Reinforced Soil Slopes

Reinforced soil slopes (RSS) are defined as structures with face inclinations of less than 70 degrees from the horizontal (FHWA, 2009a). A critical aspect of the design of reinforced slopes is the facing system. The erosion protection facilitates vegetation establishment and/or provides structural support for forming “over-steepened” slopes.

Key Features of Reinforced Soil Slopes

RSS are engineered structures that consist of soil reinforced with high tensile strength geosynthetics, typically geogrids or geotextiles, and an erosion control facing that can allow vegetation to take hold to improve aesthetics. With the use of geosynthetic reinforcement, it is possible to construct slopes steeper than 2:1 up to 70 degrees. RSS are commonly used in roadways, embankments, overpasses, and landscaping projects to maximize land use.

Advantages

- Cost-effective compared to traditional retaining walls.
- Environmentally friendly, especially when vegetated facings are used.
- Flexible and capable of withstanding ground movements and seismic forces.

Design Considerations

- Proper selection of reinforcement materials based on the slope height, angle, and loading conditions.
- Drainage systems to prevent water accumulation and excessive pore water pressure and erosion at the face.
- Vegetation for surface protection and environmental integration.

The stability of a slope is achieved through the integration of carefully selected reinforcement materials alongside engineered soil compositions. These materials, such as geogrids and geotextiles, work in harmony with the soil to provide structural integrity, enabling slopes to achieve angles and heights that would not naturally occur. Vegetated or aesthetic facings are often incorporated to enhance environmental appeal, mitigate erosion, and further strengthen these engineered formations. Drainage systems are another critical component, ensuring that water does not accumulate within the slope, which could compromise its stability or effectiveness in seismic conditions.

Reinforced slopes with a geosynthetic wrap face

Reinforced slopes that are 1(H): 1(V) and steeper generally require facing support during construction (FHWA, 2009b).

A geosynthetic face wrap and/or a hard armor facing support system is commonly used for this application.

In wrapping the face of a slope, removable facing supports (e.g., wooden forms) or left-in-place welded wire mesh (WWM) forms are typically utilized. FHWA recommends that the vertical reinforcement spacing for walls and slopes should not exceed 32 inches (FHWA, 2009a). The vertical spacing of the primary reinforcement depends on project conditions, facing type and construction methods. For example, a vertical spacing of 18 inches (450 mm) is used where WWM forms are employed. In practice, 18 inch (450 mm) vertical spacing is most common.

Geosynthetic face wraps for permanent structures should be UV stable for long-term use. If vegetation is sparse, UV stable facing helps protect the structure. Solmax MIRAGRID® Miramesh® GR, which supports soil while allowing light for vegetation is a great solution for the facing element. This material has a 75-year design life and blends aesthetically with vegetation.

Another alternative for wrapped face vegetated structures is the PROPEX Pyrawall® system. This solution comprises a HPTRM geosynthetic wrap face made of PROPEX Pyramat 75, integrated with two internal fiber-composite braces during manufacturing. These internal braces serve as vertical and horizontal supports when connected using a third fiber-composite bracing strut.

The system is resistant to corrosion, owing to the absence of metal components, and is UV stable with an expected design life of up to 75 years.

Reinforced slopes without a geosynthetic wrap face

A face wrap is typically unnecessary for slopes that are flatter than 1(H): 1(V), provided that the reinforcement (either secondary or primary) is applied at close vertical intervals (FHWA, 2009b). Under these conditions, the reinforcement may be extended to the slope surface with subsequent installation of erosion protection measures. Alternatively, the slope face may be constructed larger and trimmed back to achieve the desired gradient. It is essential to exercise caution to avoid damaging the reinforcements at the slope face. Figures 2 and 3 illustrate two common methods for shaping the face of a reinforced slope without utilizing a face wrap.

