximately three (3) feet from the back of the panels. The fill is then windrowed toward the reinforcement ends. Once this is complete, the fill is windrowed from the three (3) foot point back toward the panels.

Fig. 1.8 : Continuation of a fill placement
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- The compaction equipment rolls parallel to the wall facing. Compaction starts at least three (3) feet from the wall and works toward the end of the reinforcement.

- Compacting the remaining three (3) feet next to the wall face then completes the compaction**.** This compaction is accomplished with compaction equipment of 1,000 lbs. or less.

- Remove wooden wedges as soon as the precast component above the wedged precast component is completely erected and backfilled (see **Figure 1.9**). In no case should there be more than three rows of wooden wedges in place. Failure to remove the wooden wedges can cause the panels to crack or spall.

Fig. 1.9 : Wooden wedges
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

- Repeat steps 8, 9, 10, 11 and 12 until the top of the wall is reached. As soon as practical the front of the wall should be backfilled. This should occur prior to reaching the top of the wall (see **Figure 1.10**).
- The coping is then placed on the top of the wall. The wall is completed when the coping is properly installed on top of the wall.

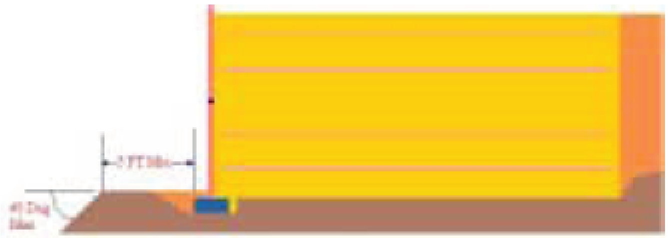

Fig. 1.10 : Place backfills in front of the wall as soon as practical and excavation next to it
(source : MSE Wall Inspector's Handbook, Paul D. Passe 2000)

2. MSE Walls: Types

The three types of MSE walls, according to TenCate Mirafi, include:

- Segmental Retaining walls
- Wrapped faced Geotextile-Reinforced walls
- Temporary Retaining walls

2.1. Segmental walls

Fig. 2.1: *Photos courtesy of StoneWall Select from ICD Corp.*
(source : http://www.concretenetwork.com/concrete/segmental_retaining/)

Segmental retaining walls consist of modular concrete blocks that interlock with each other. They are used to hold back a sloping face of soil to provide a solid, vertical front. Without adequate retention, slopes can cave, slump or slide. With the unique construction of segmental retaining walls, higher and steeper walls can be constructed with the ability to retain the force of lateral earth pressure created by the backfill soil.

Segmental retaining walls can be installed in a wide variety of colors, sizes, and textures. They can incorporate straight or curved lines, steps, and corners. They are ideal for not only slope support, but also for widening areas that would otherwise be unusable due to the natural slope of the land. Retaining walls are often used for grade changes, and for other functional reasons such as widening driveways, walkways, or creating more space in a patio outdoor area.

Segmental retaining walls are modular block retaining walls used for vertical grade change applications. The walls are designed and constructed as either gravity retaining walls (conventional) or reinforced soil retaining walls. The system consists of dry-cast concrete units that are placed without mortar (dry stacked) and rely on their unit to unit interface and mass to resist overturning and sliding. Unit to unit interfaces include friction, shear elements, and interlock. The systems may also employ soil reinforcement that extends into the backfill and allows for the construction of walls with significant height (e.g. in excess of 50 ft (15.24 m)) that could not be accomplished with the units alone (**figure 2.2**).

Segmental retaining walls are considered flexible structures, so the footing does not need to be placed below the frost line, provided there is sufficient foundation bearing capacity. SRW units are manufactured in conformance with industry standards and specifications to assure that units delivered to a project are uniform in weight, dimensional tolerances, and strength, and durability features not necessarily provided in site cast materials.

