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Recent Criteria for Design of Groins

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RECENT CRITERIA FOR DESIGN OF GROINS

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ABSTRACT

Groins are defined as an elongated obstruction with one end on the bank of a stream and the other end projecting into the flow. Groins may be permeable allowing water to flow through at reduced velocities or impermeable blocking the current. Groins have been used successfully for river bank protection since the 19th century. Extensive research was conducted to determine the most recent design criteria for groins.

The criteria necessary to design a groin field are:

1. groin orientation;
2. length and spacing of groins;
3. predicting scour at groins;
4. elevation of groin crest;
5. groin side slopes and roots;
6. location of groins within river reach;
7. riprap size; and
8. flow conditions around groins.

INTRODUCTION

Groins have been used extensively in all parts of the world as river training

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structures to enhance navigation, to provide flood control, and to protect erodible banks. Groins are defined as an elongated obstruction with one end on the bank of a stream and the other end projecting into the flow. Groins may be permeable allowing water to go through at reduced velocities; or impermeable blocking the current. Groins may be constructed of masonry, concrete, earth or stone, steel or timber piling, gabions, or brush (Copeland, 1983). A typical cross-section and plan view of a riprap groin is shown in figure 1.

Groins or spur dikes have been used successfully for river bank protection since the 19th century. One of the earliest design guides of the 20th century was the 1953 report of the United Nations. According to the report, groins should be oriented perpendicular to the bank or at an angle of 100 deg. and groin spacing should be 2 and 1/2 times the longitudinal length. Riprap should be at least 0.3 m. thick and with a maximum weight of 70 kg. for velocities of 1.8-3.7 m/s. Riprap should have a maximum weight of 120 kg. and be 0.4 m. thick for velocities of 3.7-4.6 m/s.

DESIGN PARAMETERS

Groin Orientation

Groin orientation (defined as angle between downstream bank and axis of dike) has been determined historically by design experience. Controversy exists on whether groins should be oriented upstream, downstream or perpendicular to the flow. Garde et. al. (1961) believed that the maximum scour occurred for dikes oriented normal to the flow based on laboratory tests. Proponents of groins oriented upstream believed that flow is repelled from the banks, while flow is drawn to the bank for dikes oriented downstream. More deposition will occur downstream of dikes oriented upstream therefore requiring less protection on the bank and upstream face of the groin. Those favoring downstream orientation believe that scour and turbulence are less when the dike is oriented downstream. Downstream orientation reduces scour depth at the end of the dike. According to Copeland (1983) no conclusive tests have been made in the laboratory or field to favor an upstream or downstream orientation. Dikes should probably be oriented perpendicular to the flow because dikes oriented at angles other than 90 deg. would cost more because of the increased length required (Copeland, 1983).

Various Districts of the U.S. Army Corps of Engineers orient groins differently. Groins on the Missouri River are oriented downstream at an angle of 75 deg. The Memphis and Vicksburg Districts use perpendicular dikes. The St. Louis District uses both perpendicular and downstream-oriented dikes; the Los Angeles district uses dikes with an orientation of 75 deg.

The U.S. Bureau of Reclamation orients groins downstream on the Rio Grande. The groins have performed well based on orientation judging from the flow around the groins.

Length and spacing of groins

The length of a groin is based on the length necessary to shift current away from the bank. Gupta et al (1969) developed the following equation to determine length of spur dike:

$$\frac{L}{B} = 0.11\ (n\sqrt{F})^{1.5}$$

L = length of spur dike
B = channel width
n = empirical coefficient from graph in paper
F = Froude number.

The United Nations (1953) report recommended a spacing of 2.5 times the length of groin for concave bends and 1 times the length for convex bends. The Corps of Engineers originally spaced groins 2 times the length of groins on the Mississippi, but are currently spaced 1.5 times the dike length. The Los Angeles District of the U.S. Army Corps of Engineers recommends dike spacing of 1.5 times the length for concave banks and 2.5 times the length for convex banks (Kehe, 1984).

Predicting scour at groins

An intense vortex action occurs at or near groins. Intermittent vortices also occur on the upstream and downstream sides of groins. The turbulence associated with the vortices causes bed material to become suspended resulting in scour holes. Prediction of scour at groins is usually based on prior experience with a particular river or by the use of physical model studies. Without previous design experience, equations can be used to predict scour. The equations are summarized in Table 1 (Copeland, 1983; Kehe, 1984).

Scour equations can only provide a rough estimate of the scour depth. These equations are usually based on laboratory flume tests or prototype testing. Prototype test data are difficult to obtain because the dangerous conditions associated with data collection during high stages (Copeland, 1983) There are sharp disagreements among investigators as to which parameters are important in predicting scour. Garde et al. (1961) using dimensional analysis determined that the most important parameters were Froude number, contraction ratio, angle of the groin, and drag coefficient. Kehe (1984) determined that the scour depth is related to the Froude number, contraction ratio, sediment transport characteristics, main channel geometry and flow at the dike. Garde thought grain size and velocity were important parameters. Other researchers felt that they were not important parameters.