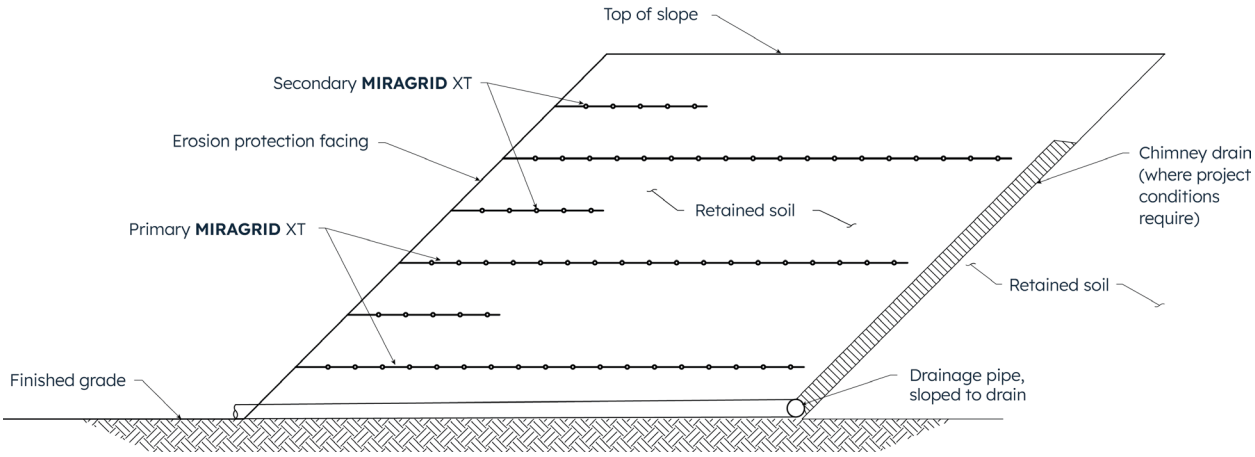


Figure 1: Typical Reinforced Soil Slope (RSS) cross section

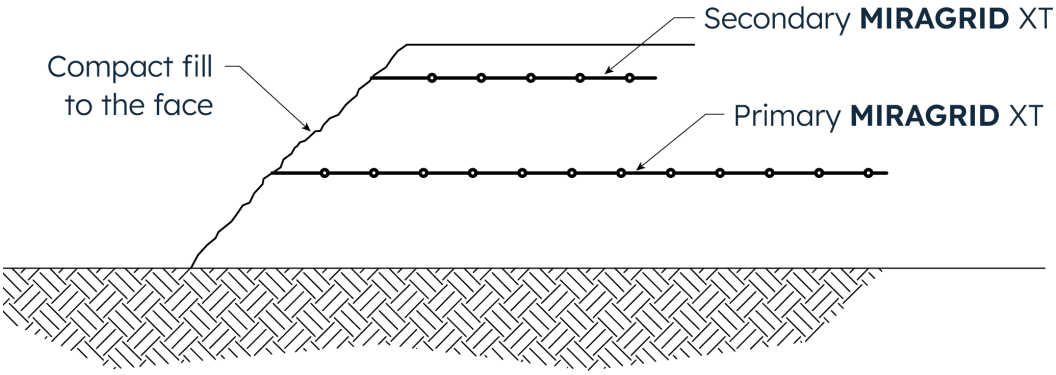


Figure 2: Compact reinforced fill to the finished face

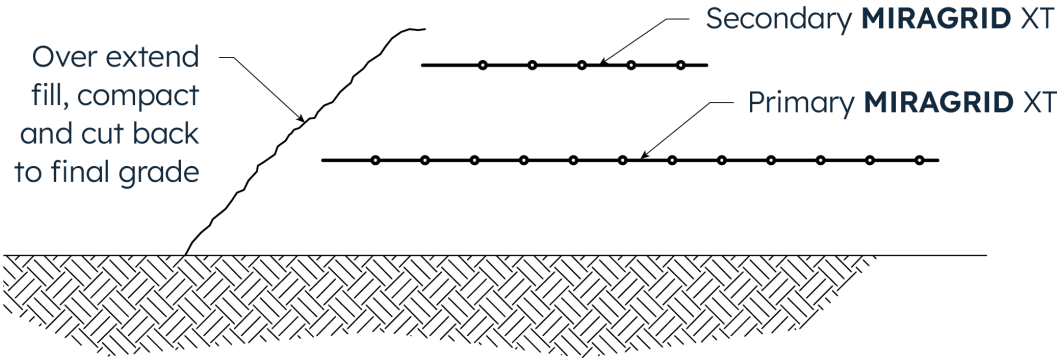


Figure 3: Construct reinforced backfill beyond the finished face, compacting lifts and cut back to final grade at end of construction

Reinforced 1(H): 1(V) slopes should be vegetated after construction to prevent erosion. A synthetic erosion control mat, like PROPEX® Pyramat® 75 shown in Figures 4, can be used. This mat has UV stabilization for a design life of up to 75 years.

