Case Study 4

Silver Creek, Silver Creek, New York



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Cover photo: Completed section of Silver Creek, Silver Creek, New York

Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

Case Study 4

Reinforced Soil Wall Silver Creek, New York

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Introduction

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) designed a 40.2-meter-long (132 ft), reinforced soil wall on Silver Creek in Silver Creek, New York, as part of an Emergency Watershed Protection (EWP) project. The geotextile-reinforced soil wall stabilized an eroding streambank that threatened a local road and exposed an old landfill. The rock-faced, reinforced soil wall is 3.4 meters high (11 ft). The cost of the reinforced soil wall saved about $50,000 over designs that included concrete retaining walls and other conventional systems. The reinforced soil wall also saved design and construction time over concrete retaining walls. Design of rock walls, such as presented in this case study, is provided in NEH654 TS14M.

Background

In January of 1996, southwestern New York State received a combination of rainfall and snowmelt that caused flooding and severe erosion. New York received federal assistance under the EWP program. The NRCS had the charge of planning and designing the repairs. The planning and design phase of EWP sites must be performed in a timely manner to prevent further damage from occurring on these already damaged sites. The Silver Creek EWP site was one of these sites.

The Silver Creek EWP site is located in Silver Creek, New York. The town of Silver Creek is located in the western part of the state on Lake Erie, approximately 40 kilometers (25 miles) southwest of Buffalo. The site is located on the west bank of Silver Creek, on an outside bend, immediately south of Highway 20.

High flows in Silver Creek ranged between 4.6 meters per second (15 ft/s) and 6.1 meters per second (20 ft/s), causing excessive toe erosion above the shale bedrock underlying the streambank. At the project site, bedrock is located near the bankfull or channel forming discharge elevation. The streambank at the site is located in a former municipal landfill. The eroded slope was 40.2 meters long (132 ft), with a height from the toe to the top of bank ranging from 4.6 meters (15 ft) to 5.8 meters (19 ft). Erosion of the streambank toe and subsequent sloughing of the banks was causing excessive amounts of sediment to be deposited in Hanford Bay.

In addition to the sediment being deposited into the bay, a local road at the top of the bank was in danger of being lost due to erosion. The local road, Spencer Place, is the only access to the Petri Baking Products, a major employer in the area.

Engineering alternatives

After the problems were identified and field data collected, alternative solutions were considered.

The first alternative was to build a compacted earthfill slope and provide protection at the streambank toe with rock riprap. It was estimated that a 2H:1V (horizontal to vertical) slope configuration would be required for a stable slope. This configuration would not fit the physical constraints at the site without encroaching on flows within Silver Creek. A reach of Silver Creek would need to be relocated for this alternative design. This alternative was not viable.

The second alternative was to excavate the slope back on a 2H:1V slope and place rock riprap at the toe. This alternative would have required relocating Spencer Place and several homes. This alternative was not desirable.

A third alternative that was investigated was to build a nearly vertical wall at the base of the slope and build a 2H:1V or 3H:1V slope above the wall up to the top of the slope. Several types of walls were considered: gabion, bin wall, sheet piling wall, and concrete retaining wall.

The sheet pile wall (fig. CS4–1) was not considered a viable alternative because of the shale bedrock foundation.

The gabion wall (fig. CS4–2) was not selected because of abrasion expected from bed-load and suspended load.

Both the bin wall (fig. CS4–3) and the concrete retaining wall (fig. CS4–4) were considered as viable alternatives. The cost estimate for a bin wall or concrete retaining wall was $90,000.

A fourth alternative, a reinforced soil wall or slope, was investigated (fig. CS4–5). The estimated cost for a reinforced soil wall or slope was $45,000. After researching this technique, it was chosen as the best alternative for stabilizing the site.

