

SECTION 5.5

ERODED STREAMBANK REPAIR

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SECTION 5.5

ERODED STREAMBANK REPAIR

Stream channel erosion can generally be corrected using either vegetative (Practices 501-506) or structural (Practices 510-515) techniques, or a combination of both (practices 507-509 and other possible combinations). Vegetation techniques are generally less expensive than structural, and are generally more compatible with stream characteristics. Structural techniques, though expensive and considered unsightly by some, may offer more permanent protection against erosion. Regardless of which technique the Handbook user decides to utilize, it is important to keep in mind that no one measure works well in all situations.

The following methods are described in terms of cost, applicability, ease of installation, and the advantage of using one technique over another. This list is not comprehensive, nor is it attempted to anticipate all circumstances in which one method might be used over another. Thus, the users must decide for themselves which method best fits the character of their particular location and problem.

Vegetative methods tend to work well along natural streams, in urban areas where a natural appearance, improved habitat, and water quality is important, and where cost may be a deciding factor as to whether a stream is restored. Visually, streams repaired using vegetative methods may take on a natural appearance after only one growing season. The network of plants critical to all vegetative techniques absorbs erosional energy during floods, provides habitat for wildlife, acts as a barrier to ice scour, conserves soil moisture, and stabilizes the soils and streambank.

Choosing a vegetative technique depends largely upon the type of problem encountered. Moderately eroded stream banks may be repaired with minimum regrading, and the installation of live stakes, a seed mix, and mulch. Live fascines, branch packings, and brush mattresses might be employed in areas with more serious erosion problems, but where there is still at least a 2:1 (1V:2H) grade to work with. However, note that the toe of slope may still require structural stabilization. Live cribwalls, lunkers, A-jacks, and vegetative geogrids work well in severely eroded areas with steep banks.

Structural techniques may be considered in highly developed areas with little to no natural overbank or where streambank pedestrian traffic is heavy. Retaining walls are generally preferred for steep to sheer, unprotected streambanks. Sheet piling may be preferred in areas where aesthetics are not important, and where space limitations prohibits the construction of a timber or concrete wall. All structural techniques should be installed in accordance with the manufacturer's specifications. Improper installation of these techniques can exacerbate erosion problems by transferring and amplifying stream velocity downstream.

Many of these techniques can and should be combined either for enhanced structural stability, improved environmental quality, or for a more aesthetically pleasing appearance. Top soil and live stakes can be placed between gabion baskets to create a more natural appearance. Riprap is sometimes advised along the eroded toe of a slope after which vegetative techniques can be used for the remainder of the slope.

Large-scale stabilization projects should be planned and designed by an experienced engineer or stream restorationist. Detailed stream studies are advised prior to tackling long, stream channel reaches. The U.S. Army Corps of Engineers' Waterways Experiment Station - Streambank Protection Guidelines for Landowners and Local Governments is one recommended reference for the engineering of major stabilization projects.

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PRACTICE 501 LIVE STAKES

- DESCRIPTION**
- Live shrub or woody plant cuttings driven into the channel bank as stakes.



Exhibit 501a: Live Stakes (Source: NRCS Engineering Field Handbook)

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- PURPOSE**
- To protect streambanks from the erosive forces of flowing water and to stabilize the soils along the channel bank

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- WHERE APPLICABLE**
- Along streambanks of moderate slope, usually 4:1 or less.
 - Applicable in original bank soil, not on fill.
 - Useful where active erosion is light and washout is not likely.
 - Often applicable in combination with other vegetative or structural stabilization methods.
 - Applicable on all sizes of channels and all character types.

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- ADVANTAGES**
- Economical, especially when cuttings are available locally.
 - Can be done quickly with minimum labor.
 - Results in a permanent, natural installation.
 - Improved riparian habitat

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- CONSTRAINTS**
- Should be combined with other techniques such as vegetative stabilization (Practice 1102) or mulching (Practice 1101).
 - Does not provide initial surface protection until top growth has occurred.
 - Will be ineffective in areas of active erosion or on channels with high fluctuation of flows.

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- DESIGN AND CONSTRUCTION GUIDELINES**
- Materials**
- Cuttings should be 24 - 30 inches long and ½ - 1½ inches in diameter.
 - Live cuttings with side branches cleanly removed and bark intact.

- The larger of thicker butt-ends should be cleanly cut at a 45 degree angle for easy insertion into the soil and the top should be cut square or blunt.
- Cuttings should have at least 2 bud scars near the top to facilitate development of branches.
- Cuttings must be fresh and kept moist. After they have been prepared into appropriate lengths, they should not be stored for more than 1 day before driving into the soil. To increase their rate of survival they should be placed the same day.

Installation

- Starting at the lower level, drive the cuttings into the bank at right angles to the slope. (A live fascine incorporated at the low water level will add stability to the toe of the slope. See Practice 502.)
- 4/5 of the length of the cutting should be driven into the ground and the soil should be firmly packed around the cutting.

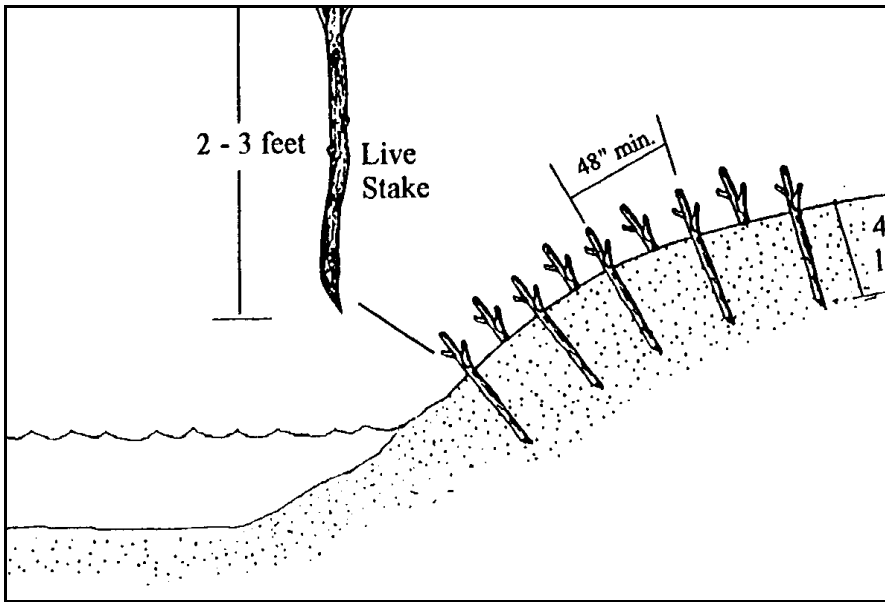


Exhibit 501b: Installation of live stakes (Source: DuPage County Streambank Stabilization Program)

- Do not split the cuttings during insertion.
 - An iron bar can be used to make the hole.
 - The density of the installation depends on the site conditions, ranging from 2 - 6 cuttings per square yard. A spacing of 2 feet or greater is recommended.
 - The stakes should be placed in off center rows.

Special Considerations

- Harvest live stakes during dormant season.
- Store live stakes under cold water (lake, stream, pond) for up to 3 days before installation.
- May need to fortify toe of slope (eg. fiber roll).
- Bank grading may be required to achieve moderate slopes before installation.

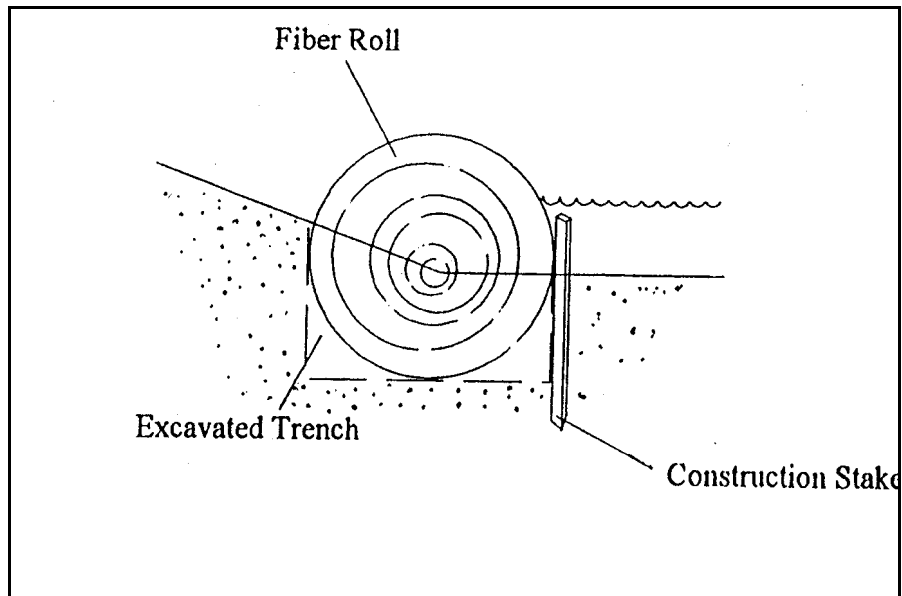


Exhibit 501c: Toe protection is often recommended when using live stakes (Source: DuPage County Streambank Stabilization Program)

MAINTENANCE ● Vegetated channel banks are vulnerable to new damage, especially right after installation. Inspect after highwater events for gaps in cover and repair with new plants. Mulch/seed exposed areas if necessary.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 505 Brush Mattress.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
- North Carolina Erosion Control Manual.
- Tennessee Riparian Restoration Handbook.
- Iowa Streambank Erosion Control.
- DuPage County Streambank Erosion Control Handbook

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PRACTICE 502 LIVE FASCINES

- DESCRIPTION**
- Sausage-shaped bundles of brush tied together, and placed in trenches cut into the bank, parallel to the stream.



Exhibit 502a: Preparation of Live Fascines (Source: NRCS Engineering Field Handbook)

PURPOSE	<ul style="list-style-type: none"> ● To protect banks from washout and seepage, particularly at the edge of a stream, and where water levels fluctuate moderately.
WHERE APPLICABLE	<ul style="list-style-type: none"> ● Effective with any stream type or size. ● Approximately 1:1 (1V:1H) slopes or flatter. ● Toe of bank and up slope area. ● Straight or curved sections.
ADVANTAGES	<ul style="list-style-type: none"> ● Immediate erosion protection. ● Traps sediment. ● Reduces gullyng. ● Slows surface water flows and increases infiltration on draughty sites. ● Provides surface stability for the establishment of vegetation. ● Improves riparian habitat
CONSTRAINTS	<ul style="list-style-type: none"> ● Labor intensive. ● Vegetative stabilization needed between fascines. ● Construction must occur during dormant season. ● Not recommended in areas with high surface drainage over bank.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> ● Cuttings should be > 4' long and < 1" in diameter from a variety of species that root easily, and have long, straight branches, such as willows (See Practice 501 Live Stakes).

