The WES Stream Investigation and Streambank Stabilization Handbook

Presented by

U.S. Army Engineer
Waterways Experiment Station (WES)
Vicksburg, Mississippi

Workshop made possible by a grant from the U.S. Environmental Protection Agency's Coastal Nonpoint Source Program

THE WES STREAM INVESTIGATION

AND

STREAMBANK STABILIZATION HANDBOOK

by

David S. Biedenharn, Charles M. Elliott, and
Chester C. Watson

October 1997

7.1.4 LONGITUDINAL STONE TOE

7.1.4.1 Description

Longitudinal stone toe is another form of a windrow revetment, with the stone placed along the existing streambed rather than on top bank. The longitudinal stone toe is placed with the crown well below top bank, and either against the eroding bankline or a distance riverward of the high bank. Typical crown elevations may vary but are commonly between 1/3 and 2/3 of the height to top bank.

The success of longitudinal stone toe protection is based on the premise that as the toe of the bank is stabilized, upper bank failure will continue until a stable slope is attained and the bank is stabilized. This stability is usually assisted by the establishment of vegetation along the bank.

7.1.4.2 Advantages

A longitudinal stone toe has the same advantages as a trenchfill and windrow. It also allows for the preservation of much of the existing vegetation on the bank slope, and encourages the growth of additional vegetation as the bank slope stabilizes. An additional advantage is that the treatment is amenable to the planting of additional vegetation behind it.

7.1.4.3 Disadvantages

A longitudinal stone toe also has the same disadvantages as trenchfill. By definition, longitudinal stone toe protection only provides toe protection and does not directly protect mid and upper bank areas. Some erosion of these mid and upper bank areas should be anticipated during long-duration, high energy flows, especially before these areas stabilize and become vegetated.

7.1.4.4 Typical Applications

Longitudinal stone toe protection is especially suitable where the upper bank slope is fairly stable (due to vegetation, cohesive material, or relatively low flow velocities), and erosion can be arrested by placing a windrow along the toe of the bank. This avoids the wasted effort of disturbing, then rearmoring, an existing stable slope. Small or ephemeral streams are especially suited to this approach.

The longitudinal stone toe technique may be appropriate where the existing stream channel is to be realigned, although for maximum effectiveness the top elevation of the stone must be high enough that it is not overtopped frequently. In this application, it actually functions as a retard.

7.1.4.5 Design Considerations

There are basically two variations of the longitudinal stone toe. These will be referred to as **longitudinal peaked stone toe protection,** and **longitudinal stone fill toe protection.** Design consideration for these two stabilization measures are discussed below.

Longitudinal Peaked Stone Toe Protection. An efficient design for a longitudinal stone toe is to simply specify a weight or volume of stone to be placed per unit length of streambank, rather than to specify a given finished elevation and cross-section dimensions. This basically results in a triangular shaped section of stone placed along the toe of the streambank. This type of protection is commonly referred to as a longitudinal peaked stone toe protection (Figures 7.7 and 7.8). A primary attraction of this treatment is its simplicity. Extensive surveys and analysis during design and construction would reduce that attraction. Since the volume of stone required at each section is determined by the estimated scour depth, simply specifying a volume or weight is all that is required. In the small streams of north Mississippi, longitudinal peaked stone toe protection placed at a rate of 1 to 2 tons per linear foot of streambank has proven to be one of the most successful bank stabilization measures used in that area. This generally results in a height of stone between 3 and 5 feet high above the streambed. A "typical" cross-section can be specified on the drawings, along with a relatively smooth alignment to fit site conditions. During construction, the selected alignment for the structure is flagged, and increments of length are measured as appropriate for the size of delivery vehicles or placement buckets. Design, bidding, and supervision of construction is, therefore, greatly simplified.

With longitudinal peaked stone toe protection, the establishment of vegetation landward of the structure is a critical component for a successful project. Consequently, it is important to maintain as much of the natural vegetation as possible. If at all possible, the construction site should be approached and the construction work accomplished from the riverward side of the bank to leave the existing upper bank vegetation undisturbed.

(a) One Ton Per Foot Immediately After Construction

(b) Same Site One Year Later

Figure 7.7 Typical Longitudinal Peaked Stone Toe Protection

Figure 7.8 Typical Longitudinal Peaked Stone Toe Protection With Tiebacks

Longitudinal peaked stone toe protection is easily combined with vegetative treatments for a composite design (Figure 7.9).

The centerline of the longitudinal peak stone toe protection should be constructed along a smooth alignment, preferably with a uniform radius of curvature throughout the bend. The upstream and downstream ends of the structure should be protected against flanking and eddy action.

Where the bank materials are highly erodible, and the adequacy of an unsupported stone placed along the toe of the bank may be marginal, stone dikes can be placed at intervals as "tiebacks" to prevent erosion from forming behind the structure. A spacing of one to two multiples of channel width can be used between tiebacks. At the very least, a tieback at the downstream limit of the structure is recommended.

Longitudinal Stone Fill Toe Protection. With longitudinal stone fill toe protection, a top elevation and crown width for the stone are specified, along with bank grading and/or filling to provide for a consistent cross-section of stone. The finished product could just as easily be classified as a thickened stone armor to provide a launchable toe, with the top elevation of the armor being well below top bank elevation. In fact, this method is sometimes referred to as **reinforced revetment**. There are two basic configurations of longitudinal stone fill toe protection. One method is to place the toefill stone adjacent to the high bank with the tieback stone fill placed in trenches excavated into the high bank as shown in Figure 7.10. In some instances it may be necessary to place the toefill stone riverward of the high bank as shown in Figure 7.11. Longitudinal stone fill toe protection is often used as the toe protection with other methods for upper bank protection.

Longitudinal stone fill toe protection can be "notched" in the same manner as a transverse dike or retard in order to provide an aquatic connection between the main channel and the area between the structure and the bank slope.

7.2 OTHER SELF-ADJUSTING ARMOR

Some armor materials other than stone which have the ability to adjust to scour, settlement, or surface irregularities are:

Concrete blocks;
Sacks filled with earth, sand, and/or cement; and
Soil-cement blocks.

Materials which have been occasionally used in the past, but which have serious shortcomings, are:

Figure 7.9 Longitudinal Peaked Stone Toe Protection In Combination With Willow Post Upper Bank Protection

Figure 7.10 Longitudinal Stone Fill Toe Protection Placed Adjacent to Bank With Tiebacks

Figure 7.11 Longitudinal Stone Fill Toe Protection Riverward of High Bank With Tiebacks