Advanced Foundation Engineering
UMASS Lowell – Course No. 14.533
Final Project

Mechanically Stabilized Earth Walls For Support of Highway Bridges

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Project Abstract

Use of Mechanically Stabilized Earth (MSE) walls to support bridges is a more economical solution than cast-in-place structures. The use of MSE walls for direct support (Abutment resting on a spread footing atop the MSE structure) and indirect support (Abutment on piles with the MSE structure supporting the fill) of bridge structures is well documented. The Reinforced Earth Company pioneered the design of MSE bridge abutment structures in the 1970's for both single span bridges with relatively light loads to heavy loaded industrial and rail structures with loads on the order of 1000 kN/m. Research utilizing finite element analysis, scale models and instrumented full scale structures has shown that the loads imparted from the spread footing can be included in the design of the wall by superposition and basic principles of soil mechanics. Pile Supported Abutments are designed as a simple MSE retaining wall, with the vertical loads from the bridge being imparted to the piles. Horizontal bridge loads may be resisted by additional earth reinforcement added to the pile cap. Integral bridge abutments may impart additional horizontal loads that must be compensated for in the internal stability design of the MSE structure. Nearly thirty years of experience in the implementation of MSE walls and abutments successfully demonstrates the applicability and performance of this technology.

In early 1960's, Henri Vidal, a French architect and engineer, published a thesis titled "Terre Armee" (Reinforced Earth) ushering the now worldwide use of Mechanically Stabilized Earth (MSE) structures. Mechanically Stabilized Earth structures take many forms: retaining walls, bridge abutments, sea walls, industrial truck tipping facilities, storage silos and slots as well as reinforced soil slopes and reinforced soil foundations. The most common MSE structure is the retaining wall. The second most common is the subject of this paper, the bridge abutment.

Basic Mechanism of Mechanically Stabilized Earth

The behavior of reinforced soil is analogous to reinforced concrete. Soil, like concrete, is weak in tension. The addition of reinforcing strips or mats in the horizontal direction compensates for the weak tensile strength of soil.

"As shown in Figure 1a, an axial load on a sample of granular material will result in a lateral expansion. Because of dilation, the lateral strain is more than one-half the axial

strain. However, if inextensible horizontal reinforcing elements are placed within the soil mass, as shown in figure 1b, these reinforcements will prevent lateral strain because of friction between the reinforcing elements and the soil, and the behavior will be as if a lateral restraining force or load had been imposed on the element." [1]

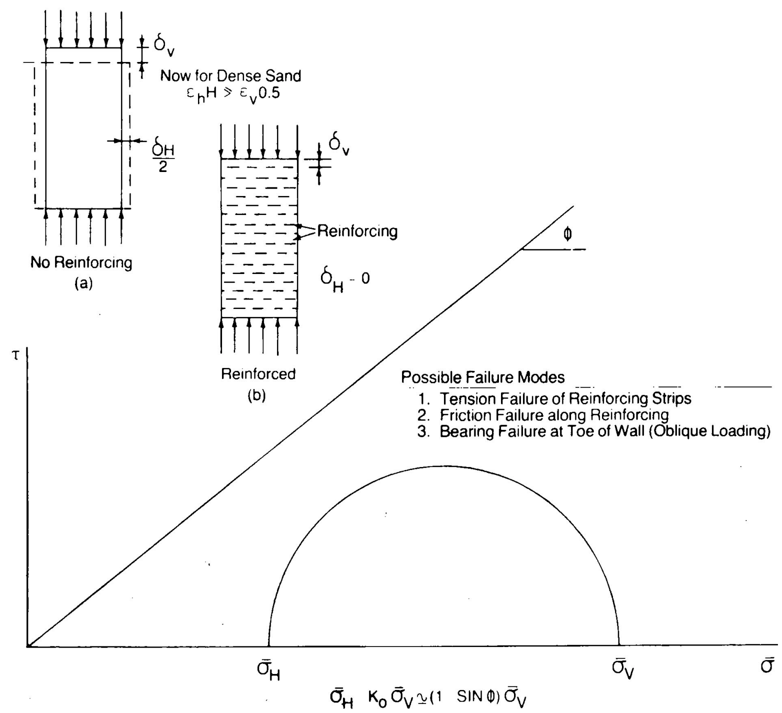


FIGURE 1 MECHANISM OF REINFORCED EARTH

Components of a MSE wall

MSE walls are composed of three major elements: soil, reinforcing elements and facing. The structural strength of a Mechanically Stabilized Earth structure is a direct result of two of these components, the soil and reinforcing elements. Mechanically Stabilized Earth is a composite material, which combines the high compressive strength of compacted select granular fill with the high tensile strength of galvanized steel earth reinforcements. To sum up, the soil reinforcement increases the overall shear strength of the reinforced soil mass.

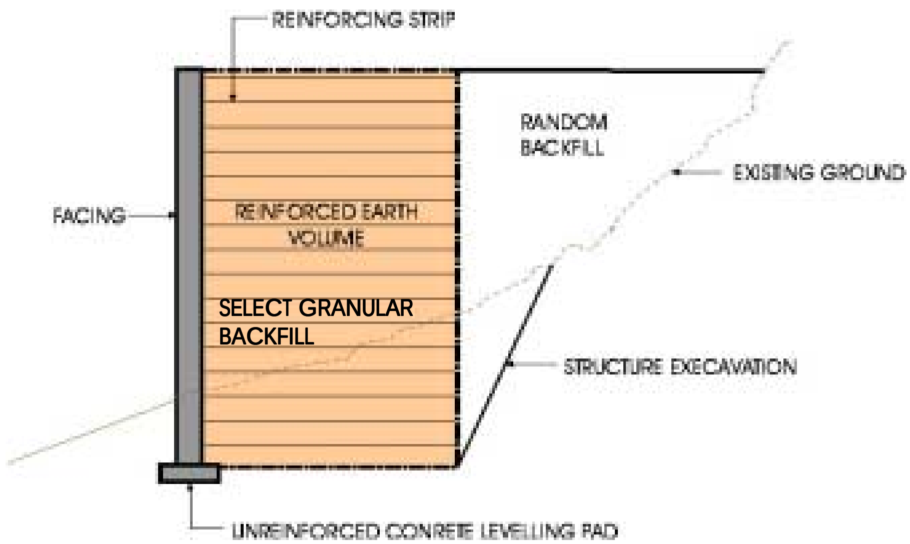


FIGURE 2 - COMPONENTS OF AN MSE WALL

Soil = Select Granular Backfill

The soil used in MSE structures is most often a granular material referred to as "Select Granular Backfill" with a maximum of 15 % fines and a maximum size of four inches (See table No. 1). Additional requirements for plasticity index (P.I.), internal friction angle (ϕ), soundness and electrochemical requirements are specified in AASHTO and FHWA specifications. Material conforming to said specifications is free-draining, frictional and durable.

U.S. SIEVE SIZE	***PERCENT PASSING***
4 inches	100
No. 40	0-60
No. 200	0-15

TABLE 1 - Gradation Limits as per AASHTO T-27[2]

Soil Reinforcement

Soil Reinforcement is most often one of two types: inextensible (steel) or extensible (plastic). Inextensible steel reinforcements come in three major categories, ribbed steel strips, welded wire bar mats, and welded wire ladders. For permanent applications, steel strips, ladders and bar-mats are galvanized. Strips are most often made of ASTM-A572 grade 65 steel. Welded wire ladders and mats are often made of ASTM A82 wire.