- Jute rope.
- 3' oak construction stakes or live stakes.
- Vegetative Stabilization (Practice 1102).

Installation

- Drive stakes in a row across the slope beginning at the base of the bank at mean low water level. Stakes should be 12"-18" on center so 6" remain above the grade.
- Assemble bundles in 8"-10" diameter rolls in lengths of 1- 1½" longer than the maximum stem length by alternating stems, tapering ends, and securing with a jute rope.
- Dig a shallow trench as deep as the diameter of the fascine. Trenching should not precede placement of the bundles by more than one hour to minimize drying of soils.
- Lay bundles in trench, overlapping tapered ends.
- Drive live stakes or construction stakes through bundle, 12" on center, with additional stakes at joints.

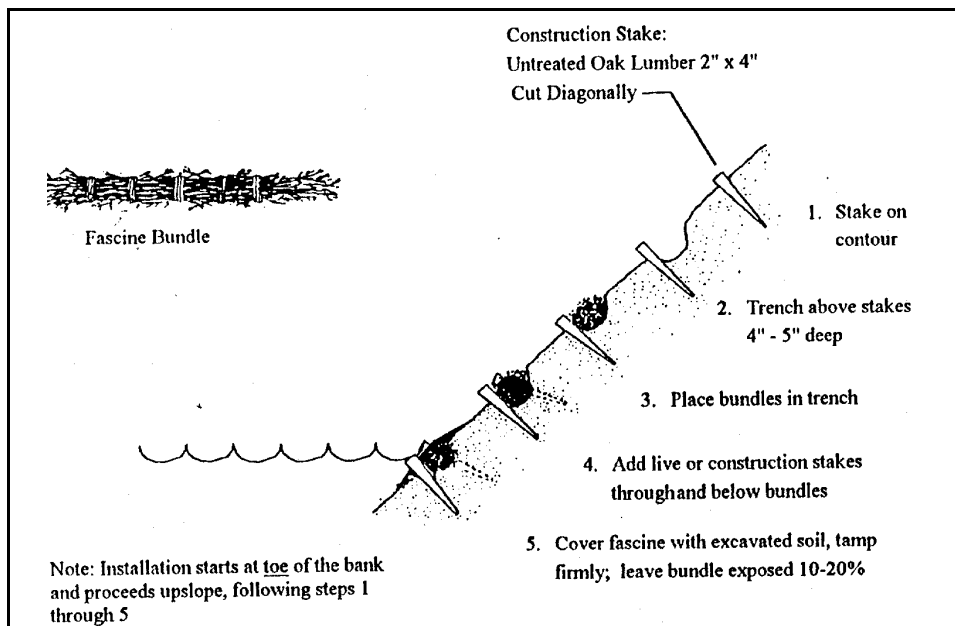


Exhibit 502b: Installation of live fascines (Source: DuPage County Streambank Stabilization Program)

- Cover fascines with excavated soil, tamping to fill voids, but leaving 10-20% of the bundles exposed.
- Eliminate air by walking on bundles.
- Continue rows to top of bank, spacing fascines according to table below (Exhibit 502c).

Slope	Slope distance between trenches (ft)	Maximum slope length (ft)
1:1 (1V:1H) to 1.5:1 (1V:1.5H)	3 - 4	15
1.5:1 (1V:1.5H) to 2:1 (1V:2H)	4 - 5	20
2:1 (1V:2H) to 2.5:1 (1V:2.5H)	5 - 6	30
2.5:1 (1V:2.5H) to 3:1 (1V:3H)	6 - 8	40
3:1 (1V:3H) to 4:1 (1V:4H)	8 - 9	50
4:1 (1V:4H) to 5:1 (1V:5H)	9 - 10	60

Exhibit 502c: Distance between fascines based on bank slope length and grade.

- Revegetate disturbed area between fascines according to vegetative stabilization method.

Special Considerations

- Make sure there is sufficient contact between soil and fascines.
- Additional toe protection may be needed in high velocity areas.
- Store cut brush under cold water (lake, stream, pond) for up to three days before installation.

MAINTENANCE

- Low. Monitor for washouts. Follow maintenance for vegetative stabilization.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 503 Branch Packings.
- Practice 505 Brush Mattress.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
- Tennessee Riparian Restoration Handbook.
- Iowa Streambank Erosion Control.
- DuPage County Streambank Stabilization Program.
- NRCS Engineering Field Handbook.

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PRACTICE 503 BRANCH PACKINGS

- DESCRIPTION**
- Alternating layers of branches and soil incorporated into a hole or slumped out area in a slope or a streambank. Branches are used both underwater and above. The branches above the water line root to form a permanent installation while those below the water line provide initial stability.



Exhibit 503a: Branch Packings (Source: NRCS Engineering Field Handbook)

PURPOSE	<ul style="list-style-type: none"> • To repair washouts and scoured holes.
WHERE APPLICABLE	<ul style="list-style-type: none"> • Particularly useful method for banks that have had washouts. • Applicable even where water is fast and moderately deep. • Washout or hole should be no more than 12' long, 5' wide, and 4' deep.
ADVANTAGES	<ul style="list-style-type: none"> • Creates an immediate barrier, redirecting water away from the washed out area. • Cuttings normally available locally. • Produces immediate filter barrier. • Useful in fast moving water. • Permanent and natural appearance. • Improved riparian habitat
CONSTRAINTS	<ul style="list-style-type: none"> • Large amounts of branches required. • Very labor intensive.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> • Live cuttings which readily root. Cuttings may be 0.5" to 3" in diameter and long enough to reach the original bank soil with 12" left exposed on the stream side.

- Stakes 6' to 8' long.
- Large rocks, soil and gravel.

Installation

- Starting below the low water line, drive stakes vertically into the soil, 3' apart.
- Place a 3" - 4" layer of compressed branches in the bottom of the washout, between the vertical stakes. Cover branch mat with 8" to 12" of soil and gravel. Rocks large enough to resist the current may be placed on top of the branch mat from the stream bottom up to the average water level.
- Layers of branches are installed with the basal ends angled down into the streambank so that they are at least 12" lower than the tips of the branches.
- Follow each layer of branches with a soil and gravel mix. Compact thoroughly to insure soil contact with branch cuttings.
- Successive layers of branches and fill are alternated until the washout is completely filled.
- Branch tips must extend beyond the soil layers to grow. Basal ends must extend into undisturbed soil.

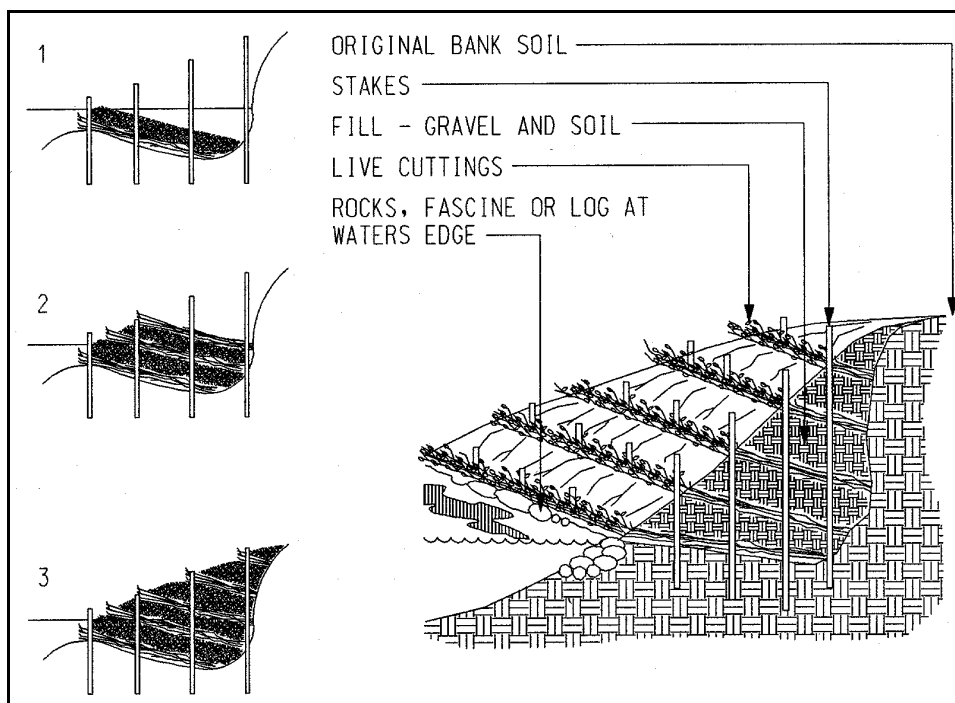


Exhibit 503b: Installation of Branch Packings (Source: CBBEL Files)

Special Considerations

- Make sure there is sufficient contact between soil and live cuttings.
- Rocks, fascine, or a log may be placed at water's edge.
- Branch packings should not be constructed over 5' in height (including the footing), and no more than 10' in length, without the assistance of a knowledgeable professional.

MAINTENANCE

- Low. Monitor and repair as necessary.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 509 A-Jacks.
- Practice 510 Stone Riprap.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
 - Soil Bioengineering Strategies.
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PRACTICE 504 TREE REVETMENTS

DESCRIPTION

- Anchoring dead, cut trees along an eroding streambank to control erosion.

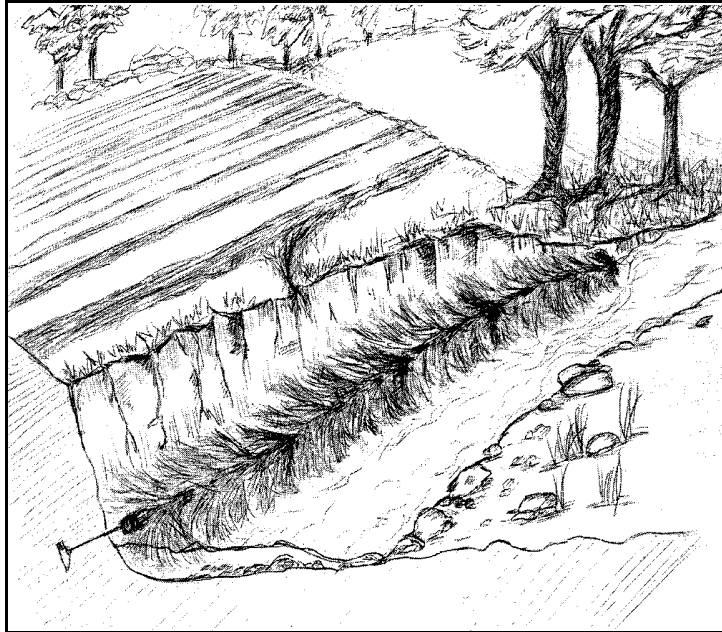


Exhibit 504a: Tree Revetments (Source: Watershed Council Shoreline Erosion Guidebook)

PURPOSE

- To slow the current along eroding banks and cause desirable deposition of silt, sand, and gravel.