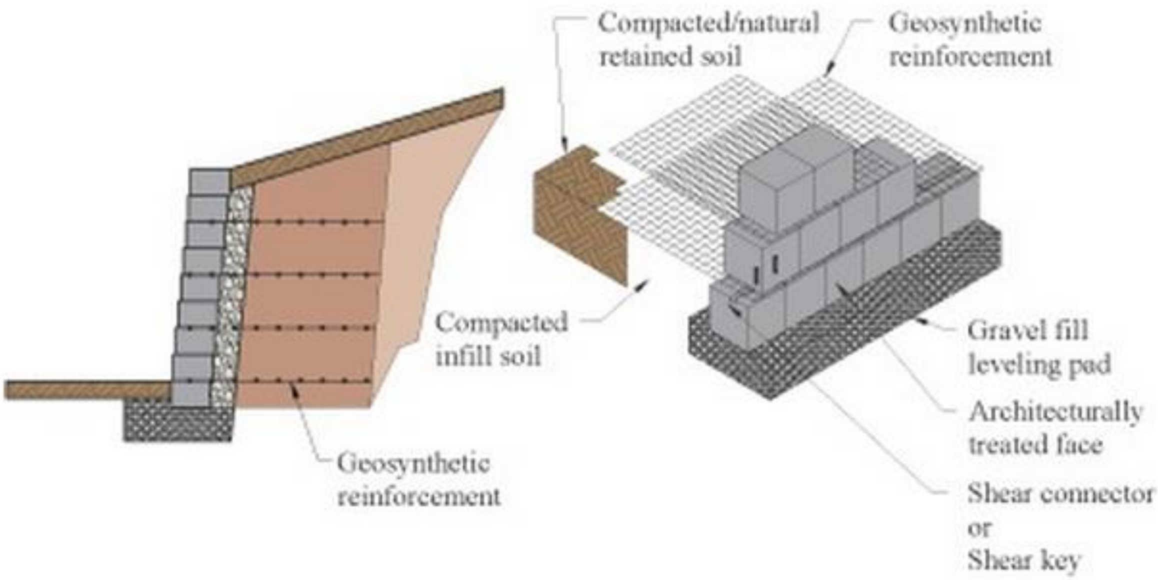

Fig. 2.2: *Components of a Segmental Retaining wall*
(source : http://ncma.org/hardscapes/srw/*)*

2.2. Wrapped faced Geotextile-Reinforced walls

Geotextile-reinforced walls with wrapped-face were first constructed in Siskiyou National Forest in Oregon in 1974 and Olympic National Forest in Shelton, Washington in 1975 by the US Forest Service. The excellent performance and low cost of these two walls provide impetus for many wrapped-faced geotextile-reinforced walls to be constructed in the US and many countries around the world.

The typical configuration of the USFS wrapped-faced geotextile-reinforced wall is shown in **Figure 2.3**. The wall facing is constructed by wrapping each geotextile sheet around its overlying layer of backfill and then re-embedding the free end into the backfill. The wrapped geotextile wall facing retains the soil immediately behind the wall face; and the embedded portion of the geotextile restrains lateral deformation of the backfill by soil geotextile friction. The geotextile face is usually covered with gunite (shotcrete) or asphalt emulsion to prevent the geotextile's weakening due to UV exposure and possible vandalism. **Figure 2.4** shows a completed wrapped-faced wall.