Inextensible by definition means that the reinforcement does not stretch considerably. Inextensible steel reinforcements are used in all mechanically stabilized earth applications and are the most common soil reinforcement for critical structures such as bridge abutments where control of deformation is crucial to the performance of the bridge and substructure. [3] It should be noted that inextensible reinforcements have been used successfully in MSE bridge abutment structures for over thirty years, while research is still underway long trying to develop an extensible reinforcement that will perform adequately in bridge applications.

Extensible geosynthetic reinforcements come in many different forms. The major types include uniaxial and biaxial geogrids and woven and non-woven geotextiles. Extensible reinforcements, by definition stretch, very often to the extent that the strain in the reinforcement is greater than or equal to the strain in the soil mass, thus there is considerable lateral movement when extensible soil reinforcements are used. Extensible geosynthetics are often used such applications as reinforced slopes, basal reinforcement and for wall applications such as temporary wire faced walls, wrapped geotextile facing and blockwalls. All of the applications discussed in this paragraph are applications where the deformation of the reinforcement and associated lateral structure movements are tolerable.

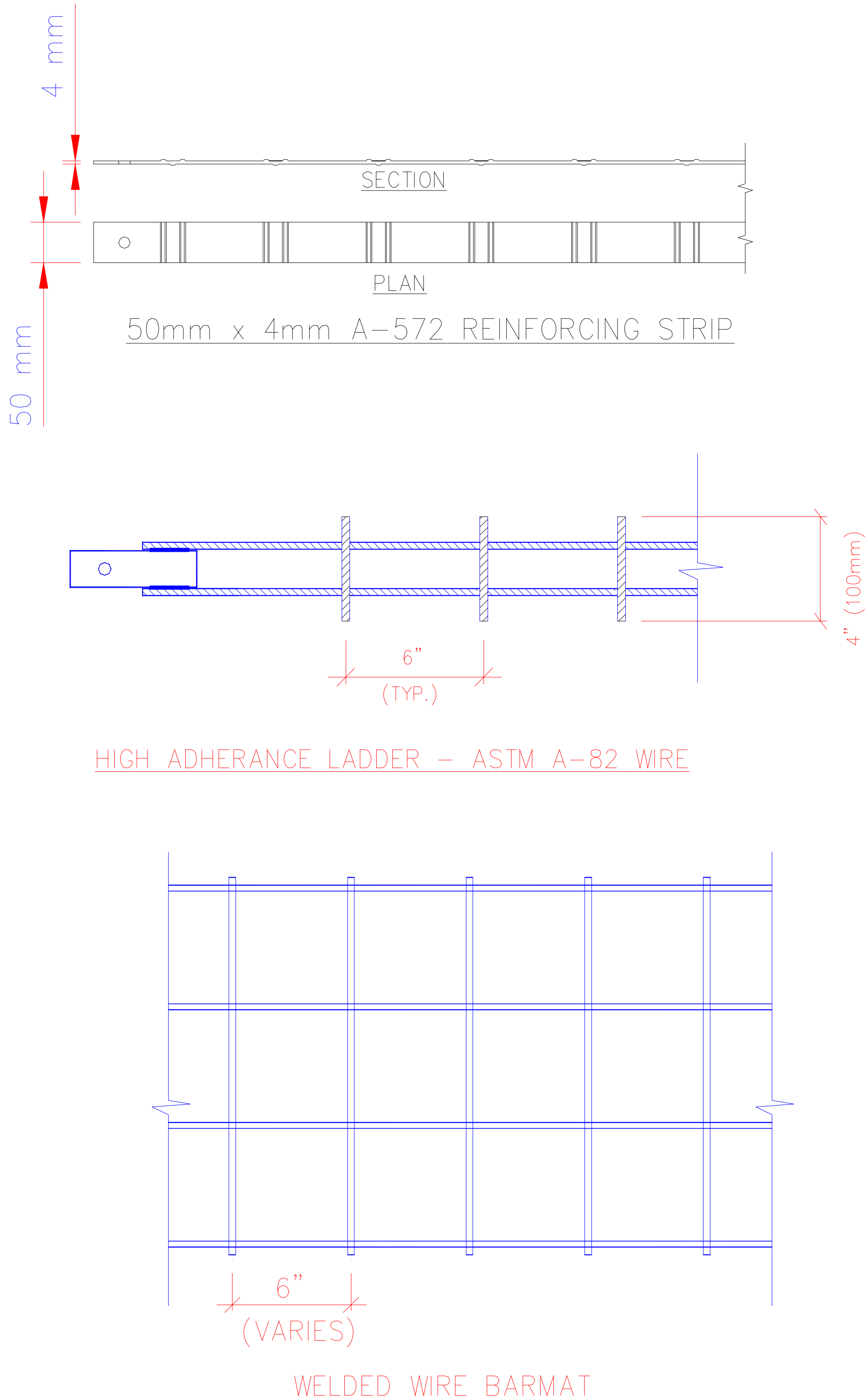


FIGURE 3
Common Types of Inextensible Soil Reinforcement

Facing

The third component of an MSE wall is the facing. The facing of an MSE wall is often composed of precast concrete, dry-cast concrete block, welded wire fabric or geotextile. For several reasons, the overwhelming majority of permanent MSE bridge abutments are cladded with discrete precast concrete facing panels. While research and experience has shown that the facing is not a structural element contributing to the stability of an MSE wall, the facing must be structurally connected to the soil reinforcement and be composed of materials durable enough to perform throughout the service life of the structure, typically 100 years. Modular concrete blocks are not commonly used for MSE abutment structures for two major reasons. First, most modular concrete block MSE structures utilize extensible geosynthetic reinforcement. As stated earlier, bridge abutment structures have a low tolerance to the lateral deformations common to structures reinforced with extensible soil reinforcement. The second concern with the use of dry cast concrete block for permanent highway structures is that there is a lack of evidence of the long-term durability of dry cast concrete. *"Recently introduced dry cast segmental block MBW (modular block wall) facings raise some concerns as to their durability in aggressive freeze-thaw environments because their water absorption capacity can be significantly higher that that of wet-cast concrete. Historical data provide little insight as their usage history is less than a decade. Further, because the cement is not completely hydrated during the dry cast process, (as is often evidenced by efflorescence on the surface of units), a highly alkaline regime may establish itself at or near the face area, and may become an aggressive aging media for some geosynthetic products potentially used as reinforcements. Freeze-thaw durability is enhanced for products produced at higher compressive strengths and/or sprayed with a posterection sealant."* [4]

Galvanized welded wire fabric in combination with rock-fill or galvanized steel mesh may be used as a facing for temporary bridge structures or in locations where a concrete facing is not deemed feasible, such as in mining or forest roads. Geotextile wrapped facing is not used in permanent applications due to vandalism concerns and the lack of long-term durability of geotextiles exposed to direct sunlight. See Figure 4 for common facing types used for MSE bridge abutments.