WHERE APPLICABLE

- On bends of small to medium sized streams where original cover has been removed.

ADVANTAGES

- Inexpensive.
- Easy to install.
- Materials readily available.
- Provides aquatic and wildlife habitat.

CONSTRAINTS

- Only recommended for small to medium sized streams with minimal to moderate erosion problems.
- Not recommended for highly unstable streams or channels.
- Should not be used if the eroding stream bank is over 12' high.
- Not recommended if the toe is more than 2.5' below the NWL.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Large, live trees (evergreens work best).
- Driven earth anchors or steel fence posts.
- Cable (3/16" aircraft cable or larger) and cable clamps.

Installation

- The first tree revetment should be placed at the downstream end of the eroding bank, with the butt-end pointed upstream.

- Anchor both ends of each revetment tightly against the toe of the bank using earth anchors or steel fence posts, and aircraft cable.
- Each subsequent revetment should overlap the prior revetment in a fishscale pattern, and anchored as described earlier.

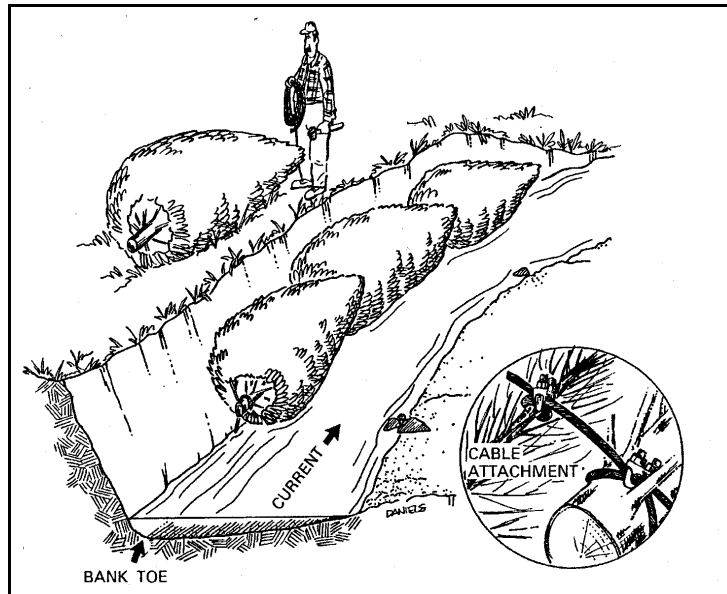


Exhibit 504b: Installation of tree revetments (Source: Missouri Tree Revetments)

Special Considerations

- Live, cut trees work better than dead trees because they are more flexible, and last longer.
- Evergreens are preferred over hardwoods because of the conical shape of evergreens, and dense branches and needles.
- Large trees are preferred over small trees.
- Cedar trees placed in early summer can dry out and lose their needles, thus reducing their ability to trap sediment and slow water flow.
- Revetments may be fortified with other vegetative techniques once enough silt has been deposited to support a seed bed or live stakes.

MAINTENANCE

- Revetments should be inspected following flood events and repaired as necessary.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 505 Brush Mattress.

Other Sources of Information

- Missouri Tree Revetments.
- Watershed Council Shoreline Erosion Guidebook.
- Stream Habitat Improvement Handbook.

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PRACTICE 505 BRUSH MATTRESS

- DESCRIPTION**
- Mat of live brush fastened down over an eroded bank.



Exhibit 505a: Brush Mattress (Source: NRCS files)

PURPOSE	<ul style="list-style-type: none"> ● Erosion protection; rebuilds banks by capturing sediment
WHERE APPLICABLE	<ul style="list-style-type: none"> ● Approximately 2:1 (1V:2H) slopes or flatter. ● Low to high velocity reaches.
ADVANTAGES	<ul style="list-style-type: none"> ● Captures sediment during flood events which helps rebuild the bank. ● Produces immediate surface protection against floods. ● Establishes dense riparian growth.
CONSTRAINTS	<ul style="list-style-type: none"> ● Labor intensive. ● Gullies may form under mat before brush takes root. ● Additional toe protection often necessary.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> ● Approximately 6' long flexible, live brush. ● Oak construction stakes (2" x 2"), at least 3' long. ● Live Fascine (Practice 502), Riprap (Practice 510), or coconut roll. ● Polyethylene net or jute rope. ● Sod staples. ● Topsoil.

Installation

- Install live fascine, riprap, or coconut fiber log at toe of slope.
- Place live brush on slope with stems tucked under toe protection structure, and stems smooth against the slope.
- Continue placing brush in a shingle pattern up the slope, at least 12" thick.
- Drive stakes perpendicular to the slope in rows, 3' on center, with only a few inches remaining above the brush.
- Place polyethylene net over brush and staple to wood stakes.
- Drive stakes deeper into the bank to tighten the net.
- Cover mattress with 1"-2" of topsoil.
- Broadcast seed a cover crop such as annual and perennial ryegrass.

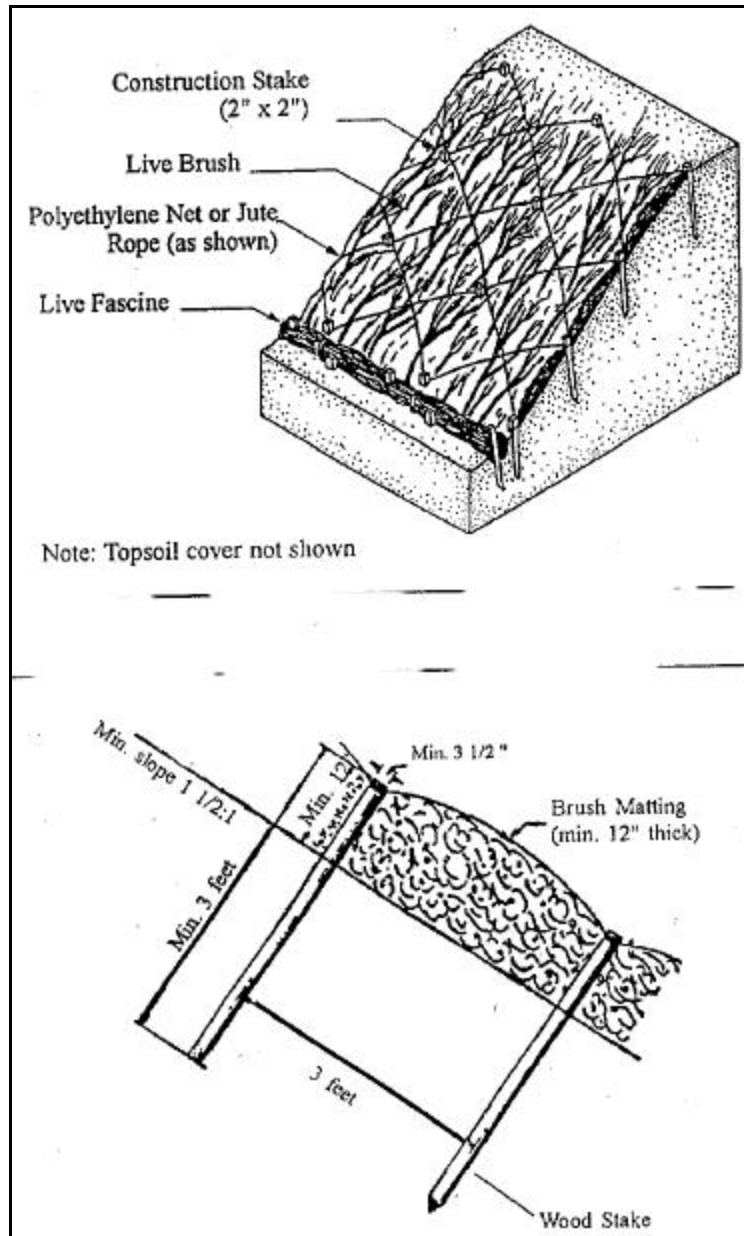


Exhibit 505b: Installation of a brush mattress (Source: DuPage County Streambank Stabilization Program)

Special Considerations

- Brush should contain a diverse assemblage of species recommended in vegetative stabilization technique (Practice 1102), and prepared according to the live stakes method (Practice 501).
 - Jute rope may be laced between stakes in a diamond pattern in place of netting; the rope must be stapled to the wood stakes before final driving.
 - Make sure there is good branch to soil contact so brush can root along the entire length of the branches.
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MAINTENANCE

- Monitor and repair as necessary.
 - Beware of gullies forming beneath the mattress before roots become established.
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REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 504 Tree Revetments.

Other Sources of Information

- DuPage County Streambank Stabilization Program.
 - Watershed Council Shoreline Erosion Guidebook.
 - Tennessee Riparian Restoration Handbook.
 - Soil Bioengineering Strategies.
 - Metropolitan Washington Watershed SourceBook.
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PRACTICE 506 VEGETATIVE GEOGRID

- DESCRIPTION**
- Soil lifts wrapped with natural or synthetic geotextile materials between which are placed layers of live branches.



Exhibit 506a: Vegetative Geogrid (Source: Biotechnical Erosion Control Limited)

PURPOSE	<ul style="list-style-type: none"> ● Rebuilds banks by capturing sediment; reinforces bank.
WHERE APPLICABLE	<ul style="list-style-type: none"> ● Streams with moderate to steep slopes. ● High velocity areas.
ADVANTAGES	<ul style="list-style-type: none"> ● Immediately reinforces bank at a steeper angle. ● Captures sediment and contributes to rebuilding the bank. ● Provides medium for revegetation.
CONSTRAINTS	<ul style="list-style-type: none"> ● Labor intensive.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> ● Brush of varying species and lengths (See Practice 501 Live Stakes). ● Suitable soil or soil/gravel fill. ● Vegetative stabilization (See Practice 1102). ● Natural (burlap) or synthetic geotextile fabric. ● 1" x 2" oak stakes, 1' - 2' long. <p>Installation</p> <ul style="list-style-type: none"> ● Live cut brush is placed on the ground, perpendicular to the stream. ● Brush is covered with the geotextile. ● Fill material is placed over the geotextile and compacted.