Figure CS4–1 Sheet pile wall



Figure CS4–2 Gabion wall



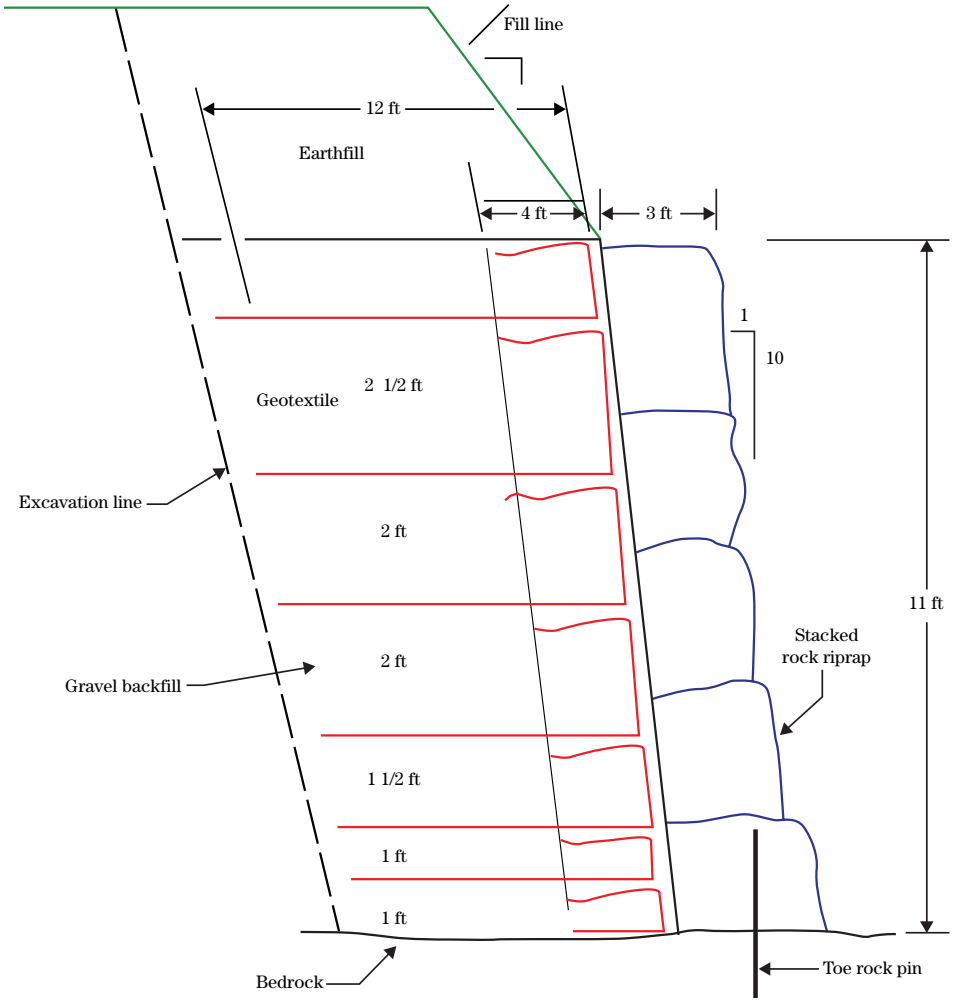
Figure CS4–3 Bin wall



Figure CS4–4 Concrete wall alternative



Figure CS4–5 Reinforced soil wall detail, Silver Creek, NY



Reinforced soil walls

Reinforced soil walls use elements to provide tensile reinforcement and increase shear strength of the soil backfill. Reinforced soil systems have been used successfully in the United States for more than 25 years. The USDA Forest Service has been building geotextile reinforced walls since 1974. Reinforced walls have many advantages over conventional reinforced concrete retaining walls (Mitchell and Villet 1987), in that they:

- are coherent and flexible and thus can tolerate relatively large settlements
- are easy to construct
- are relatively resistant to seismic loadings
- can form aesthetically attractive retaining walls and slopes because of a variety of available facing types
- are very often less costly than conventional retaining structures, especially for high steep slopes and high walls
- can use a wide range of backfill material

Before cost comparisons could be made, different types of tensile reinforcement had to be considered. The tensile reinforcement types that were considered were polymeric geogrids and geotextiles. After the analysis of the performance criteria for different geogrids and geotextiles, the decision was to use a geotextile for tensile reinforcement. Site conditions that made geotextiles the material of choice were: low height, 4.6 meters (15 ft) to 5.8 meters (19 ft); the ability to use a steep slope face (nonvertical), instead of a wall face (vertical); type of facing material; and cost.

Because of the layout of the site, a steep reinforced slope was able to be used instead of a vertical wall. There was enough area behind the facing to provide both internal and external stability. Also, there was enough area to provide a steep slope without encroaching on Silver Creek. This significantly reduced the amount of tensile reinforcement required to stabilize the streambank. Because of the steep slope, 1H:10V, the reinforced soil slope is called a reinforced soil wall for this application.