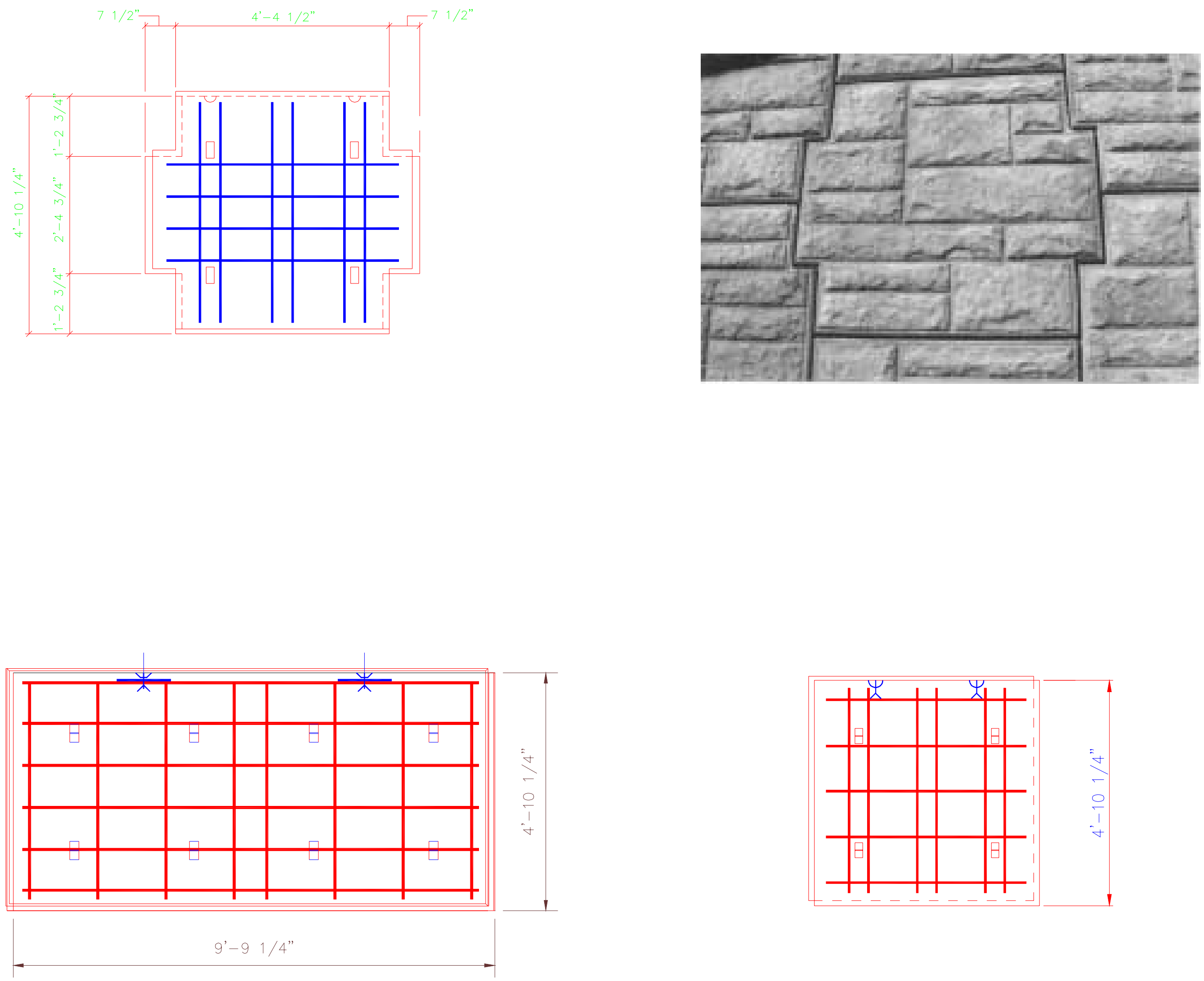


FIGURE 4
<u>Precast Concrete Facings</u>

Bridge Abutments

Early in the development of Reinforced Earth it became clear that bridge abutments were an application where owners could reap the benefits of the performance and economy of mechanically stabilized earth structures. There are two types of bridge abutments associated with mechanically stabilized earth walls. A "MSE Abutment" is where the bridge beams are supported on spread footing, which is directly supported by the MSE mass (See Figure 5). A "Mixed Abutment" is a pile supported abutment with MSE walls providing support of the fill. (See Figure 7) Either type may be an "Integral" abutment.

It is well established that bridge structures founded on spread footings can tolerate vertical settlements on the order of two to four inches. [5] Tolerable horizontal movement (angular distortion) typically ranges from 0.004 to 0.005 (ie. 0.4% to 0.5%). Thus, horizontal movements of one to two inches can cause bridge girders to jam up against backwalls, close expansion joints and damage bearings. [6] MSE walls reinforced with inextensible reinforcements are proven to perform within the tolerable range of horizontal movement. Unfortunately, the creep of extensible soil reinforcement leads to horizontal deformations easily approaching and exceeding two inches for a typical size abutment structure. One recent test project in Colorado utilizing geosynthetic reinforcement displaced one inch in the first year since the beams were set. [7] Due to the time dependent nature of creep in geosynthetics, time will tell how much displacement will occur.

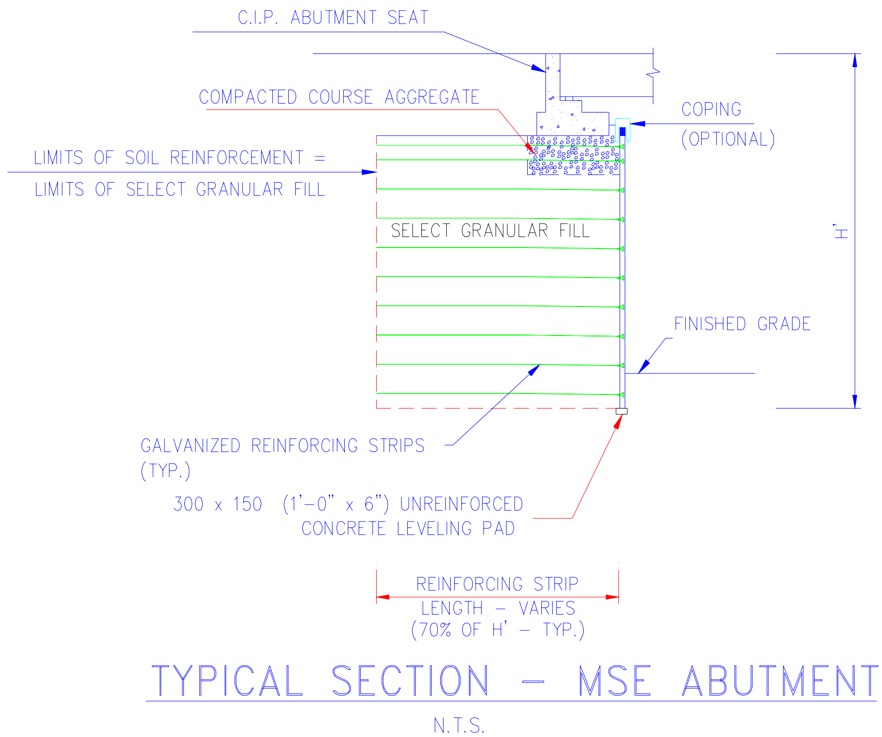


FIGURE 5

Benefits of MSE Abutments

- Lower costs
  - Elimination of piles
  - Less cast in place concrete
- More flexible wall system
  - Better seismic performance than traditional abutments
  - Excellent performance on soft soils
  - Ability to withstand severe post construction settlements
- Eliminates the "Bump Behind the Bridge"
  - Abutment settles with approach fill

Performance of MSE Abutments

The first mechanically stabilized earth (MSE) bridge abutment was constructed in Strasbourg, France in 1969 with Reinforced Earth®. The first U.S. MSE bridge abutment was constructed in Lovelock, Nevada in 1975 with Reinforced Earth®. Since

1975, over 220 MSE abutments have been constructed in the United States with Reinforced Earth technology. Other companies such as VSL and the Neel Co. have also constructed MSE abutments. MSE abutments are approved for use by 20 state DOT's. In the northeast region, over 100 MSE abutments have been constructed in Connecticut, Maine, Massachusetts, New Hampshire, New York and Vermont. New York State DOT (NYSDOT) has been a leader in the use of MSE abutments among state highway agencies. Since 1977, over 80 MSE abutments have been constructed along the NYS highway system. Among these abutments is Route 417 over Conrail in Gang Mills, NY. (See figure 6 for profile of bridge and abutment) This abutment supports a single span steel superstructure with a span of 238 feet, the longest span supported by an MSE abutment in the United States. The structure was constructed in 1999 and is now in service.