- Geotextile is tightly wrapped around the soil layer and secured with the stakes.
- Live brush is placed between each soil lift.
- Continue the above process until the desired height is achieved. The final level should be finished with branch packings.

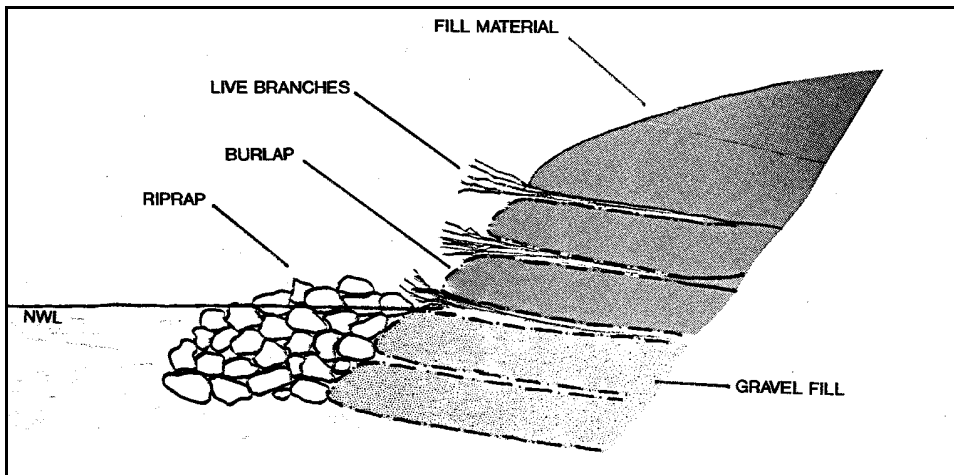


Exhibit 506b: Construction of a vegetative geogrid (Source: CBBEL Files)

Special Considerations

- Gravel fill may be used in the bottom tiers; rock may be placed at the toe of the slope for added protection.

MAINTENANCE

- Monitor and repair as necessary.
- Beware of gullies forming beneath the mattress before roots become established.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 507 Live Cribwalls.
- Practice 508 Lunkers.
- Practice 509 A-Jacks.

Other Sources of Information

- DuPage County Stream Stabilization Program.
- Soil Bioengineering Strategies.

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PRACTICE 507 LIVE CRIBWALLS

- DESCRIPTION**
- A rectangular framework of logs, rock, and woody cuttings used to protect an eroding streambank, especially at outside bends of main channels where strong currents are present, and at locations where an eroding bank may eventually form a split channel.



Exhibit 507a: Live Cribwalls (Source: NRCS Engineering Field Handbook)

PURPOSE	● To protect eroding streambanks.
WHERE APPLICABLE	● Especially useful at outside bends of main channels with strong currents, and at locations where an eroding bank may eventually form a split channel.
ADVANTAGES	<ul style="list-style-type: none"> ● Immediate erosion protection. ● Permanent and natural appearance. ● Improves aquatic and wildlife habitat.
CONSTRAINTS	<ul style="list-style-type: none"> ● Requires local availability of logs and rocks. ● Very labor intensive. ● More complex than fascines or branch packings. ● May require riprap at end points. ● Not applicable where bed is severely eroded as undercutting will occur. Not suitable for rocky terrain or for use in narrow reaches with high banks on both sides.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> ● Bark free logs at least 6" in diameter. ● Plant cuttings (See Practice 501 Live Stakes). ● Fill must include granular material to support plant growth. ● Timber spikes or rebar.

Installation

- Dig out cribwall base 2 - 3' below existing streambed.
- Place first log parallel to the water's edge, and at bottom of excavated channel.
- Place fiber roll or live fascine at toe of slope.
- Place next layer of logs on top of and perpendicular to first log, approximately 4' apart. Attach logs to each other using spikes or rebar.
- Install Branch Packings (Practice 503) and fill between the logs.
- The top layer should be compacted with fill; the top log should be parallel to the edge of the stream.
- Height of cribbing should be 50-70% of the height of the bank.
- May require riprap at endpoints.
- A double cribwall may be constructed by placing an additional log parallel and adjacent to the bank for each layer.

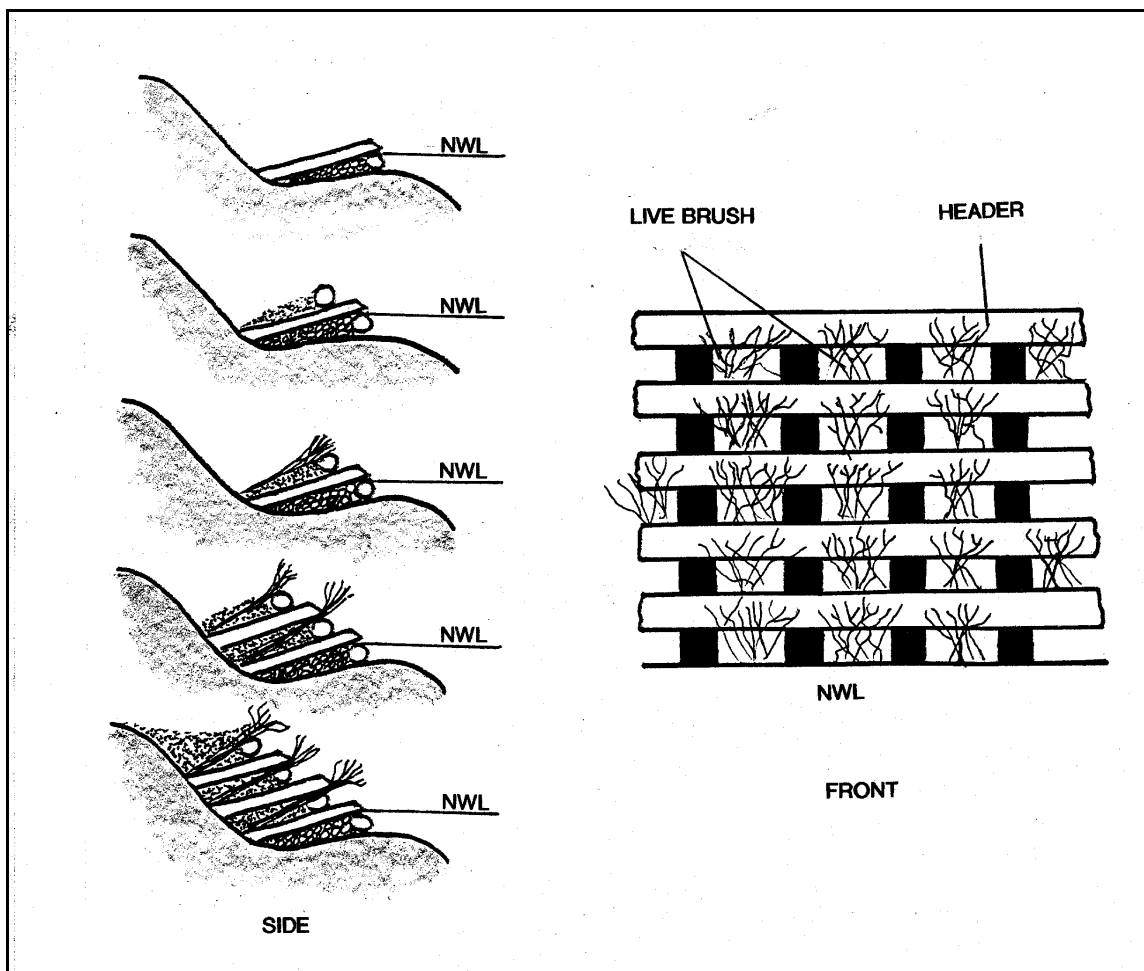


Exhibit 507b: Construction of a live cribwall (Source: CBBEL Files)

Special Considerations

- Live cribwall over 6' tall should not be constructed without the assistance of a knowledgeable professional.

MAINTENANCE

- Low. Monitor and repair as necessary, especially at ends of structure.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 508 Lunkers.
- Practice 509 A-Jacks.
- Practice 506 Vegetative Geogrid.
- Practice 510 Stone Riprap.
- Practice 512 Gabion Retaining Wall.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
 - Soil Bioengineering Strategies.
 - DuPage County Streambank Stabilization Program.
 - IWL Streambank Protection Methods.
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PRACTICE 508 LUNKERS

- DESCRIPTION**
- Oak or plastic (Eco-wood) rectangular boxes built into toe of bank to eliminate scour and provide fish habitat.



Exhibit 508a: Lunkers (Source: CBBEL Files)

PURPOSE	<ul style="list-style-type: none"> ● Protect toe of bank and provide aquatic habitat.
WHERE APPLICABLE	<ul style="list-style-type: none"> ● Undercutting at toe of bank. ● Approximately 3:1 (1V:3H) slope. ● Straight or curved sections.
ADVANTAGES	<ul style="list-style-type: none"> ● Immediate erosion protection at toe of slope. ● Provides habitat.
CONSTRAINTS	<ul style="list-style-type: none"> ● Labor intensive. ● Requires equipment for excavating and backfilling.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> ● Eco-wood or oak lunker. ● 5/8" rebar in 5' lengths (9 per lunker) ● Geotechnical fabric. ● Live Stakes (Practice 501). ● Vegetative Stabilization (Practice 1102).

Installation

- Follow procedures for vegetative stabilization.
- Excavate trench in channel at toe of bank so extending end of stringer lies flat across undistributed soil.
- Lay lunkers in trench end to end.
- Drive 9 rebars through each lunker, into streambed.
- Place riprap on top of lunkers, and backfill with excavated material.
- Slope stream bank back at 3:1 (1V:3H) slope and tamp.
- Revegetate disturbed area according to vegetative stabilization method.