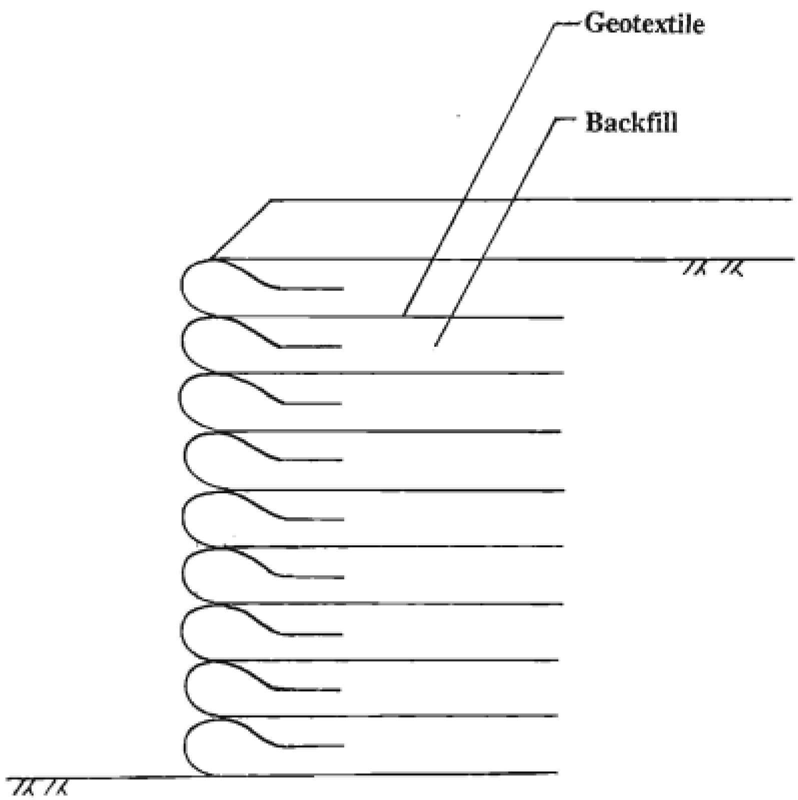

Fig. 2.3: *Typical Configuration of a Wrapped-Faced Geotextile-Reinforced wall*
(source : https://www.codot.gov/programs/research/pdfs/1994-research-reports/retainingwalls*)*

.

Fig. 2.4: *A completed Wrapped-Faced GRS wall (courtesy Washington Department of Transportation)*
(source : https://www.codot.gov/programs/research/pdfs/1994-research-reports/retainingwalls*)*

For the wrapped-faced geotextile-reinforced walls that have been constructed to date, the backfill typically consists of granular fill ranging from silty sand to coarse gravel. Compacted cohesive backfill has also been used in numerous walls. A wide variety of geotextiles with a wide range of mechanical properties and environmental resistances have been used, including nonwoven, needle-punched or heat-bonded polyester and polypropylene, and woven polypropylene and polyester. The wrapped-faced geotextile reinforced walls have in the past been constructed in remote areas or were used for temporary purposes; however, they are now being used for permanent urban installations, as well (Mitchell and Villet, 1987). The wrapped-faced geotextile-reinforced walls generally range in height from 3 to 20 ft. A 40-ft high temporary vertical wall has been constructed in Seattle, Washington, and a sloping wall with a height of 66 ft has been constructed in Allemand, France.

2.3. Temporary Retaining walls

MSE Structures are often employed to provide temporary support of roadways and bridges. Temporary MSE walls are economical and they are often simply “buried” within the permanent construction as the project progresses. In common with permanent MSE walls, temporary walls are simple and rapid to construct using semi-skilled site labor. And their ability to carry heavy loads with minimal distortion makes them ideal abutments for temporary bridges and to provide support for elevated temporary roads.

EarthTec Wire Walls incorporate free standing welded wire baskets with a mechanical connection to either geosynthetic straps or steel strips depending on which form of soil reinforcement is more appropriate for the customer's specific application. Wire Walls incorporate the largest basket size and strip spacing in the industry, making our wire wall systems the fastest, easiest and most economical to install.

3. MSE walls failure

Internal failure of the MSE component is addressed with appropriate backfill materials, suitable vertical spacing of reinforcement, and adequate reinforcement strength and lengths.

Internal stability design of the MSE component of an SMSE wall system should address the following potential internal failure mechanisms:

- Soil reinforcement rupture (elongation or breakage of the reinforcements).
- Soil reinforcement pullout.