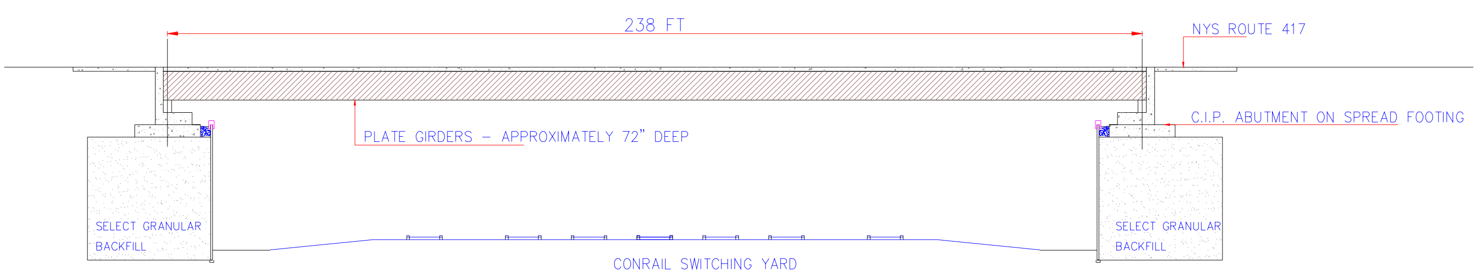


Figure 7

Route 417 over Conrail - The longest single span bridge supported by Reinforced Earth in the United States

Settlement Performance

Studies have shown that bridge abutments founded on medium-dense granular soils (typical of a mse structure) will tolerate post deck construction settlements on the order of 2 to 4 inches. Typically, a maximum 1/4" of settlement can be expected of granular fill after construction of the deck. [8] Experience has shown that settlement greater than six inches can be accommodated with special details and jacking the superstructure. [9] Thus, for the case of MSE abutments, the settlement of the select granular backfill will be on the order of 1/4". It is the settlement of the foundation soils that need to be essentially complete prior to construction of the bridge deck.

The ability of MSE abutments to withstand even extreme settlements is another benefit of this extremely flexible construction technology. Total settlements over 3 feet and differential settlements on the order of 1 ft in 100 ft have been accommodated by MSE walls prior to the construction of spread footings for bridge abutments. The ability of MSE walls to endure extreme total settlements allows for MSE abutments to be constructed in locations were even pile supported abutments may be infeasible. Such applications are where the settlement of deep deposits of soft soils would create excessive down-drag forces on piles.

Early applications of MSE abutments in extreme cases of extreme settlement include a 103 ft single span bridge carrying US Route 1 over the Boston & Maine Railroad, constructed in 1980 in Wells, Maine. Significant settlement, up to twenty-five (25") inches at the abutment locations, was expected due to over 150 feet of layers of loose to medium sands and clay. Reinforced Earth® walls were selected at bid time as the most economical alternate. The single span bridge, abutments and retaining walls cost $725,000, a 32% cost savings of a three span pile supported structure, estimated at

$1,060,000. The approach embankments and Reinforced Earth retaining walls were constructed and preloaded prior to construction of the bridge abutment seats. Eight and one half inches of settlement occurred prior to construction of the bridge. After removing the preload and constructing the abutment seat and bridge, an additional six and one-half inches of settlement occurred within the first two years of service. Approximately twelve additional inches of settlement was expected over the next ten years. Provisions were made in the design and construction of the bridge and substructure to allow for jacks to raise the bridge to maintain the design profile elevations. Most importantly, gages to monitor lateral movement were installed, and essentially no lateral movement of the wall panels has been measured. [10]

Another example of extreme settlements of MSE abutments in the northeast: a Reinforced Earth Abutment for a railroad unloading trestle in Burlington, Vermont was expected to settle approximately six inches. The actual settlement exceeded sixteen inches prior to the construction of the abutment seats. The contractor was able to adjust the elevations of the bridge pedestal to compensate for the settlement. A now common solution for foundation improvement is to utilize a permanent MSE wall as a preload prior to the construction of the bridge and substructure.

It is clear that MSE abutment structures can withstand extreme total settlements, another benefit is the capacity to withstand differential settlements. The use of discrete facing elements typically allows for a differential settlement of one percent (1 ft in 100 ft of wall facing). If differential settlement is expected to be greater than one percent, slip joints may be added to the wall and/or foundation improvements such as dynamic compaction, replacement of unsuitable materials and/or preloading may be performed prior to the construction of the MSE wall.

Seismic Performance

Another benefit of the flexibility of MSE structures is the outstanding performance during seismic events. Many MSE walls and several MSE abutments have been constructed in highly seismic regions. In the U.S. over 50 MSE abutments have been constructed with Reinforced Earth® in the western region, including Alaska where the seismic acceleration coefficient A is greater than or equal to 0.35g. The inherent flexibility of MSE structures provides a distinct advantage over rigid traditional abutments. The seismic design of MSE walls has been studied since the 1970's. Scale models, finite element analysis and full-scale structure tests have been studied in order to understand the effect of earthquake-induced forces on MSE walls. Through research and testing it has been found that a psuedo-static analysis can be performed for earthquake design. The current seismic design procedure is similar to the Monoboe-Okabe approach. For the design of MSE abutments, the inertia of the superstructure and substructure as well as the reinforced fill is accounted for in addition to the seismic lateral loads of the retained backfill. The pullout strength of steel reinforcing strips (Reinforced Earth) subject to vibration was studied in France in 1975 (smooth strips) and the United States in 1983 (ribbed strips). This research provided evidence that the pullout resistance is reduced due to the reduced overburden pressure induced by vertical accelerations within the structure and not due to any change in the frictional properties of the strips or the soil. For both strip types, the reduction in pullout resistance is conservatively taken as 20 percent for accelerations as high as 1.2g, which is many times the acceleration expected in structures subjected to actual earthquakes. [11]