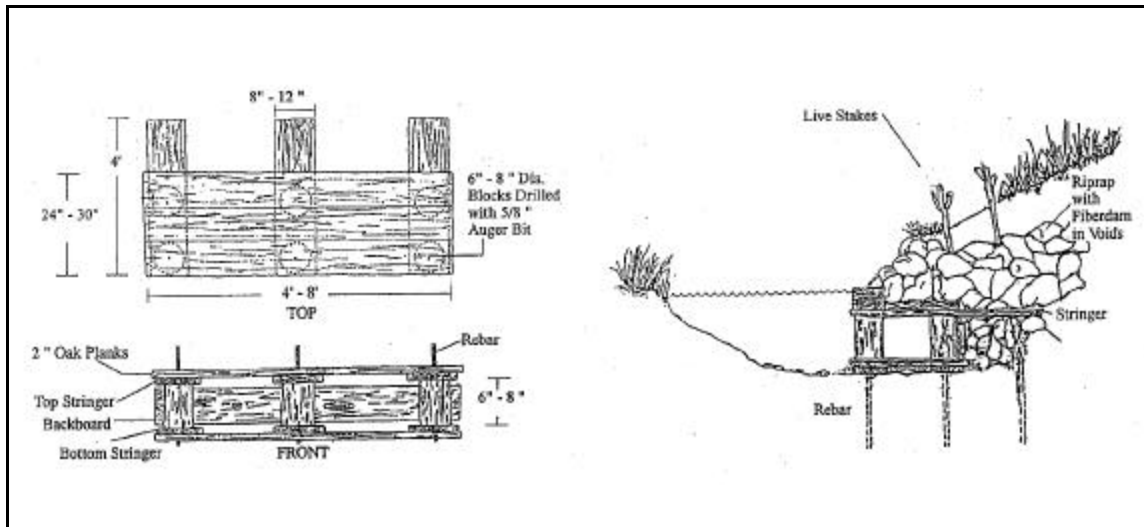


Exhibit 508b: Construction of a lunker structure (Source: DuPage County Streambank Stabilization Program)

Special Considerations

- Only use oak lunkers where baseflow is high enough to completely submerge lunker.

MAINTENANCE

- Low. Monitor and repair as necessary, especially at ends of structure.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 506 Vegetative Geogrid.
- Practice 510 Stone Riprap.
- Practice 512 Gabion Retaining Wall.

Other Sources of Information

- DuPage County Streambank Stabilization Program.

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PRACTICE 509 A-JACKS

- DESCRIPTION**
- Concrete, jack-like structures set at toe of bank. Often integrated with live stakes and other vegetative stabilization techniques.



Exhibit 509a: A-Jacks Installation (Source: Illinois State Water Survey Publication)

-
- PURPOSE**
- To protect streambanks from the erosive forces of flowing water and to stabilize the soils along the channel bank.

-
- WHERE APPLICABLE**
- Along eroded toe.
 - Low to high velocity areas.
 - Scour holes.

-
- ADVANTAGES**
- Protects soil from scour during plant propagation.
 - Provides erosion control protection even if vegetation does not become established.
 - Immediate erosion protection at toe of slope.
 - Improves aquatic and wildlife habitat.

-
- CONSTRAINTS**
- Labor intensive.
 - Must be used in conjunction with vegetative stabilization.

-
- DESIGN AND CONSTRUCTION GUIDELINES**
- Materials**
- 2' A-Jacks.
 - Live Stakes (Practice 501).
 - Fiberdam - geotechnical material.
 - Vegetative Stabilization (Practice 1102).
 - Suitable backfill.

Installation

- Follow preparation procedures for vegetative stabilization.
- Excavate 1' deep trench in channel at toe of bank.
- Lay an interlocking row of A-Jacks in trench.
- Place live stakes according to live stakes method, and fiberdam in voids between A-Jacks.
- Backfill until A-Jacks are completely buried.
- Slope streambank back at 3:1 (1V:3H) slope, if possible, and tamp.
- Revegetate disturbed area according to vegetative stabilization methods.

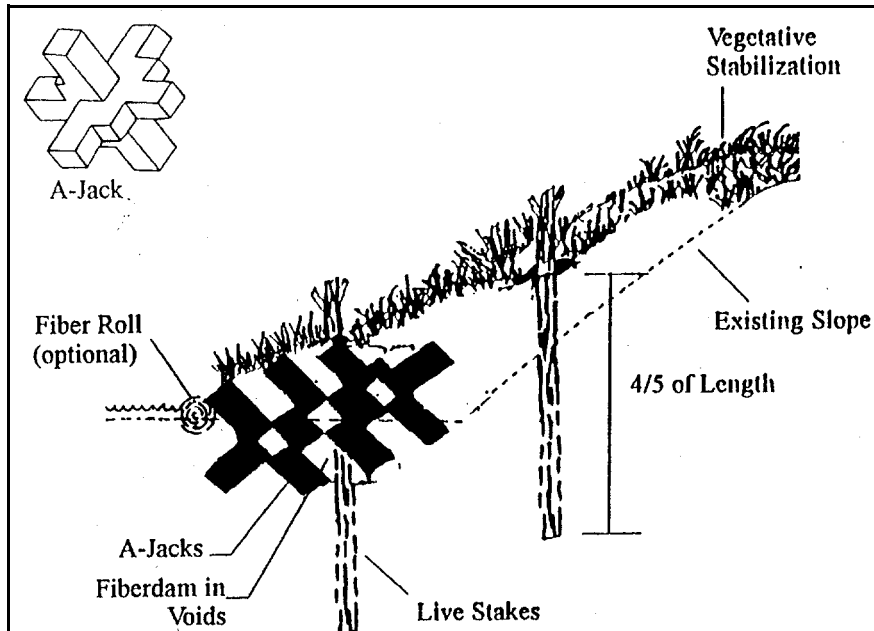


Exhibit 509b: Installation of A-jacks in conjunction with live stakes and vegetative stabilization (Source: DuPage County Streambank Stabilization Program)

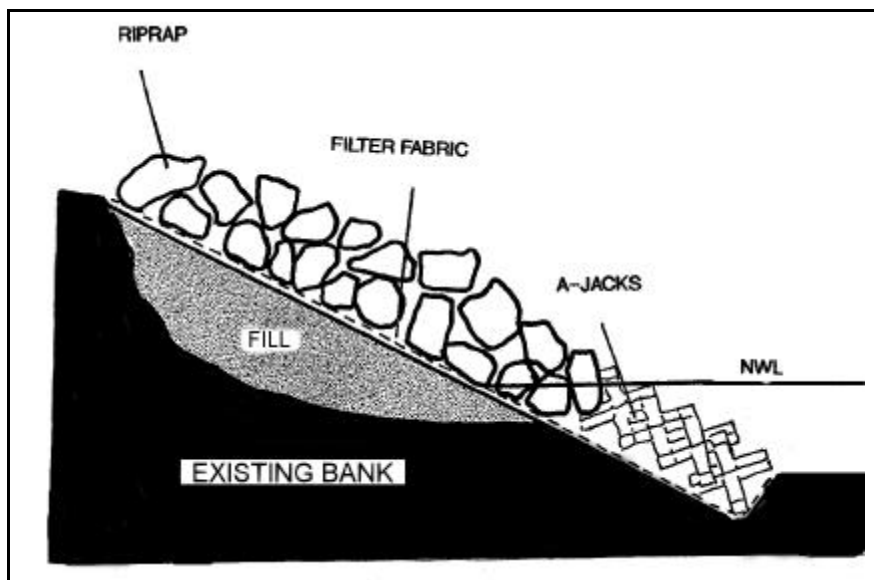


Exhibit 509c: A-jacks used in conjunction with riprap (Source: CBEL Files)

Special Considerations

- A-Jacks should be stacked above the 5-year high flow elevation and trenched in 2' deep.
 - Combine fiber roll with A-Jacks when wave action is evident or immediate natural appearance is desired.
 - May be combined with riprap.
-

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packing.
- Practice 506 Vegetative Geogrids.
- Practice 507 Live Cribwalls.
- Practice 508 Lunkers.

Other Sources of Information

- DuPage County Streambank Stabilization Program.
 - Illinois State Water Survey Publication.
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Last Print/Revision Date: October 13, 1996

PRACTICE 510 STONE RIPRAP

- DESCRIPTION**
- Covering of a portion of a channel bank with a layer of stone that approximates the natural slope of the channel bank. (Note: This practice is also included in the Indiana Erosion Control Handbook.)



Exhibit 510a: Stone Riprap (Source: North Carolina Erosion Control Manual)

PURPOSE	● To protect streambanks from the erosive forces of flowing water.
WHERE APPLICABLE	<ul style="list-style-type: none">● On small to medium sized channels and on all character types.● Generally applicable where flow velocities exceed 6 ft/sec or where vegetative streambank protection is inappropriate.● Shaded areas.● Streams where water levels fluctuate.● Actively eroding banks usually along channel curves or wherever it is desirable to reduce the energy of the water.
ADVANTAGES	<ul style="list-style-type: none">● Relatively inexpensive, especially compared to other structural methods such as walls.● Flexible and resistant to scour.● Allows for water percolation.
CONSTRAINTS	<ul style="list-style-type: none">● Available stone must be able to resist the force of high velocity water flows.● Not recommended on steep slopes or areas where slope cannot be regraded to 2:1 (1V:2H) or flatter.● Hand-placed riprap is labor intensive.● Flooding may wash riprap into stream.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Hard, angular and weather-resistant stone having specific gravity of at least 2.5.
- Where available, use local stone. Local stone can often be obtained at lower cost and it also blends better into the existing streambank environment.
- 50% of stone (by weight) must be larger than specified d_{50} and no more than 15% of the pieces (by weight) should be less than 3 inches.
- Geotextile fabric or sand/gravel layer should be used for stabilization under all permanent riprap installations.

Installation

- Remove brush, trees, stumps and other debris.
- Excavate only deep enough for filter and riprap.
- Compact any fill material to density of surrounding natural soil.

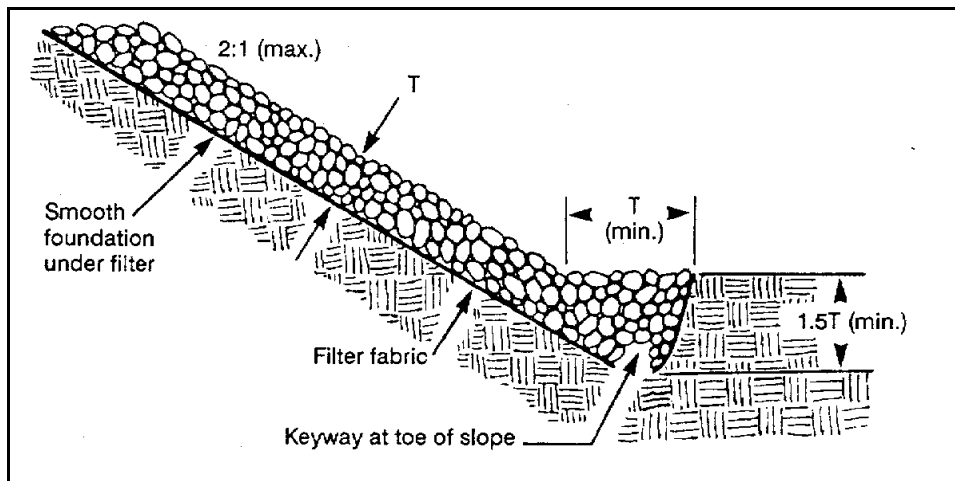


Exhibit 510b: Construction of a riprap bank with toe protection (Source: Indiana Erosion Control Handbook)

- Cut keyway at base of slope to reinforce the toe; keyway depth should be $1\frac{1}{2}$ times the design thickness of the riprap and extend a horizontal distance equal to the design thickness.
- Place geotextile fabric. If using sand/gravel filter, spread the well-graded aggregate in a uniform layer at least 6 inches thick; if 2 or more layers are required, place the layer of smaller gradation first and avoid mixing the layers.
- Add riprap to full thickness in 1 operation.
- Place smaller rock in voids to form a dense, uniform, well-graded mass. Some hand placement of material will most likely be necessary.
- Blend the riprap surface smoothly with the surrounding area to eliminate protrusions or overfalls.
- Riprap may be either hand-placed or dumped.

