Analysis of Scour Countermeasures from a Constructability Point of View on Bridges for the Puerto Rico Territory

Author: Héctor Maldonado López
Advisor: Christian Villalta Calderón, Ph.D.
Master of Engineering in Civil Engineering

Abstract

Bridge scour is considered the main reason for bridge failures due to the holes that can form and compromise the structure stability. Federal regulations require all proposed bridges to be designed for scour resistance and all existing bridges to be evaluated for scour vulnerabilityVarious equations to evaluate scour are available, however many of them are considered conservative and leading to overestimation of the scour depths.For countermeasuring this failures we intend to provide Overall, the choice of abutment protection method that should consider not only constructability but also factors such as site conditions, erosion potential, environmental considerations, and design requirements.

Introduction

Bridge scour is a major problem faced by the transportation industry worldwide. Scour is the result of water flow that causes erosion of the soil around the bridge piers, leading to a loss of soil and bedrock material. This loss of material can ultimately undermine the foundation of the bridge piers, leading to structural failure. As a result, it is critical to understand the causes of scour and implement effective countermeasures to prevent bridge failures. One such countermeasure is the use of HEC-23 countermeasures.

Background

HEC-23 Countermeasures: HEC-23, or Hydraulic Engineering Circular No. 23, is a document that provides guidance on the design and construction of countermeasures for bridge scour. The document outlines a range of countermeasures that can be used to reduce the impact of scour on bridge piers. These countermeasures can be classified into three categories: structural, non-structural, and monitoring. Constructability is the ability to construct a countermeasure that meets the requirements of the design. The HEC-23 guidelines provide detailed specifications for the design and construction of countermeasures. The guidelines include information on the materials, installation procedures, and quality control measures required to ensure that the countermeasures are constructed correctly. Constructability is critical to the success of the countermeasure. If the countermeasure is not constructed correctly, it may not provide the required level of protection against scour.

Problem

The main objective of this article is to determine the best countermeasures based on constructability based on the scour evaluation results of bridges and its observed scour after the strike of a 100-year storm event within others. Furthermore, this article seeks to weigh the impact of scour overestimation on the evaluation of bridges in Puerto Rico for the implementation of countermeasures.

Methodology

The evaluation process is divided into the following four phases:

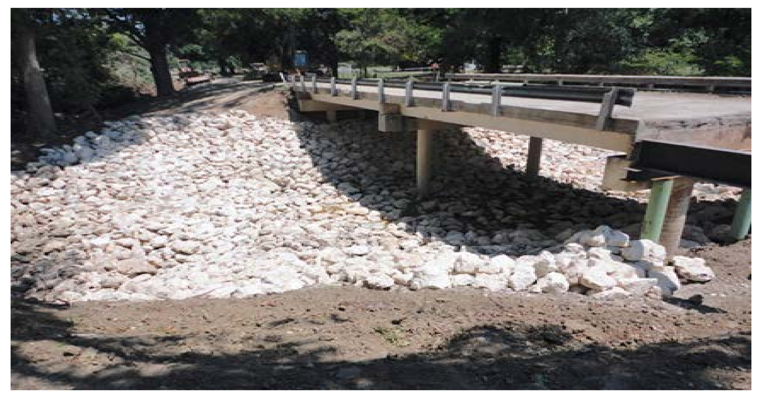
- Phase I – Data Collection and Qualitative Analysis
- Phase II – Hydrologic and Hydraulic Assessment for Scouring Analysis
- Phase III – Geotechnical and Structural Scour Assessment
- Phase IV – Plan of Action (POA)