Fig. 2.4: *A failure of an MSE wall in Crossgate Shopping Center Nashville, TN (source : http://www.marshall.edu/cegas/geohazards/2012pdf/presentations/S7/1_Geohazards-%20Emergency%20Response-%20Beard%20SNLI)*

4. Project

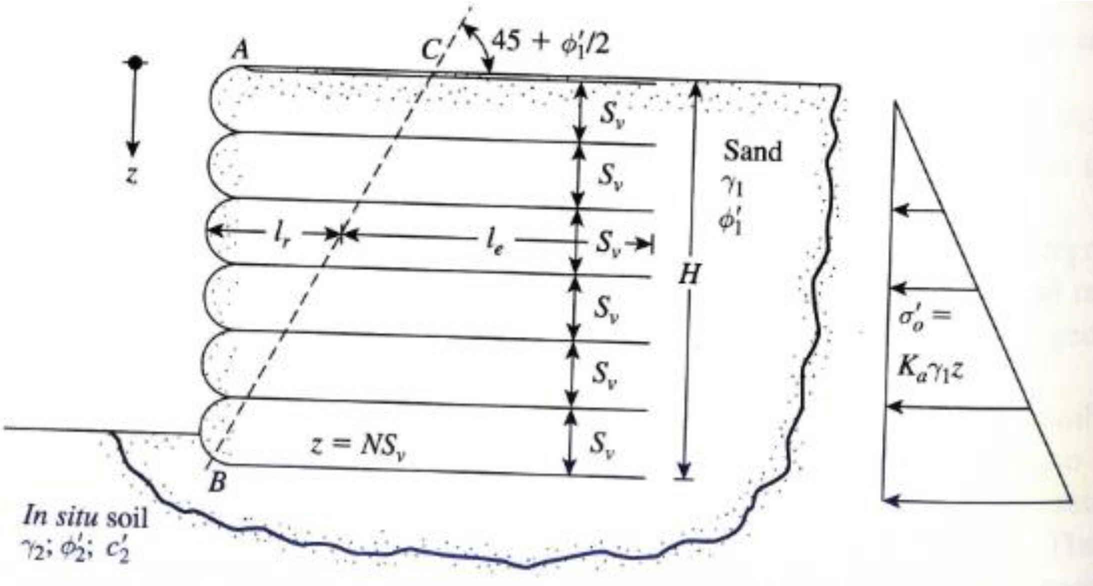

Fig. 4.1: *Analysis of an MSE wall*

H = 35 ft ; Υ_1 = 110 lb/ft^3 ; ϕ_1 = 30° ; $FS_{(B)}$ = 3 ; $FS_{(P)}$ = 3 ; f_y = 29.000 psi ; ϕ_{tie} = 20° ; Υ_2 = 120 lb/ft^3 ; ϕ_2 = 30° ; c = 150 lb/ft^3 ; w = 4' = 1/3 '' ; $S_H = S_V$ = 5''

- Tie thickness :

$$t = \frac{FS_B.\sigma_{h\,max}.S_H.S_V}{w.f_y}$$

$$with\ \sigma_{h\,max} = \gamma_1.H.K_a = \gamma_1.H.tan^2(45 - \frac{\varphi_1}{2})$$

So a tie thickness of ***t = 0.71 in*** would be enough.

- Tie length :

$$L = \frac{H - z}{tan^2(45 + \frac{\varphi_1}{2})} + \frac{FS_P.S_H.S_V.K_a.\gamma_1.z}{2.w.\gamma_1.z.tan(\varphi_{tie})}$$

z(ft)	**Tie length L(ft)**
2.5	113.00
7.5	110.53
12.5	108.86
17.5	107.19
22.5	105.53
27.5	103.86

So we will use tie length of ***L = 113 ft***

References:

Peter L. Anderson, P.E. M.ASCE, Robert A. Gladstone, P.E., M.ASCE, John E. Sankey, P.E., M.ASCE (2002): "*State of the Practice of MSE Wall Design for Highway Structures*".

NHI – National Highway Institute Office of Bridge Technology (2001): "*Mechanically Stabilized Earth Walls and Reinforced Soil Slopes: Design & Construction Guidelines*"

Tencate Mirafi: "*MSE Mechanically Stabilized Earth Systems – Permanent and Temporary MSE Walls Reinforced Soil Slopes Embankments*".

Paul D. Passe, P.E., CPM State Geotechnical Engineer (2000): "*Mechanically Stabilized Earth Wall Inspector's Handbook*".

James M. Schmidt, P.E., P.Eng. Daniel L. Harpstead, P.E.: "*MSE Wall Engineering – A New Look at Contracting, Design, and Construction*".