Special Considerations

- Use the peak 10-year storm discharge for computing the minimum expected (design) velocity.
- Foundation toe must be properly reinforced to prevent undercutting or slumping.
- Slopes steeper than 2:1 (1V:2H) should be flattened so stone material will not become displaced.
- Riprap must be properly graded to prevent stone movement and erosion of the foundation.
- Compact the slopes before placing riprap or stone settlement and displacement may occur.
- Extend riprap sections the entire length between well-stabilized points of the stream channel.
- Riprap used must be of large enough size and extend at least 12 inches below normal water level to provide habitat for aquatic organisms in the voids
- May secure toe using A-Jacks (See Practice 509)

MAINTENANCE

- Inspect periodically for displaced stone material, slumping and erosion at edges (especially downstream or downslope). Properly designed and installed riprap usually requires very little maintenance if promptly repaired.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 507 Live Cribwalls.
- Practice 508 Lunkers.
- Practice 512 Gabion Retaining Wall.
- Other Combined Practices.

Other Sources of Information

- Indiana Erosion Control Handbook.
- North Carolina Erosion Control Manual.
- Pennsylvania Streambank Stabilization Guide.
- COE Streambank Guidelines.

Last Print/Revision Date: October 13, 1996

PRACTICE 511 CONCRETE RETAINING WALL

DESCRIPTION ● A permanent concrete wall which retains a stream bank.



Exhibit 511a: Concrete Retaining Wall (Source: Land and Water Magazine)

PURPOSE	<ul style="list-style-type: none"> ● Create permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.
WHERE APPLICABLE	<ul style="list-style-type: none"> ● Stream channels of all types and sizes. ● Stream channels with widely fluctuating water levels, and with high velocities.
ADVANTAGES	<ul style="list-style-type: none"> ● Low maintenance. ● Provides permanent stability. ● Prevents erosion and scouring.
CONSTRAINTS	<ul style="list-style-type: none"> ● Expensive compared to other types of walls. ● Requires heavy equipment. ● Lacks ecological value. ● May exacerbate downstream erosion problems if not installed properly. ● Limited to areas with sufficient room for installation. ● May be objectionable aesthetically. ● Must be designed by an engineer to fit conditions to the site.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> ● Concrete. ● Support structures. ● Reinforcing steel (some types). ● Forms and formwork.

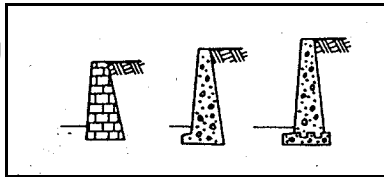
Installation

- Assemble general information: topographical and physical surveys, controlling dimensions.
- Analyze subsoil conditions.
- Select type and tentative wall proportions.
- Compute each pressure and surcharge pressure.
- Analyze structural stability.
- Analyze foundation stability.
- Design structural elements.
- Select drainage in backfill.
- Predict settlement and movement of walls.

Special Considerations

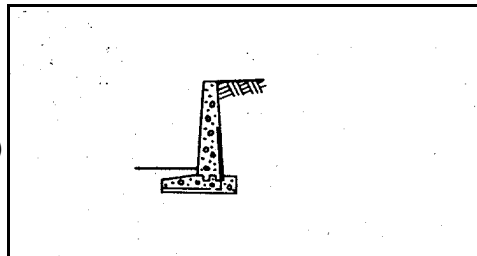
- There are five principle types of concrete retaining walls:
- Gravity Walls: No tensile stress. Heavy construction provides plenty of relative strength, but may not be economical for high walls.

Exhibit 511b: Gravity Retaining Wall (Source: Teng Foundation Design)



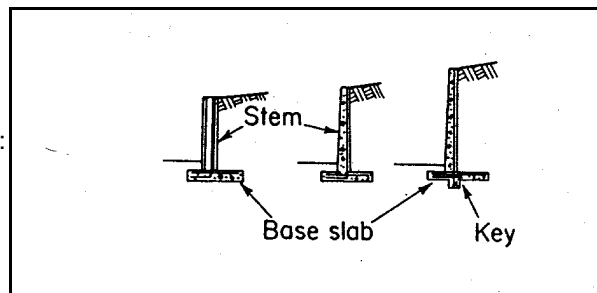
- Semi-Gravity Walls: Some reinforcing steel necessary to reduce the mass of concrete.

Exhibit 511c: Semi-Gravity Retaining Wall (Source: Teng Foundation Design)



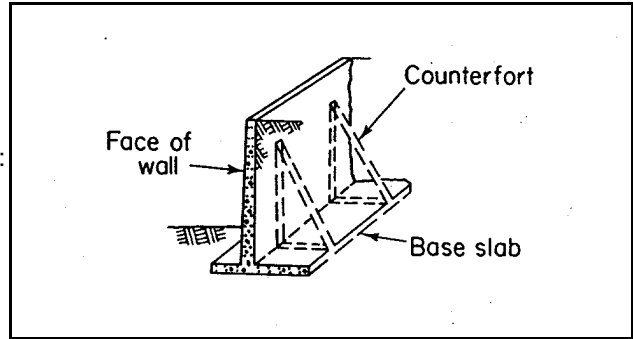
- Cantilever Walls: Inverted T forms base and acts as cantilever. Usually made of reinforced concrete, but concrete blocks may be used. Economical for walls $\leq 25'$.

Exhibit 511d: Cantilever Retaining Wall (Source: Teng Foundation Design)



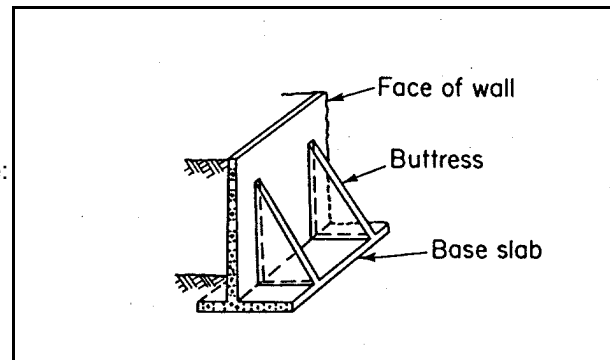
- Counterfort Walls: Like cantilever walls but with vertical brackets called counterforts on the bank side of the wall.

Exhibit 511e: Counterfort Retaining Wall (Source: Teng Foundation Design)



- Butressed Walls: Like counterfort walls but brackets (buttresses) are on stream side of wall.

Exhibit 511f: Butressed Retaining Wall (Source: Teng Foundation Design)



MAINTENANCE

- Low.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.

REFERENCES

Related Practices

- Practice 507 Live Cribwalls.
- Practice 510 Stone Riprap.
- Practice 511 Concrete Retaining Walls.
- Practice 512 Gabion Retaining Wall.
- Practice 513 Timber Retaining Walls.
- Practice 514 Sheetpile Retaining Walls

Other Sources of Information

- Teng Foundation Design.
 - Bulkheads and Seawalls.
-

Last Print/Revision Date: October 13, 1996

PRACTICE 512 GABION RETAINING WALL

- DESCRIPTION**
- Rock-filled baskets of wire or plastic. Baskets are wired together to form a wall or mattress for erosion control along a bank or channel.



Exhibit 512a: Gabion Retaining Wall (Source: North Carolina Erosion Control Manual)

PURPOSE	<ul style="list-style-type: none"> ● Protect steep banks where scouring or undercutting are problems.
WHERE APPLICABLE	<ul style="list-style-type: none"> ● Lining confined channels. ● Medium to large size streams and on all character types.
ADVANTAGES	<ul style="list-style-type: none"> ● Relatively economical when rock fill is available. ● Flexible, especially when combined with live plant material. ● Very effective in immediately securing unstable streambanks.
CONSTRAINTS	<ul style="list-style-type: none"> ● Labor intensive. ● Skill is required to install correctly. ● Expensive to correct if not installed correctly. ● Lacks ecological value ● May exacerbate downstream erosion problems if not installed properly. ● Requires more space than retaining walls.
DESIGN AND CONSTRUCTION GUIDELINES	<p>Materials</p> <ul style="list-style-type: none"> ● Gabion baskets. ● 4" - 8" rocks for gabions, and 2.5" - 4" for mattresses. ● Filter fabric in highly erodible areas. <p>Installation</p> <ul style="list-style-type: none"> ● Gabions and gabion mattresses must be keyed into the streambed to prevent undermining and slumping.

- Empty baskets are wired together and anchored to the streambed.
- Baskets are filled by hand or machine in one foot layers. Two connecting wires are installed with each layer until the gabions are filled.
- Adjoining gabions are wired together by their vertical edges; empty gabions, stacked on filled gabions, are wired to the filled gabions at front and back.
- Baskets are closed and securely laced once filled.
- Gabions may be built as mass gravity structures with wide bases and narrow tops.

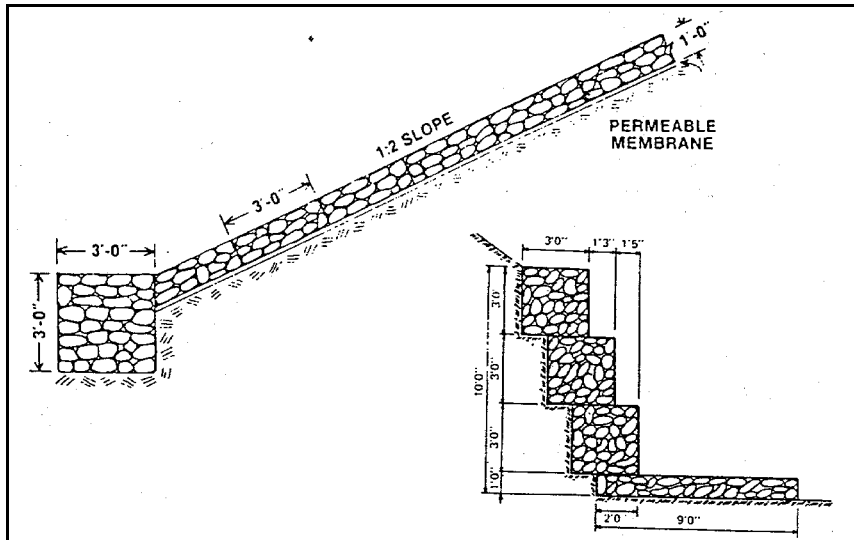


Exhibit 512b: Construction of a gabion retaining wall and mattress
(Source: North Carolina Erosion Control Manual)

Special Considerations

- Live Stakes (Practice 501) may be placed between baskets and secured into the soil when used on slopes.