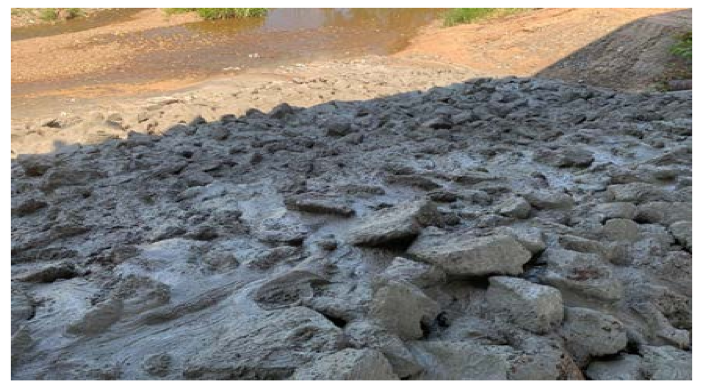
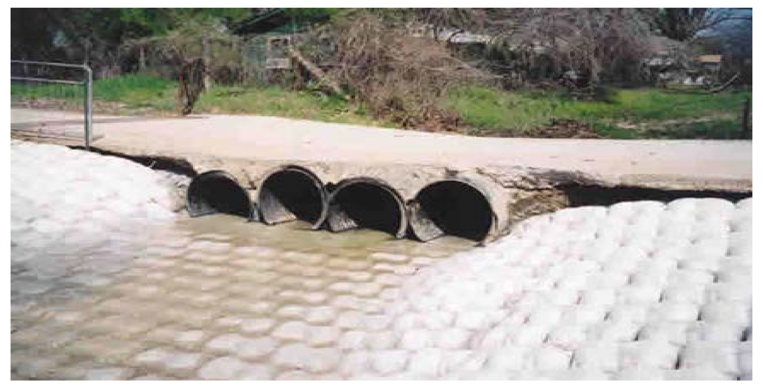
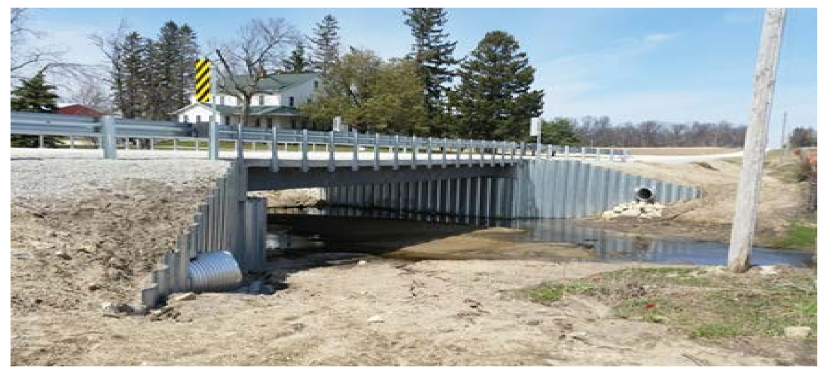
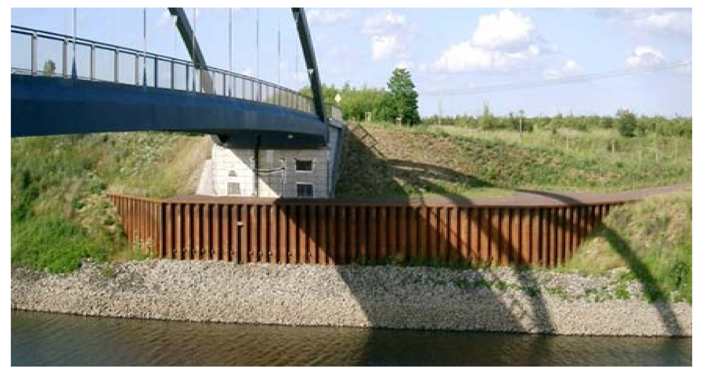
Results and Discussion

The choice of abutment protection method should consider not only constructability but also factors such as site conditions, erosion potential, environmental considerations, and design requirements. Consulting with engineers and considering the specific project constraints will help determine the most suitable method for bridge abutment protection. It's important to note that these guidelines are general in nature, and the selection of the appropriate method should be based on a thorough engineering analysis, site-specific conditions, and project requirements. Consulting with experienced engineers and considering the input of relevant stakeholders will help determine the most suitable method for bridge abutment protection in a given scenario.