The erosion control mat (FHWA, 2009b):

- Protects the soil slope face until vegetation is established.
- Decreases runoff velocity for better water absorption, promoting vegetative cover longevity.
- Reinforces the root system of the vegetation.

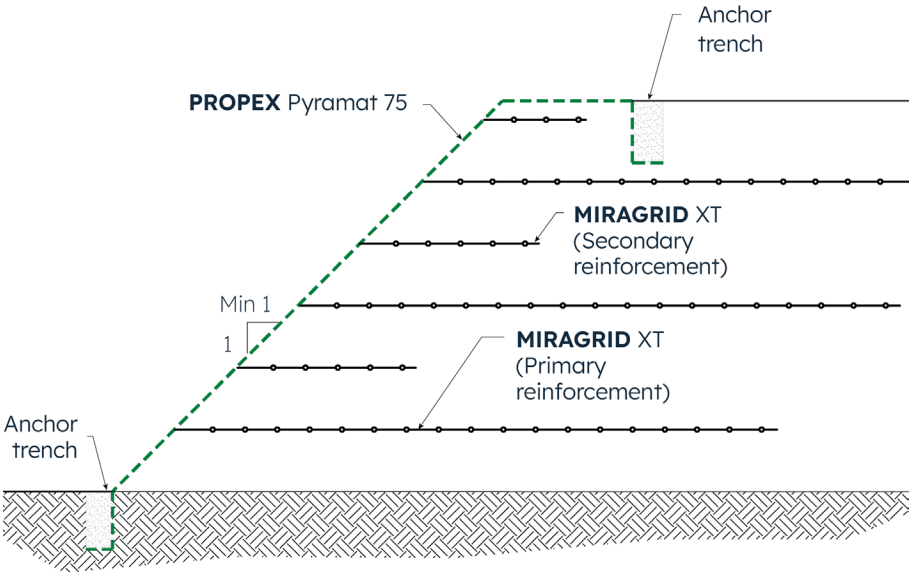


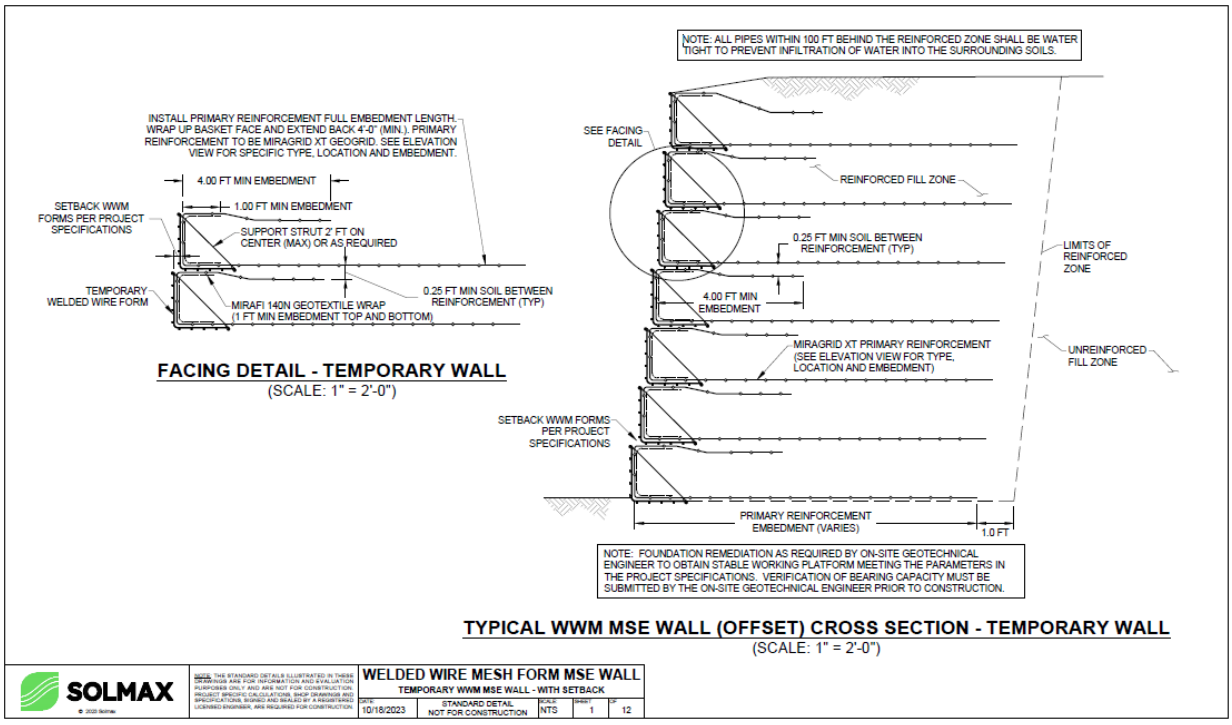
Figure 4: A typical reinforced soil slope with PROPEX Pyramat 75, a high-performance turf reinforcement mat (HPTRM) for UV stable erosion protection