MAINTENANCE

- Low. Monitor and repair as necessary.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 511 Concrete Retaining Walls.
- Practice 513 Timber Retaining Walls.
- Practice 514 Sheetpile Retaining Walls.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
 - Maccaferri Gabions, Inc. Technical Handbooks.
-

Last Print/Revision Date: October 13, 1996

PRACTICE 513 TIMBER RETAINING WALL

DESCRIPTION ● A permanent timber wall which retains a streambank.



Exhibit 513a: Timber Retaining Wall (Source: NRCS Engineering Field Handbook)

PURPOSE ● Create permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.

WHERE APPLICABLE

- Stream channels of all types and sizes.
- Stream channels with widely fluctuating water levels, and with high velocities.
- Wall heights up to 4' differential.

ADVANTAGES

- May use less skilled labor and lighter material than other walls.
- Can be adapted to a range of stream bank configurations.
- Low maintenance.
- Prevents erosion and scouring.

CONSTRAINTS

- Expensive.
- Limited to areas with sufficient room for installation.
- May be objectionable aesthetically.
- Lacks ecological value and may be discouraged by agencies due to concerns about potential negative impacts of treated lumber or plastic especially where constant or considerable contact exists with water.
- May exacerbate downstream erosion problems if not installed properly.
- Must be tied back at heights above 3' which may require excavation.
- Less permanent than stone or concrete walls.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Wood timbers treated with a preservative.
- Steel bins.
- Open graded granular backfill.

Design

- Assemble general information: topographical and physical surveys, controlling dimensions.
- Analyze subsoil conditions (visual; requires geotechnical report if over 3' high).
- Select type and tentative wall proportions.
- Compute earth pressure and surcharge pressure (over 3' high).
- Analyze structural stability (over 3' high).
- Analyze foundation stability (over 3' high).
- Design structural elements (over 3' high).
- Select drainage in backfill.

Installation

- Establish firm foundation soil. Put in at least 6". Open graded gravel as bedding.
- Lay successive courses of timbers with offset joints.
- Every fourth course, turn a timber at least as long as the height of the wall perpendicular and embedded in the soil behind the wall with a steel pin.
- Backfill with open graded aggregate and compact with each horizontal course.

Special Considerations

- The space behind the wall must be free draining so that the water pressure differentials caused by stream fluctuations are minimized.
- Wall heights over 3' should be reviewed by a structural engineer prior to installation.

MAINTENANCE

- Check for rotting timbers and replace as necessary.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.
- Watch for erosion at the wall base as undermining is often the cause of wall failure.

REFERENCES

Related Practices

- Practice 507 Live Cribwalls.
- Practice 510 Stone Riprap.
- Practice 511 Concrete retaining Walls.
- Practice 512 Gabion Retaining Wall.
- Practice 513 Timber Retaining Walls.
- Practice 514 Sheetpile Retaining Walls.

Other Sources of Information

- Teng Foundation Design.
- Bulkheads and Seawalls.

Last Print/Revision Date: October 13, 1996

PRACTICE 514 SHEETPILE RETAINING WALL

- DESCRIPTION**
- Steel, concrete, wood, or plastic sheet piles that interlock to form a continuous wall along a stream channel. The wall may be partially supported by anchors imbedded in the soil behind the wall, called tie-backs.



Exhibit 514a: Sheetpile Retaining Wall
(Source: NRCS Files)

PURPOSE	<ul style="list-style-type: none">● Create a temporary or permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.● Where land ownership or rights prohibit flattening a slope or other types of armor.
WHERE APPLICABLE	<ul style="list-style-type: none">● Stream channels of all types and sizes.● Stream channels with widely fluctuating water levels, and with high velocities.● Where permanent channel obstructions such as bridge abutments cause significant erosion.
ADVANTAGES	<ul style="list-style-type: none">● Low maintenance.● Provide permanent stability if necessary.● Prevents erosion and scouring in immediate area of sheet piling.● May be used along channels where space prohibits the construction of other structures that require more space to work.
CONSTRAINTS	<ul style="list-style-type: none">● Expensive.● Requires heavy equipment.● Should not be used in areas where boulders or bedrock would

- prevent driving piles to the appropriate depth.
- Should not be used to create very high walls in which the flexural strength of the wall might be compromised.
- May be objectionable aesthetically.
- Lacks ecological value and may be discouraged by agencies due to concerns about potential negative impacts of treated lumber or plastic especially where constant or considerable contact exists with water.
- May exacerbate downstream erosion problems if not installed properly.
- Must be reviewed by a structural engineer for stability.
- May transfer erosion downstream from sheeting if not properly transitioned.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Rolled steel, precast concrete, wood or plastic piles.
- May require anchoring structures such as cantilevers or tie rods.
- Steel: Interlocking, rolled steel sheet piles of varying weights driven into the ground. Steel is the most widely used pile material.
- Wood: Independent or tongue-and-groove interlocking planks driven edge to edge into the ground. May be permanent if permanently inundated, though generally used as a temporary structure for short to moderately high walls.
- Concrete: Precast, concrete piles driven side by side into the ground. Long service life but high initial costs. Concrete piles are more difficult to handle and drive than steel piles. May be useful in streams with high abrasion, and where the wall must support an axial load. Can induce settlement in soft foundations.
- Plastic: High density, interlocking plastic sheets. Usually vibrated into the ground. Plastic has lower structural capacities than other materials and is generally used in tie-back situations.

Installation

- The most common methods for installing sheetpiling include driving, jetting and trenching. The type of sheetpiling used usually governs the method of installation.
- Driving: Sheetpiling is typically driven with traditional pile driving equipment.
- Jetting: Water jets are sometimes necessary when driving piles into dense, cohesionless soils. Jetting should be performed on both sides of piling simultaneously but must be discontinued during the last 5'-10' of penetration.
- Trenching: Usually necessary when pile penetration is shallow and driving is impossible.
- Sheetpile retaining walls should be designed by a qualified engineer and installed in accordance with the manufacturer's specifications.

Special Considerations

- Anchored walls are required when the height of the wall exceeds heights recommended for cantilever walls, or when lateral deflections are a consideration. Proximity of an anchored wall to an existing structure is governed by the horizontal distance required for the installation of an anchor.

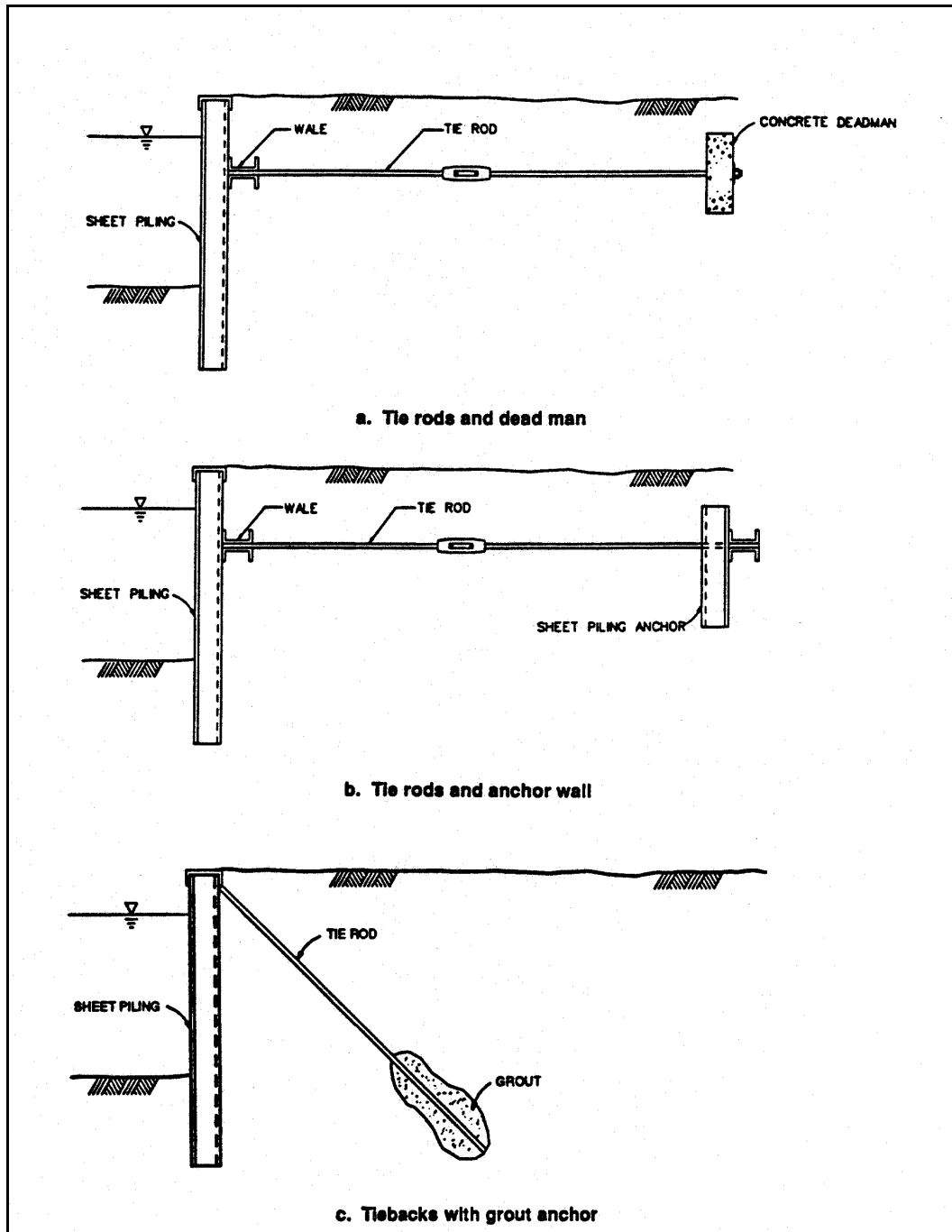


Exhibit 514b: Anchored walls (Source: COE Engineering Manual)

- Cantilever walls are usually used as floodwalls or earth retaining walls < 10' - 15' high. Cantilever walls derive their support solely from foundation soils so they may be installed relatively close (≥ 1.5

times the length of the piling) to an existing structure.

