NC STATE UNIVERSITY

Executive Analysis and Flume Study of the Rock Cross Vane

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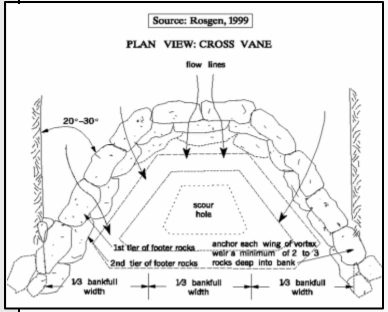
Abstract

Little research has been completed on the hydraulics and failure mechanisms of the rock cross vane. Here, a qualitative assessment of NC rock cross vanes finds the frequency, degree and causes of failures. A flume study provides physical and statistical models of the effects of recommended vane geometry on the velocity distribution of the stream flow.

Cross vane at Sharpe Creek



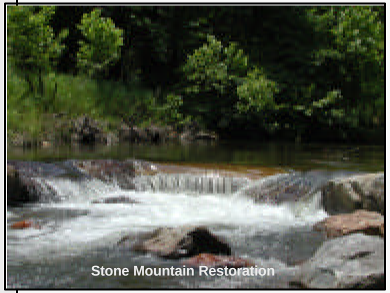
Background

What is a rock cross vane?

The rock cross vane is a specific rock formation used in stream restoration Rocks cross the stream as a U-shaped weir with an apex upstream at bed elevation and up-sloping arms.

What are its functions?

- Can maintain the channel grade and allow a protected step via large boulders.
- Angled and sloped arms turn water away from the banks to the center of the stream.
- Drop and flow constriction help establish a scour pool.



Stone Mountain Restoration

Design Specifications:

The design specifications for rock cross vane installation in North Carolina stream projects are typically 20 to 30 degree arm angle and a 3-7% arm slope. A drop no greater than 1ft drop is recommended for fish passage and structural stability .

Qualitative Analysis of the Rock Cross Vane

Goal: To obtain data from stream restoration site visits on the type, frequency and degree of functional failures and the primary and secondary causes of failures.

Methods: **1)** Identification of failure indicators and causes **2)** Development of Rapid Assessment Took and Failure Guidebook **3)** Site Assessments **4)** Analysis of assessment results **5)** FMEA Development.

Sill blow-out

Functional Failures Under Research:

- Lack of Durability of Arms and Sill
- Lack of Grade Control
- Lack of Bank Protection at Structure and Downstream of Structure
- Lack of Pool Development/ Pattern Maintenance

Downstream bank erosion

Headcut

Top 5 Paths of Failure (there can be multiple paths per failure):

1) Improper Alignment → Side cutting → Bank Erosion at the Structure (23%)
2) Sill Installed too High → Side cutting → Head Cut (22%)
3) Insufficient Backfill or matting → Undercutting → Bank Erosion at the Structure (16%)
   Insufficient Backfill or matting → Undercutting → Head Cut (16%)
   Placed in a Bend → Side Cutting → Bank Erosion at the Structure (16%)

Table 1. Failure Modes and Effects Analysis for the Rock Cross Vane

Failure Mode	Consequence Rating	Occurrence Rating	Detection Rating	Risk Priority Number
Arm Washout	4	8	4	128
Sill Washout	4	4	4	64
Headcut	4	10	4	160
Bank Erosion at Vane	7	10	4	280
Bank Erosion Downstream of Vane	7	10	4	280
Lack of Scour Pool Development	1	10	4	40

Flume Study of the Rock Cross Vane

Goals: To determine the effects of arm angle, arm slope and drop on the up and downstream velocity distributions. To develop a statistical and physical model of velocity distribution.

Methods: **1)** Chose model scale **2)** Chose factors and factor levels **3)** Constructed flume **4)** Conducted tests **5)** Analyzed results **6)** Model development

Model arms

Model Scale:

The study uses dimensionless analysis. The flume is 44 ft long and 6.5 ft wide. The bankfull depth was chosen to be 5.5 in lending a Width to Depth ratio of 14:1

Contraction:

Contraction is defined in this study as the ratio of the average center velocity to the average outer velocity. The rock cross vane is used to increase this contraction ratio. To measure contraction, five velocity points were taken across three transects in the model of the cross vane.

Velocity profile measurement

Results:

- Significant effects of drop and drop X drop. As drop increased, contraction increased.
- Significant effects of slope X drop. As drop increased, slope had a weaker positive correlation to contraction.
- Significant effects of angle X drop. As drop increased, angle had a stronger positive correlation to contraction.

Conclusions:

- Maintaining drops greater than 25% bankfull depth should provide a contraction ratio of at least 1.5 regardless of arm slope or angle.
- Focus should be on protecting the banks at the structure, thus calling for more gentle slopes on the arms.
- Geometry should first be designed to prevent reduction of cross-sectional area, then to maximize contraction.

Flow over cross vane

Paige Puckett's research is funded by the NSF Graduate Research Fellowship Program and the Department of Biological and Agricultural Engineering at NCSU. She is a Ph.D. student under the direction of Dr. Gregory Jennings.

Resources:

Rosgen, D L 1999. The Cross-Vane, W-Weir and J-Hook Vane Structures...Their Description, Design and Application for Stream Stabilization and River Restoration. Wildland Hydrology, Inc.