The facing of a reinforced soil wall is used to prevent the wall face from unraveling. The facing provides protection of the geotextile from degradation due to ultraviolet rays and provides an abrasion resistant surface, protecting the geotextile from streamflow and vandalism. The cost of reinforced soil walls is heavily dependent on the cost of the facing. The type of facing that was selected for the Silver Creek site was a rectangular-shaped massive limestone. The stones varied in size, but averaged 61 centimeters high (24 in) by 61 centimeters wide (24 in) by 76 centimeters long (30 in).

Design

AMOSPEC™ design software, by Amoco Fabrics and Fibers Company, was used to design the reinforced soil wall on Silver Creek. AMOSPEC™ evaluates reinforced soil wall and slope stability design using limit equilibrium analysis. The output derived from the computer program specifically addresses design and construction of geotextile wrapped-face walls.

AMOSPEC™ assumes that additional strength provided by the facing is not considered in the design, that the backfill material is free draining and does not consider deep slope stability, including shear failure surfaces through the foundation.

AMOSPEC™ evaluates the following modes of failure:

- sliding along the base of the reinforced wall
- bearing capacity at the toe of the reinforced wall
- internal stability of the reinforced wall

AMOSPEC™ selects a minimum geotextile embedment length and a minimum geotextile strength or spacing.

The input variables are:

- reinforced wall height
- reinforced wall inclination
- backslope angle of earthfill
- soil properties

- soil/geotextile interface strength
- geotextile strength or spacing
- uniform surcharge loading
- stability factors of safety

Input variables

The height of the slope varies from 4.6 meters (15 ft) to 5.8 meters (19 ft). The height of the reinforced soil wall is 3.4 meters (11 ft) (fig. CS4–5).

Several trials were run to achieve the optimum combination of compacted earthfill slope and reinforced soil wall. The backslope angle of the compacted earthfill above the wall is 3H:1V. The inclination of the wall face is 1H:10V.

The gravel backfill material was required to meet the gradation shown in table CS4–1.

No laboratory tests were performed. Soil properties were estimated based on gradation and correlations to similar soils. The estimate of the angle of internal friction was estimated to be 36 degrees. The assumptions that were made to estimate the angle of internal friction were: a poorly graded to well-graded gravel, GP or GW based on the Unified Classification System, and soils were compacted to 70 percent relative density. Based on these assumptions, the angle of internal friction was estimated to be between 37 and 40 degrees. Without laboratory tests, a conservative value of 36 degrees was chosen. A moist unit weight of 2.08 grams per cubic centimeter (g/cm^3) (130 lb/ft^3) was used.

The wall is located on a shale bedrock foundation. A unit weight of 2.24 grams per cubic centimeter (140 lb/ft^3) and an angle of internal friction of 40 degrees were chosen for the foundation. These values are very conservative. Deep seated slope stability, including failure surfaces through the foundation, were not a concern in the bedrock foundation.

A uniform surcharge load of 4.8 kilopascal (kPa) (100 lb/ft^2) was chosen to represent the load from semi-trucks that use Spencer Place.

The following geotextile properties were used:

- Ultimate wide-width tensile strength was 70 kilonewtons per meter [kN/m] (4,800 lb/ft).
- Design tensile strength was 11.7 kilonewtons per meter (800 lb/ft).
- Geotextile-soil interface friction angle was 20 degrees.

The following were chosen as factors of safety, FS:

- FS against block sliding was 1.5.
- FS against bearing capacity failure was 2.
- FS for geotextile strength was 6.
- FS for geotextile spacing was 1.4.

The spacing of the geotextile ranged from 0.31 meters (1 ft) to 0.76 meters (2.5 ft), with an embedment length equal to the height of the wall (fig. CS4–5). No secondary reinforcement was required because the backfill soil was compacted against the rock riprap facing. This resulted in no sagging of the geotextile-wrapped face.

Table CS4–1 Backfill particle size requirements

U.S. standard sieve size	Sieve opening size (mm)	Percent finer by weight
3 in	75.0	100
No. 4	0.425	50–0
No. 200	0.075	5–0

Cost

The cost of the 3.4-meter-high (11 ft), 40.2-meter-long (132 ft), reinforced soil wall, including earth work above the wall and concrete associated with an existing structure, was $39,334. Of this total cost, approximately $34,300 was for the reinforced soil wall. The reinforced soil wall cost approximately $250 per

square meter ($23/ft^2). The reinforced soil wall saved an estimated $50,000 in construction costs over concrete retaining walls and other alternatives proposed. The cost breakdown is listed in the table CS4–2.