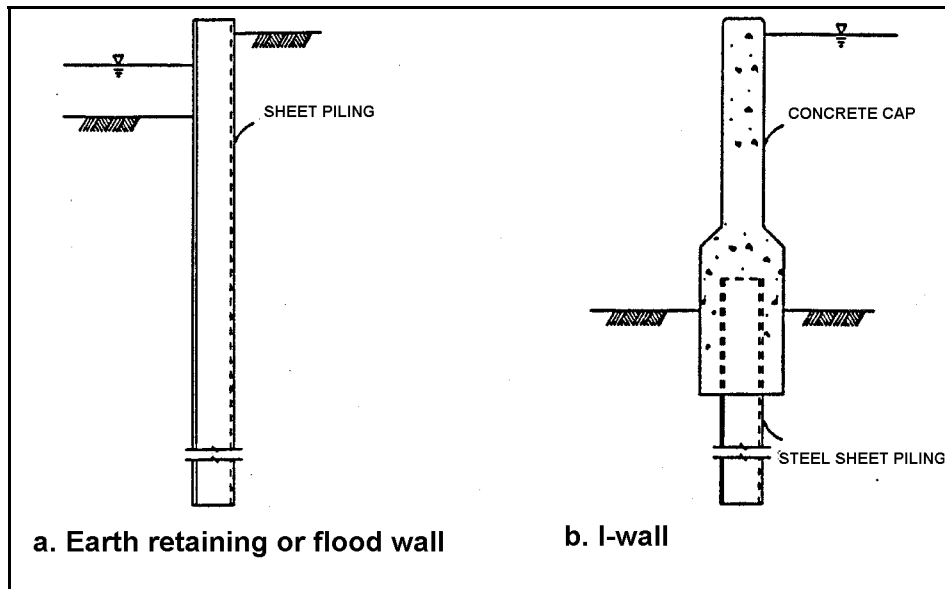


Exhibit 514c: Cantilever walls (Source: COE Engineering Manual)

- A geotechnical investigation should be conducted to identify foundation conditions, and to assist in the choice of pile material and design.
- An evaluation of system loads applied to the piling should be conducted prior to designing a wall. Loads governing the design arise primarily from the soil and water surrounding the wall, and other influences such as surface surcharges, and external loads applied directly to the piling.

MAINTENANCE

- Low.
- Uncapped, exposed sheet piling corrodes at varying rates averaging 2 - 10 mils per year, depending on surrounding atmospheric conditions. Sheetpiling driven into natural, undisturbed soils has a negligible corrosion rate. Increased erosion occurs with piles installed in organic or fresh fills.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.

REFERENCES

Related Practices

- Practice 507 Live Cribwalls.
- Practice 508 Stone Riprap.
- Practice 511 Concrete Retaining Walls.
- Practice 512 Gabion Retaining Walls.
- Practice 513 Timber Retaining Walls.
- Practice 515 Composite Retaining Walls.

Other Sources of Information

- COE Engineering Manual.

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PRACTICE 515

COMPOSITE RETAINING WALL (Soldier Pile with Sheeting)

- DESCRIPTION**
- A permanent retaining wall in which timber or pre-cast concrete are installed horizontally between steel I-beam piles.



Exhibit 515a: Composite Retaining Wall (Source: CBBEL Files)

-
- PURPOSE**
- Create a temporary or permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.
-
- WHERE APPLICABLE**
- Stream channels of all types and sizes.
 - Stream channels with widely fluctuating water levels, and with high velocities.
-
- ADVANTAGES**
- Low maintenance.
 - Provide permanent stability if necessary.
 - Prevents erosion and scouring.
 - May be used along channels where space prohibits the construction of other structures that require more space to work.
 - May be more aesthetically acceptable than sheetpiling.
-
- DISADVANTAGES**
- Expensive.
 - Requires heavy equipment.
 - Should not be used in areas where boulders or bedrock would prevent driving piles to the appropriate depth.
 - Should not be used to create very high walls in which the flexural strength of the wall might be compromised.
 - Lacks ecological value and may be discouraged by agencies due to concerns about potential negative impacts of treated lumber or plastic especially where constant or considerable contact exists with water.
 - May exacerbate downstream erosion problems if not installed properly.

- Requires professional design and geotechnical review.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Steel I-beam piles.
- Pre-cast concrete sheets, tongue and groove wood planks, or railroad ties.

Installation

- Assemble general information: topographical and physical surveys, controlling dimensions.
- Analyze subsoil conditions.
- Analyze structural stability.
- Analyze foundation stability.
- Design structural elements.
- Predict settlement and movement of walls.

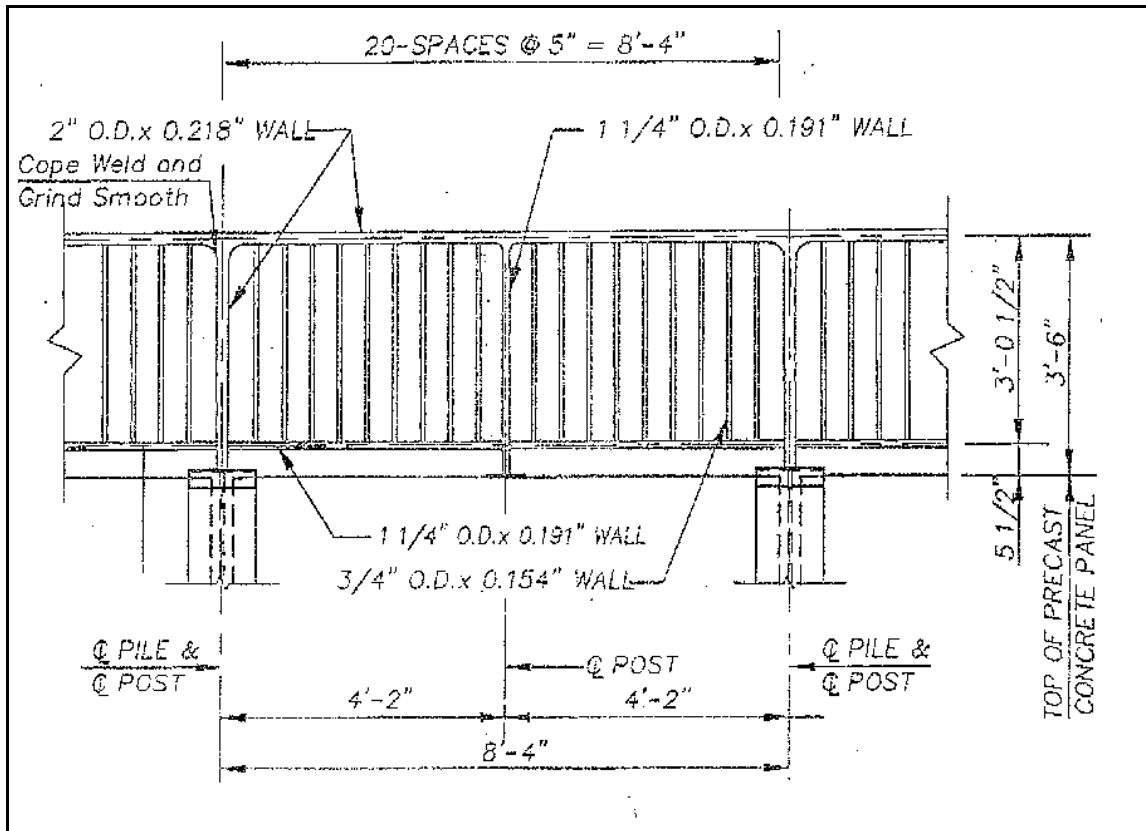


Exhibit 515b: Typical Example of a Composite Wall Design (Source: CBEL Files)

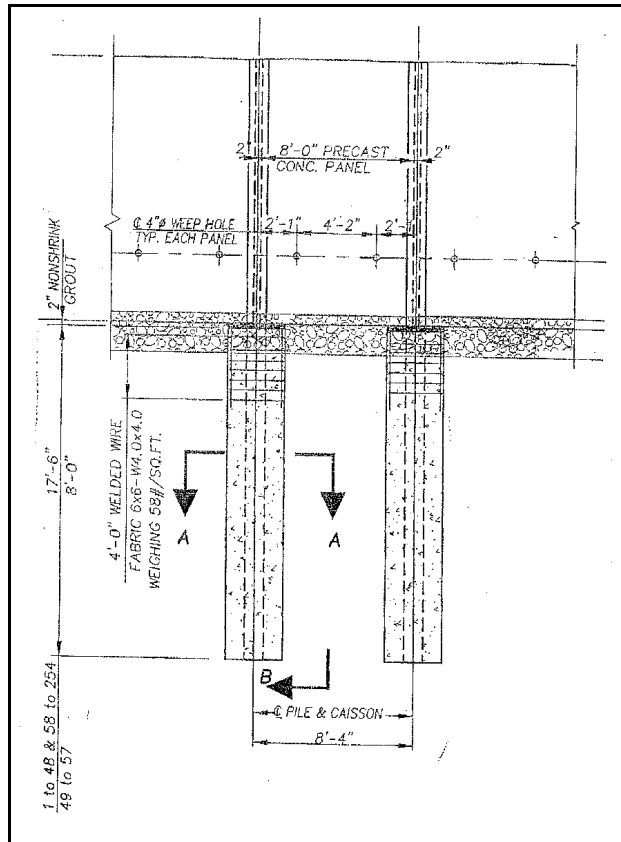


Exhibit 515c: Typical Example of a Composite Wall's Pile and Post Design Details (Source: CBBEL Files)

Special Considerations

- A geotechnical investigation should be conducted to identify foundation conditions, and to assist in the choice of pile material and design.
- An evaluation of system loads applied to the piling should be conducted prior to designing a wall. Loads governing the design arise primarily from the soil and water surround the wall, and other influences such as surface surcharges, and external loads applied directly to the piling.

MAINTENANCE

- Low.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.

REFERENCES

Related Practices

- Practice 510 Stone Riprap.
- Practice 511 Concrete Retaining Walls.
- Practice 512 Gabion Retaining Walls.
- Practice 513 Timber Retaining Walls.

Other Sources of Information

- COE Engineering Manual.

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