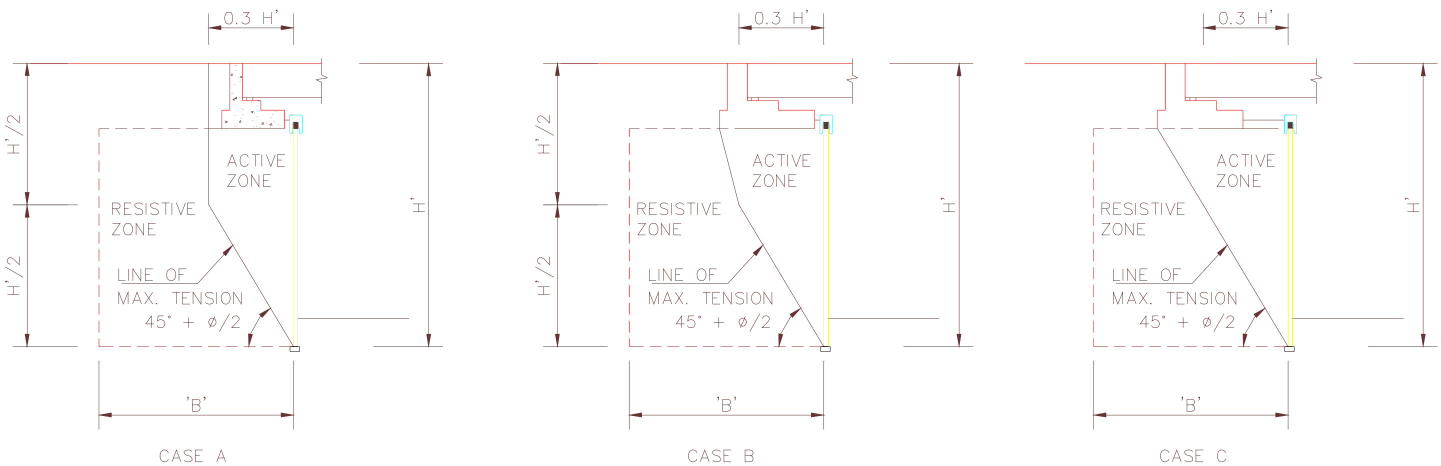
Reinforced Earth® walls and abutments have performed exceptionally well during recent earthquakes. The Reinforced Earth Company has documented several case studies, including the summary: "Reinforced Earth Structures in Seismic Regions" and presented technical papers at the International Symposium on Earth Reinforcement. A short list of case studies follows:

- Liege, Belgium, 1983. Three abutments and several high retaining walls (up to 17m) were within 3.5 km of the epicenter of a Richter Magnitude 5.0 earthquake. None of these structures showed any damage or deformation.
- Bay of Plenty, New Zealand, 1987. Two Reinforced Earth abutments were nearing completion in Maniatutu, 30km from the epicenter of a Richter magnitude 6.3 earthquake. The structures performed perfectly during the earthquake and construction was completed with no remedial action required.
- Northridge, California, 1994. Twenty-one Reinforced Earth Walls and two Reinforced Earth bridge abutments were subjected to this Richter magnitude 6.7 earthquake in the densely populated San Fernando Valley, 20 miles northwest of downtown Los Angeles. Sever damage occurred to buildings, bridges, and freeways. All of the Reinforced Earth Structures performed extremely well, with only superficial damage to a few facing panels of one wall.

Design of MSE Abutments

The design of a MSE abutment is similar to that of a conventional MSE wall. The effects of the bridge and abutment loads are super-imposed onto the soil loads. Research including finite element analysis, scale models and full-scale instrumented structures has led to the development of a design method that is both conservative and predictable.
In 1973 a full-scale load test of a Reinforced Earth MSE abutment was conducted by the French Road Research Laboratory (Lille, France). A 5.6 m high by 15 m long Reinforced Earth structure supported a spread footing which supported a bridge structure consisting of a 19 m span with a c.i.p. slab. Strain gages were attached to the earth reinforcements to measure the tensile stresses during all phases of construction and service. The study confirmed the theoretical basis of mse abutment design. [12]
From this and other studies, the decrease in the earth pressure coefficient, K, with depth was confirmed. In addition, the location and distribution of tensile stresses in the earth

reinforcements was verified. Further studies have confirmed the state of stress and location of maximum tension for MSE Abutment structures. [13]



LOCATION OF LINE OF MAXIMUM TENSION
IN A MSE ABUTMENT DEPENDING ON SEAT GEOMETRY

FIGURE 8 [14]

In the design of a MSE abutment, the vertical loads from the bridge are transmitted from the abutment seat along a 2 V to 1 H distribution to the bottom of the wall. Horizontal loads from the bridge are distributed along a Rankine plane of $45° + \phi/2$. The "active zone" of the MSE structure may be affected by the geometry of the abutment seat. The pullout safety of the reinforcing elements is determined by dividing the total resisting force (via friction of the reinforcing elements and soil) by the total driving force (the tension in the reinforcing elements created by the soil and bridge loads). The maximum stress in the reinforcing elements is also checked to be sure it is less than the allowable stress of the reinforcing elements at the end of the service life, typically 100 years. It should be noted that the service life calculations for galvanized steel reinforcements are very conservative. Research is now underway by several state DOT's including Florida and New York, and preliminary findings show that the corrosion rates, as recommended by AASHTO, are nearly twice what is being found through tests of retrieving buried reinforcements that have been buried for over 15 to 20 years. [15] Thus there is a hidden safety factor being imposed over and above the safety factors already used in design.

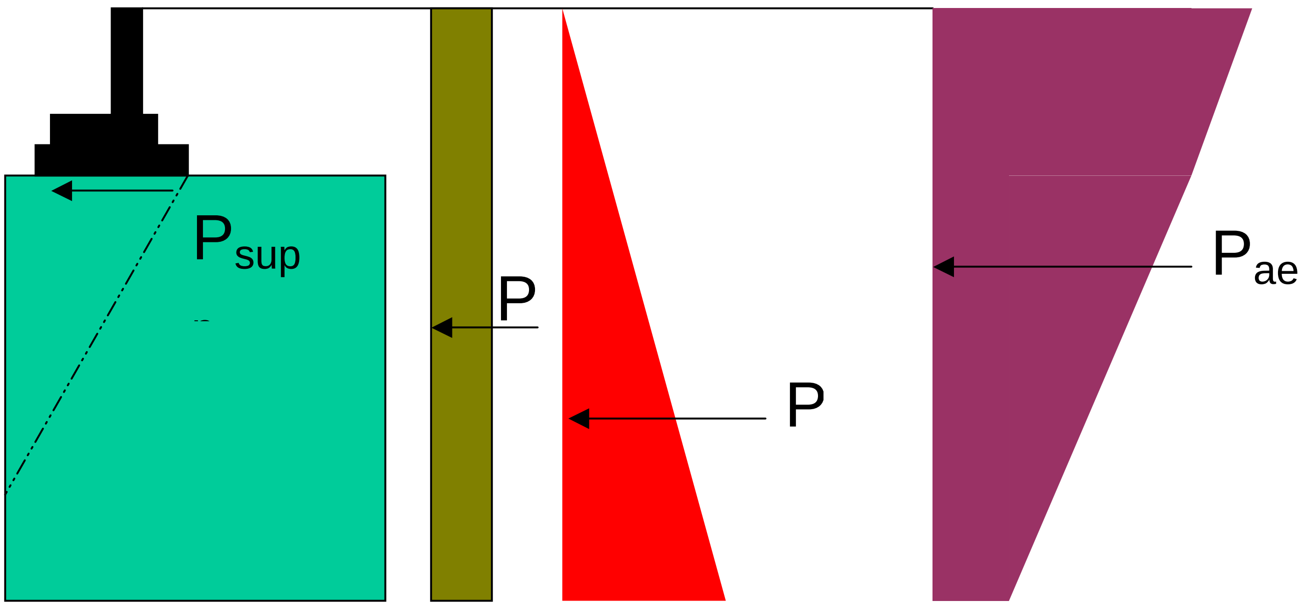
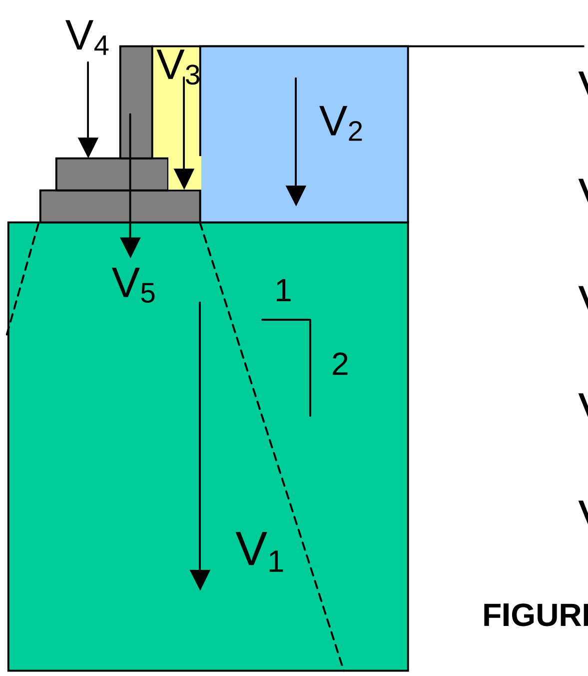