The U.S. Department of Transportation Federal Highway Administration publication, Reinforced Soil Structures Volume I, Design and Construction Guidelines, states that for segmental concrete-faced structures, the typical costs are:

- Reinforcing materials equal 10 percent to 20 percent of the cost.
- Backfill materials, including placement, equal 30 percent to 40 percent of the cost.
- The facing system equals 40 percent to 50 percent of the cost.

The cost of the backfill was on the low side, and the facing was on the high side of ranges given above. This can be attributed to the bid schedule. The backfill was a lump sum item in the bid schedule, while the riprap facing was bid by the ton.

Table CS4–2 Costs of installation

Work or material	Quantity	Cost	Percent of total cost
Mobilization	Lump sum	4,000	10
Compacted gravel backfill	Lump sum	4,000	10
Facing, stacked riprap, in-place	394,980 kg (435 tons)	21,760	55
Geotextile, in-place	1,272 m^2 (1,522 y^2)	4,566	12
Miscellaneous		5,008	13
Total costs		39,334	100

Construction

The project was completed on schedule with no problems (figs. CS4–6 through CS4–13), even though the contractor had no previous experience with reinforced soil stabilization.

The backslope of the proposed reinforced soil wall was prepared by excavating a smooth surface for good soil contact between the *in situ* material and the compacted gravel backfill material.

Of concern was the potential for erosion of the first course of rock being at high velocity flows. This concern was addressed by pinning the first course of rock (toe rock) to the underlying shale bedrock. The pinning was accomplished by 1-inch-diameter steel bars driven through the toe rock into the bedrock.

One of the big advantages of using stacked rock riprap as the facing was that the gravel backfill could be compacted against the facing, eliminating the need for slip forms or some other method of compacting the backfill material near the facing. Small pieces of limestone were used to fill in the voids between the larger stacked riprap to protect the wrapped geotextile face.

The geotextile reinforcement and gravel backfill were "brought up" with the stacked riprap facing (figs. CS4–8 and CS4–9). The gravel backfill was compacted with a rubber-tired Case 1285 backhoe, a small bulldozer (Caterpillar® D4 equivalent), and a manually directed vibrating drum roller (figs. CS4–6 and CS4–7). The backfill within 2 feet of the wall facing was compacted with a manually directed power tamper (plate).

The geotextile length was run parallel to the slope to reduce the number of overlaps (fig. CS4–8).

The reinforced soil wall was completed within 15 construction days (figs. CS4–12 and CS4–13). John Burt, Silver Creek Village Manager, reported that 2 weeks after the wall was completed, flows within Silver Creek came within 2 feet of the top of the wall. He stated that, "we would have lost the (Spencer Place) road for sure without the wall."

Figure CS4–6 Compaction equipment



Figure CS4–7 Manually directed vibrating drum roller



Figure CS4–8 Primary reinforcement geotextile



Figure CS4–9 Primary geotextile anchorage length



Figure CS4–10 Stacked riprap face placement



Figure CS4–11 Flow during construction



Figure CS4–12 Completed wall



Figure CS4–13 Completed wall



Observations

The reinforced soil wall has been tested by high flows and is functioning as designed. The limestone riprap provided an aesthetically pleasing face. There is some herbaceous vegetation growing on ledges and openings within the rock face. Over time, sediment trapped within the interstices of the stacked riprap should expedite vegetation growing on the rock face. This will add to the aesthetics of the reinforced soil wall.

Conclusion

The reinforced soil wall was easily adapted to the site. The wall is flexible and can withstand large strains and deformation. The wall is functional, attractive, and inexpensive, when compared to reinforced concrete retaining walls and cellular confinement systems. The limestone riprap provided an aesthetically pleasing face. EWP projects require fast action. Because of the limited time available for design and construction, a reinforced soil wall was an excellent choice for the Silver Creek site. Using the coarse-grained, free-draining backing reduced the design time and also reduced the earth load on the reinforced soil wall. Construction was fast and simple and did not require skilled labor. Cost and aesthetics were very important on this project. The stacked rock riprap facing addressed both of these concerns.