Table 1.0 Constructability Advantages and Disadvantages with Recommendations

Method	Advantages	Disadvantages	Recommendations
Riprap	Provides effective erosion protection for bridge abutments. Relatively simple and cost-effective to install. Allows for natural drainage and reduces the potential for hydrostatic pressure buildup. Durable and requires minimal maintenance.	Requires careful placement and compaction to ensure stability. Limited effectiveness in high-velocity flow conditions. May require periodic inspection and maintenance to address stone displacement or loss.	Ensure proper site preparation, including grading and compaction of the underlying soil. Place riprap stones carefully, ensuring proper interlocking and compaction. Consider the size and gradation of stones to provide stability and resist erosion. Inspect and maintain the riprap periodically to address any displacement or loss of stones.
Semi-Grouted Riprap	Enhanced stability compared to traditional riprap due to the grout filling voids. Provides effective erosion control in moderate flow conditions. Offers increased resistance to stone displacement. Can be more aesthetically pleasing compared to riprap alone.	Increased complexity and cost compared to traditional riprap. Grout flow control and uniform coverage are essential for proper performance. Potential for cracking or deterioration of the grout over time, requiring maintenance.	Follow the same recommendations as for riprap installation. Coordinate the grouting process to ensure proper grout flow and coverage. Use appropriate grout mix proportions to achieve desired strength and durability. Conduct inspections to address any grout cracking or deterioration.
Grouted Riprap	Improved stability and erosion resistance compared to traditional riprap. Provides effective protection against high-velocity flow and scour. Can be designed to withstand specific hydraulic conditions. Increased durability and reduced maintenance compared to traditional riprap.	More complex and time-consuming to install compared to riprap. Requires careful proportioning and placement of the grout mix. Higher material and labor costs associated with grouting process	Prepare a well-graded stone bed to facilitate grout flow and compaction. Pay attention to the grout mix proportions, ensuring proper strength and consistency. Place the grout evenly over the stones, filling all voids thoroughly. Use compaction techniques to ensure optimal consolidation and stability of the grouted riprap layer.
Grouted Mats	Provides a continuous, interlocked surface for erosion control. Offers high stability and resistance to scour. Allows for customization of mat design to meet specific project requirements. Can be precast, reducing on-site construction time.	Requires specialized equipment and skilled labor for proper mat placement. Higher initial cost compared to other methods. May require additional maintenance and inspection to address grout cracking or mat displacement.	Coordinate with the manufacturer to ensure proper handling and placement of the precast mats. Prepare the subgrade to achieve uniform support for the mats. Fill the voids between mats with grout, ensuring complete coverage and consolidation. Conduct quality control inspections to verify interlocking, alignment, and grout flow.
Sheet Piling	Provides a structural barrier against soil and water infiltration. Offers high strength and durability. Effective in high-velocity flow conditions and scour protection. Can be designed to accommodate various soil conditions.	Requires specialized equipment for installation. Higher initial cost compared to other methods. Limited aesthetic appeal compared to natural stone-based methods. Potential for corrosion or degradation of sheet piles over time, requiring maintenance.	Prepare the site by removing any obstructions and ensuring proper soil conditions for driving sheet piles. Use specialized equipment, such as pile drivers, to install the sheet piles accurately. Ensure proper alignment and interlock between adjacent sheet piles during installation. Monitor and address any potential corrosion or degradation of sheet piles over time.



Conclusions

HEC-23 countermeasures are an effective way to prevent bridge failures caused by scour. The countermeasures include structural, non-structural, and monitoring measures that can be used to reduce the impact of scour on bridge piers. Constructability is critical to the success of the countermeasure. The HEC-23 guidelines provide detailed specifications for the design and construction of countermeasures to ensure that they are constructed correctly. By following these guidelines, it is possible to construct effective countermeasures that provide long-term protection against scour. For the Puerto Rico territory we have to be aware that due to the topographic composition of the iland, the rivers observe faster velocities and larger shear forces in shorter times than in USA wich is a major cause for the difference in the equations results and the real behavior of the rivers and water bodies.

Future Work

As a next step for this research, it would be great to develop an equation that adjusts to our reality in the territory of Puerto Rico and to the construction industry and funds as well.

Acknowledgements

It's been an honor to be working in this project under the advisory of Prof. Christian Villalta Calderón, Ph.D and in integration with my Master Project classmates. They all did an excellent job.

References

1. U.S. Department of Transportation, Federal Highway Administration, *Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance*, 3rd ed., September 2009, Hydraulic Engineering Circular Number 23, vol. 2, Publication No. FHWA-NHI-09-112.

2. S. E. Yochum, "Guidance for Stream Restoration," in *U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center, Technical Note TN-102.4*, Fort Collins, CO, 2018.

3. U.S. Department of the Interior, "Bank Stabilization Design Guidelines," in *Bureau of Reclamation, Technical Service Center*, Denver, Colorado, Report No.: SRH-2015-25, June 2015.