FIGURE 9 - Horizontal Free Body Diagram

P_{supp} = Supplemental Horizontal load from bridge. P_s = Surcharge

P = Earth Pressure P_{ae} = Seismic Earth Pressure



V_1 = Weight of reinforced zone

V_2 = Weight of retained zone

V_3 = Weight of soil above toe

V_4 = D.L. + L.L. of Bridge

V_5 = Weight of abutment seat

FIGURE 10 Vertical Free Body Diagram

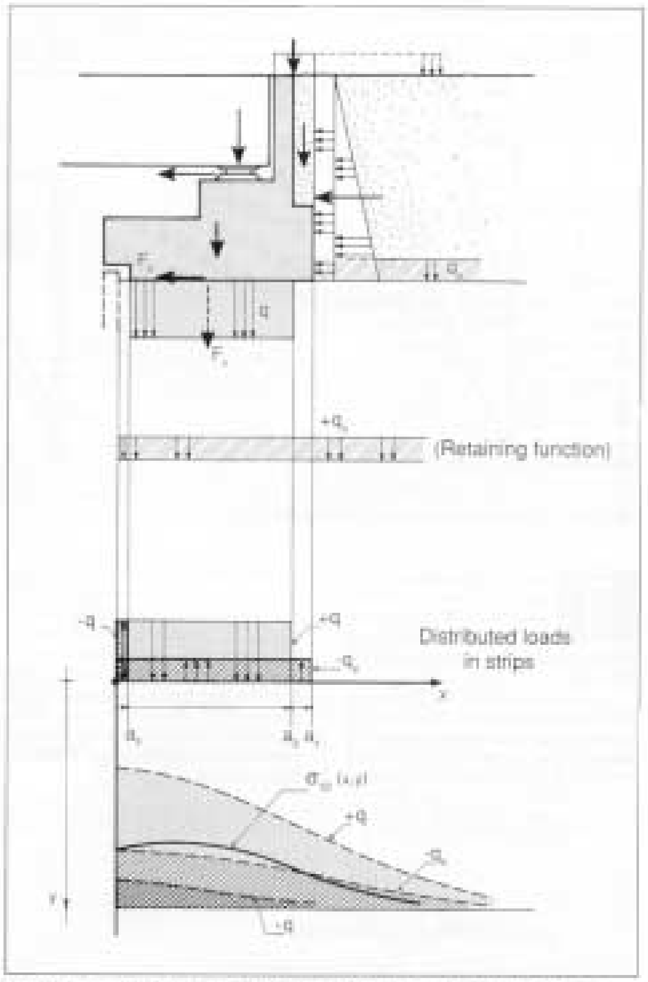


Figure 19. Principle of the decomposition of distributed loads, for the superimposed calculation

Figure 11- Distribution of bridge loads in Reinforced Earth

Determination of Reinforcement Pullout Safety Factor

$$F.S. = \frac{2\, b\, \gamma\, h\, f^*\, Le\, N}{\sigma_h\, A}$$

b : effective width of reinforcement (50 mm for ribbed reinforcing strips)
γ : unit weight of soil
h : height of overburden above reinforcement level
f* : coefficient of friction between reinforcing and soil
Le : effective length of reinforcement
N : Number of reinforcements per design width
σ_h : Total horizontal earth pressure including effects of bridge loads

A : Tributary area

Determination of Maximum Stress in the Reinforcing

Maximum Tension per reinforcing element = (σ_h A) / N

σ_h : Total horizontal earth pressure including effects of bridge loads
A : Tributary area
N : Number of reinforcements per design width

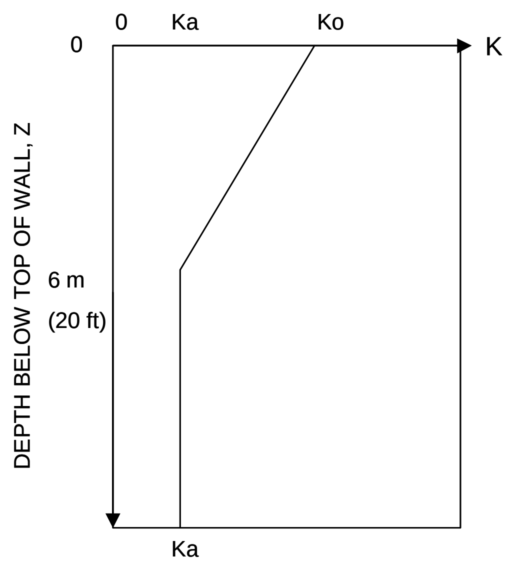


FIGURE 11 - Variation of coefficient of earth pressure K with depth in a MSE wall with ribbed steel strip soil reinforcements.

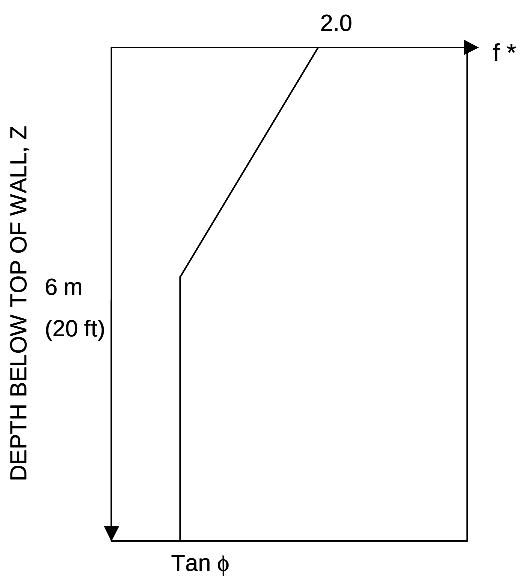


Figure 12 - Variation of Coefficient of Friction f* with Depth

Pile Supported Abutments (Mixed Abutments)

The second type of bridge abutment associated with MSE walls is one in which the bridge beams rest on a stub footing supported by piles. Vertical bridge loads are taken by the piles. The MSE wall is designed as a simple retaining wall with design height H', with a slight reduction in overburden due to the section of the structure supported on piles. Horizontal bridge loads may be resisted by multiple pile rows or additional soil reinforcement in the upper portions of the wall or connected to the pile cap.