Copeland (1983) compared the results of the scour prediction equation to scour depths measured in the laboratory. The predictive equations varied as much as 200 percent from measured data. Therefore care should be taken when using these equations. Averaging the results for all of the scour equations may be the best procedure to determine the scour as well as comparing results to general knowledge of scour on the river.

Elevation of groin crest

Groins are frequently designed with crests at about the same elevation. However, the crest can be sloped downwards toward the bank when mid-channel erosion is necessary for a large range of stages. Kehe (1984) also concluded that stepped down dikes prevent shoaling.

Groin side slopes and roots

The slope of the spur dike at its head end affects the scour near the head. Kehe (1984) recommends using a head slope of 3 to 1 or 5 to 1. For the main portion of the dike, upstream slopes of 1.5 to 1 or 3 to 1 are recommended and downstream slopes of 2 to 1 or 4 to 1 are recommended. The root of the dike should be embedded into the bank 4 to 10 meters (Kehe, 1984).

Location of groins within river reach

The location of groins within a river reach is dependent on the location of erosion areas and appropriate groin spacing. For groins located in a bend, recommendations of 0.5 and 0.6 times the length of the bend have been used for 2 groins. For 3 groins located in a bend, groins should be located at 0.4, 0.5 and 0.65 times the length (Kehe, 1984).

Riprap sizing

Riprap sizing for groins should be based on criteria developed by the California Division of Highways. Riprap sizes are based on the average channel velocity and the location of the groin within the inside or outside of a channel curve. Riprap is usually placed at a thickness of 0.3 to 0.4 m. and filter blankets are usually used depending on the gradation of the fill material.

Flow conditions around groins

Groins constructed in a channel cause changes in the velocity and pressure fields resulting in flow that is 3-dimensional in character. Eddies with large velocities are generated downstream. Groins constructed on the Rio Grande at Santa Clara in March 1991 experienced the 2 year flood in June 1991. The three dimensional flow and pressure characteristics and rounded riprap probably caused the damage to the riprap. Adequate riprap size, shape, and thickness and properly designed filter blankets should be used to prevent riprap removal.

SUMMARY AND CONCLUSIONS

A literature review was conducted to obtain the most recent design criteria for groins. The following recommendations were obtained based on design experience and literature review:

1. Groins should be oriented either normal to the flow or slightly downstream for best performance.

2. Groin spacing should be 1.5 to 2 times the longitudinal length of groin. Groin side slopes should be set at a slope of 1.5:1 to 3:1. Groins should have a sloping crest from bank to channel and the elevation of the groins should be set below the design flood.

3. Prediction of scour at the toe of groins should be approached with caution. Wide variations in the prediction of local scour with scour equations were demonstrated in hydraulic laboratory tests (Copeland, 1983).

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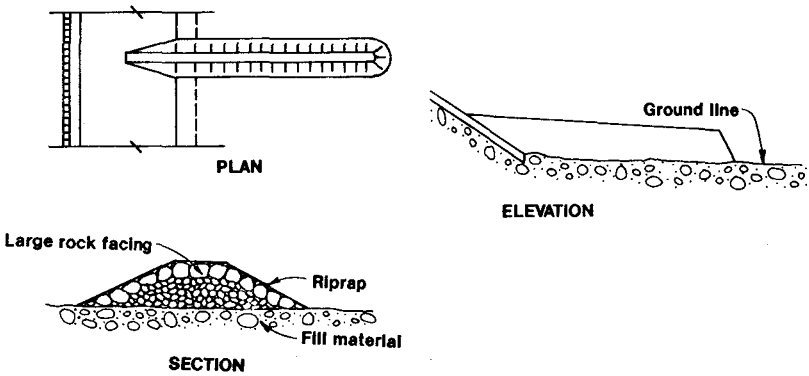

Figure 1 - Typical plan view and section of a groin.

Table I - Summary of Scour Prediction Equations

$$Y_s = k\left(\frac{Q}{f}\right)^{0.33}$$ *Inglis*

k varies between 0.8 and 1.8

$$y_s = k\left(\frac{q^2}{F_{bo}}\right)^{0.33}$$ *Blench*

k varies between 2.0 and 2.75

$$y_s = kq^{0.67}$$ *Ahmad*

$$\frac{L}{y} = 2.75\frac{y_s-y}{y}\left\{\left[\frac{1}{r}\frac{y_s-y}{y}+1\right]^{1.70}-1\right\}$$ *Laursen*

$$y_s = yK\left(\frac{B_1}{B_2}\right)F_n^n$$ *Garde et al.*

$$y_s = y + 1.1y\left(\frac{L}{y}\right)^{0.4}F_n^{0.33}$$ *Liu et al.*

$$y_s = 8.375y\left(\frac{D_{50}}{y}\right)^{0.25}F_n^{0.33}$$ *Gill*