Notes:

FHWA. (2009a). Federal Highway Administration FHWA-NHI-10-024 "Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes" - Volume I. Washington, D.C.: NHI.

Temporary Walls

Temporary MSE walls are frequently used in fill applications where access needs to remain open while installing extended fill depths adjacent to the access. These temporary structures are frequently used for road expansion or bridge building projects during construction phasing. Geogrids or geotextiles can be utilized for reinforcement and frequently, it may not require a facing element but instead is wrapped with reinforcement. To wrap the slope face, turn the reinforcement up and extend it at least 3 feet (1 meter) into the slope beneath the next layer. For structures with geogrid wrapped faces, a geotextile fabric may be needed to retain backfill soils, especially slopes steeper than 1(H): 1(V). For Installation simplicity, wire facing units can be used.



Recommended Facing Recommendations:

			Recommended facing type[7][8]			
			No wrapped face		Geosynthetic wrapped face	
Slope face angle	**Wall height[1] ft**	**Special conditions**	**Vegetated face**	**Hard facing**	**Vegetated face[1]**	**Hard facing[2][4]**
< 70° to 45° < 0.35H:1V to 1.0H:1V	All	N/A	NR[3]	NR[3]	Miramesh w/**MIRAGRID**	WWM w/ **MIRAGRID** Miramesh
	≤ Note 1				**PROPEX** Pyrawall	WWM w/ **MIRAGRID** Miramesh
	> Note 1				**PROPEX** Pyrawall w/**MIRAGRID**	WWM w/ **MIRAGRID** Miramesh
< 45° to 33.7° < 1.0H:1V to 1.5H:1V	All	N/A	**PROPEX** Armormax[5] **PROPEX** Pyramat[5] w/**MIRAGRID**	NR[3]	**MIRAGRID** Miramesh w/**MIRAGRID**	WWM w/ **MIRAGRID** Miramesh (Hard facing not required)
	≤ Note 1				**PROPEX** Pyrawall	
	> Note 1				**PROPEX** Pyrawall w/**MIRAGRID**	
< 33.7° to 26.6° < 1.5H:1V to 2.0H:1V	All	N/A	**PROPEX** Armormax[5] **PROPEX** Pyramat[5] w/**MIRAGRID**	NR[3]	Miramesh w/**MIRAGRID**	Hard facing not required
	≤ Note 1				**PROPEX** Pyrawall	
	> Note 1				**PROPEX** Pyrawall w/**MIRAGRID**	
Vertical (varies)	All	Hydraulic loading[6]	NR[3]	NR[3]	NR[3]	WWM w/**PROPEX** Pyramat
< 76° (varies)					**PROPEX** Pyrawall w/**MIRAGRID**	WWM w/**PROPEX** Pyramat