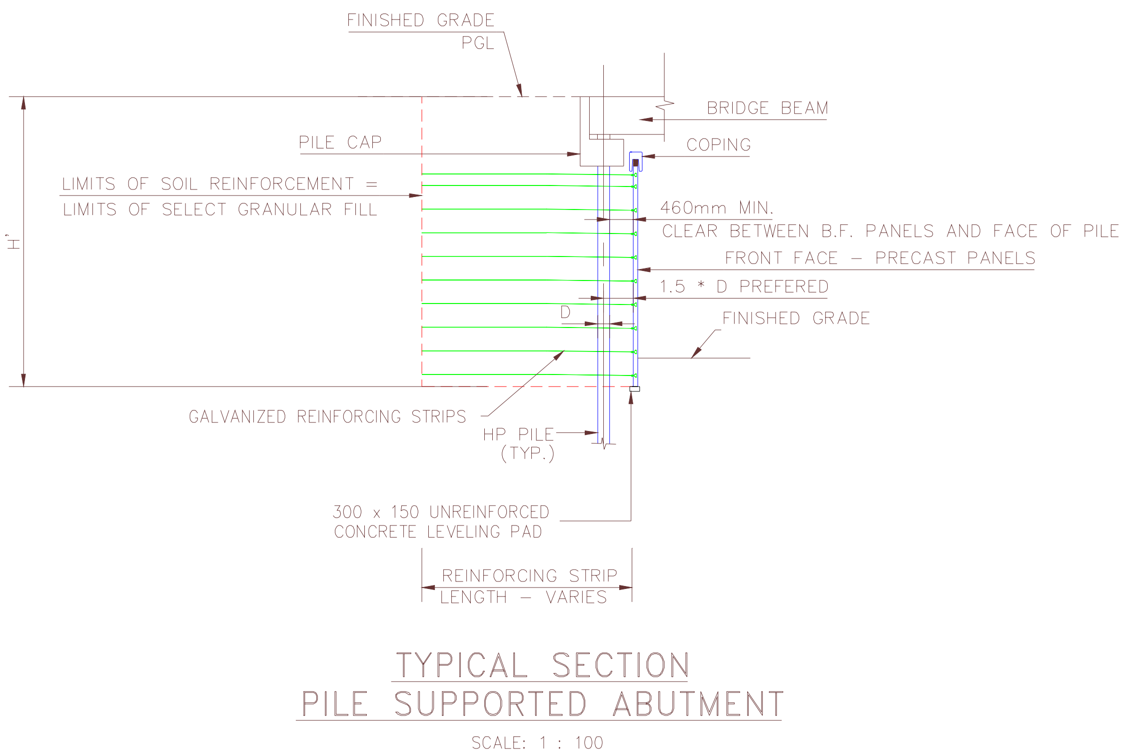


FIGURE 13
Mixed Abutment

Pile Supported Abutment with reinforcing strips skewed around piles.

Integral Bridge Abutments and MSE structures

Integral bridge abutments are a relatively new application in the United States. An integral bridge is one without joints or bearings. The repair of joints and bearings on traditional abutments are one of the more costly maintenance items of highway bridge structures. The goal of integral bridges is to construct a nearly maintenance free substructure. Integral bridges are most often supported by piles, with the weak axis of the pile parallel to the centerline of bearing. The goal of integral bridge abutments is to allow for the thermal movement of the superstructure to be carried through to the piles and then transmitted to the soil. When integral bridge abutments are used in conjunction with MSE walls, several provisions are made so that both structures will perform satisfactorily. The additional horizontal forces due to the deflection of the piles can be accommodated in the design of the earth reinforcement. Per FHWA the additional design details common with the use of integral abutments and MSE walls are to:

- Provide a clear horizontal distance of 0.5m between the back of the panels and the front edge of the pile.

- Provide a casing around piles, through the reinforced fill, where significant negative skin friction is anticipated.
- Where pile locations interfere with the reinforcement, specific methods for installation must be developed. Simple cutting of the reinforcements is not permissible.

Note that the design details listed above are also applicable to traditional pile supported abutments in conjunction with MSE walls. The provision for 0.5m clear between the piles and the back of facing not only allows for the deflection of the piles and transfer of stress to the reinforced soil, it also allows for small compaction equipment such as walk-behind vibratory plate tampers to be used between the piles and the facing. Also note that systems utilizing strip reinforcement with bolted connections may simply skew the reinforcements around the piles. Systems utilizing welded wire mesh must incorporate special angle connections to transfer the reinforcement around the piles.

Historical use of MSE and Mixed abutments in the Northeast

Since 1970, MSE and Mixed abutments account for approximately 30% of highway projects constructed with MSE systems. MSE abutments and Mixed abutments have been constructed in nearly every state in the U.S., Canada, Mexico, South America, Europe, Asia, and Australia. Locally, there have been over 100 MSE abutments and 30 mixed abutments constructed in New York and New England. See the following table for a list of projects (Sorted by State):

Project	Town	State	Type	Year	Company
US Route 1 over B&M RR	Wells	ME	MSE	1980	RECo
Maysville Street Bridge	Presque Isle	ME	MSE	1992	RECo
Topsham Brunswick	Topsham	ME	Mixed	1996	RECo
Sligo Road over MCRR	N. Yarmouth	ME	MSE	2000	RECo
Mt. Auburn Ave over Center St.	Auburn	ME	Mixed	2000	RECo
Brunswick Bike Path	Brunswick	ME	MSE	1998	VSL
Pleasant Ave. Abutment		ME	MSE	1997	VSL
Bike Path/Pedestrian Bridge	Portsmouth	NH	MSE	1998	RECo
Hillsborough Bypass	Hillsborough	NH	MSE	1999	RECo

Project	Town	State	Type	Year	Company
Berlin Gorham Bridge	Berlin	NH	MSE	1999	VSL
Main Street over D&H RR	Oneonta	NY	MSE	1977	RECo
Sprain Brook Parkway	Westchester	NY	MSE	1977	RECo
I-590 over I-390	Rochester	NY	MSE	1978	RECo
Harlem Rd over Conrail	Sloan	NY	MSE	1979	RECo
Route 67 over B&M RR	Mechanicsville	NY	MSE	1980	RECo
Route 147 over Amtrak	Glenville	NY	MSE	1981	RECo
Route 9W over Conrail	Saugerties	NY	MSE	1982	RECo
Sunrise Highway	Islip	NY	MSE	1982	RECo
Wende Rd over Conrail	Alden	NY	MSE	1982	RECo
STE over Conrail	Steuben Co.	NY	MSE	1982	RECo
STE tunnel over Conrail	Corning	NY	MSE	1984	RECo
I-690 over Conrail	Baldwinsville	NY	MSE	1984	RECo
I-690 & I-90 Interchange	Balswinsville	NY	MSE	1984	RECo
M.U.D. (2) I-790 & 49	Utica	NY	MSE	1984	RECo
I-87 and I-90	Albany	NY	MSE	1985	RECo
M.U.D. (06) over Conrail	Utica	NY	MSE	1985	RECo
W. Main Street Bridge	Frankfort	NY	MSE	1985	RECo
I-88 Connector over Phelps St.	Broome Co.	NY	MSE	1986	RECo
Route 8 over NYS & WRR	Buffalo	NY	MSE	1986	RECo
Route 417 over Conrail	Utica	NY	MSE	1986	RECo
M.U.D. (07) over Conrail	Utica	NY	MSE	1986	RECo
Fort Drum Rd. Over Conrail	Evans Mills	NY	MSE	1987	RECo
Hamilton St. over So.Tier Pkwy	Painted Post	NY	MSE	1987	RECo
Route 11	Chateaugay	NY	MSE	1987	RECo
Nassau X-Way over LIRR	Hempstead	NY	MSE	1987	RECo
Cemetery Rd over Conrail	Lancaster	NY	MSE	1988	RECo
Country Rd. over Conrail	Harmony	NY	MSE	1988	RECo
Route 158 over Conrail	Schenectady	NY	MSE	1988	RECo
Port Road over Conrail	Rensselaer	NY	MSE	1988	RECo
Derby Road over Conrail	Wallkill	NY	MSE	1988	RECo
Route 34 over Conrail	Newfield	NY	MSE	1988	RECo
Route 33 over Conrail	Genessee Co.	NY	MSE	1989	RECo
Route 5 over Conrail	Buffalo	NY	MSE	1989	RECo
East Water St. Over Conrail	Chemung Co.	NY	MSE	1989	RECo
Route 417 over Conrail	Cattaragus Co.	NY	MSE	1989	RECo
River St. over Conrail	Oneida	NY	MSE	1989	RECo
Bronx River Parkway	Westchester	NY	MSE	1989	RECo
Emmetts Drive over LIRR	East Quoge	NY	MSE	1998	RECo
Route 417 over Conrail	Erwin	NY	MSE	1999	RECo
Route 27A over LIRR	Islip	NY	MSE	1999	RECo
Bull Road over NSRR	Orange	NY	MSE	2000	RECo
I-290 Lockport Expressway	Amherst	NY	Mixed	1981	RECo
Lockport X-way/Sweethome Rd	Amherst	NY	Mixed	1981	RECo
MUD (02) I-790 & 49	Utica	NY	Mixed	1984	RECo
Port Road over Conrail	Rensselaer	NY	Mixed	1988	RECo
Routes 17 and 144	Corning	NY	Mixed	1992	RECo
Corning By-Pass II	Corning	NY	Mixed	1993	RECo
Schodack Island State Park	Schodack	NY	Mixed	1998	RECo
Construction of Route 49	Marcy/Utica	NY	Mixed	1999	RECo
McNeil Generating Station	Burlington	VT	MSE	1982	RECo
Route 7 over VT RR	Wallingford	VT	MSE	1995	RECo
Okemo Mountain Bridges	Ludlow	VT	MSE	1998	RECo

Project	Town	State	Type	Year	Company
I-495 Snake River	Taunton	MA	MSE	1980	RECo
General Lawrence Bridge	Medford	MA	Mixed	1986	RECo
Central Artery C01A2	Boston	MA	Mixed	1996	RECo
Route 146/Route 20	Millbury	MA	Mixed	1997	RECo
Brightman Street Bridge	Fall River	MA	Mixed	1999	RECo
Central Artery C01A3	Boston	MA	Mixed	2001	RECo
Exit 9 over Conrail	North Haven	CT	MSE	1982	RECo
Mohegan Sun Casino	Uncasville	CT	Mixed	1996	RECo

Cost Comparisons

Typically, the installed cost of a MSE structure is on the order of $20 to $35 per square foot of wall face. This includes facing, reinforcing elements, select granular backfill and the construction of all the elements. Compared to an installed cost of $50 to $75 per square foot of wall face for a cast-in-place cantilever wall, the MSE option is very often the most cost effective. As the height of the wall increases, the economy of a MSE structure increases without substantial increase in cost. MSE walls have been built to heights exceeding 150 ft. For abutment structures, the cost of a pile supported structure is often 25% higher than a spread footing option. The same holds true for MSE abutment structures. While there is a slight additional cost for more soil reinforcement in an MSE abutment, the total cost is still quite lower than a pile supported structure. The final installed cost of a MSE abutment is approximately $25 to $40 per square foot of wall face plus the cost of the abutment footing.

Conclusions

The use of mechanically stabilized earth (MSE) abutments with precast concrete facing panels and inextensible soil reinforcements is an economical and often the only cost-effective, feasible alternative to conventional cast-in-place cantilever and pile-supported abutments. The use of mse abutments in locations of marginal foundation soils may be the best alternative in terms of cost and time of construction. In situations where very soft soils underlay the embankment and bridge abutment, mse abutments may be used in conjunction with preloads or other methods of foundation improvement in lieu of a pile supported abutment structure. Mixed abutments may be used when differential settlement between the abutments due to varying soil conditions would pose undo stresses on the superstructure. Mixed abutments may also be used when significant settlements are expected and in integral bridge abutments.

The seismic performance of mse walls and abutments is proven. Worldwide experience in nearly all of the major earthquakes of the last thirty years has provided ample data on the structural stability of MSE structures during seismic loading.

The design methods for mse walls, abutments and mixed abutments are fairly simple and straightforward. Over thirty years of research and experience has combined to develop a design method in which the effects of the bridge and earth loads are easily calculated.

The use of inextensible reinforcements with precast concrete facing panels in bridge applications is proven and reliable. Much more research and development must occur before extensible reinforcements can perform to the level of inextensible reinforcements in bridge applications.   The performance of dry-cast concrete block must be improved in freeze thaw situations in order for block walls to be applicable to highway structures.

The economy of MSE walls and abutments is one of the major reasons that the technology has become the standard for retaining walls built in fill situations. Along the way, the performance of MSE walls and abutments on marginal foundations has made it the engineered solution to difficult foundation problems.

Definitions

MSE Abutment -	A bridge structure founded on a spread footing supported by a reinforced soil retaining structure
Mixed Abutment-	A bridge structure founded on a footing on piles with a reinforced soil retaining structure providing earth retention only.
Integral Bridge Abutment -	A structure in which there are no joints between the beams and abutment. Thermal stresses of the superstructure cause deflection of the abutment and pile foundation.
Select granular backfill-	Backfill material meeting specifications including friction angle, gradation, soundness, salt content and plasticity.
Facing-	A component of a reinforced soil system used to prevent the soil from raveling out between rows of reinforcement. For bridge abutment structures, the facing is almost always precast concrete panels.
Mechanically Stabilized Earth (MSE)	A generic term that includes reinforced soil (a term used when multiple layers of inclusions act as reinforcement in soils placed as fill)
Reinforced Earth®	A registered Trademark of The Reinforced Earth Company. Reinforced Earth is the one of the most widely used and researched of any proprietary mse wall systems.
Extensible-	"To stretch". The deformation of the reinforcement at failure is comparable or greater than the deformability of soil. Geosynthetic materials (for example: polyester, polyetheline and pvc) are extensible.
Inextensible-	The opposite of extensible. The deformation of the reinforcement at failure is much less than the deformability of soil. Most steel reinforcements (for example: strips, ladders and bar mats) are inextensible.
Dilation -	The phenomenon in which dense granular soil particles expand during shear, typical of soils less than 20 feet deep.

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