



TECHNICAL SUMMARY

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\$124,831



Researchers were unable to fail matrix riprap with rushing water in flume tests, verifying that it was far stronger than regular riprap.



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Preventing Bridge Scour with Matrix Riprap

What Was the Need?

Transportation agencies need to protect waterway bridges from scour, where fast-moving water strips away the rocks and sand that support bridge foundations like piers and abutments. One common countermeasure to scour is riprap—rocks placed near bridge foundations to shield them from the eroding effects of moving water. To resist the stripping force of the water, riprap must be of the appropriate size and angularity to interlock and form a sufficiently strong barrier. The faster the current, the larger riprap must be. Such rocks can be difficult to source in certain parts of Minnesota and are very expensive to transport long distances, dramatically increasing the construction costs of bridge projects.

An alternative to larger riprap involves cementing smaller rocks together with grout, expanding the availability of riprap sources. This matrix riprap, also called partially grouted riprap, uses enough grout to bond rocks to each other without completely sealing the gaps between them, providing drainage and allowing the riprap to move and “self-heal” after floods. Matrix riprap is particularly promising for protecting spill-through abutments—abutments that are set back from the channel with an embankment that slopes down to the river. While the effectiveness of matrix riprap has been studied for bridge piers, it has not been studied for bridge abutments.

What Was Our Goal?

The goal of this study was to evaluate the performance of matrix riprap when used on spill-through abutments, including the effects of size, stone angularity and percent grout under a variety of flow conditions.

What Did We Do?

After an initial literature review, researchers conducted site visits to observe the installation of matrix riprap on bridges. Then they performed laboratory experiments to evaluate matrix riprap application and installation, placing it in watertight boxes and applying grout according to MnDOT recommendations. Researchers then conducted mechanical pull tests on riprap specimens with and without grout, connecting steel cables to rocks and using a half-ton electric hoist to pull the specimens until they either failed or the hoist’s maximum load was achieved.

To test the performance of riprap with moving water, researchers performed a series of hydraulic experiments that sent water through steep water chutes, called flumes, toward a scale model of a spill-through abutment with dimensions based on typical MnDOT bridges. Researchers shielded the abutment with various kinds of miniature-scale riprap, which varied by stone size, stone shape and the absence or presence of grout (or substitutes for grout, including various kinds of glue and cement). Researchers increased the angle of the flume and consequently the velocity of water until the ungrouted riprap failed by having at least one of its rocks moved from its original location. Researchers then attempted to achieve a velocity of water flow that would fail matrix riprap.

The use of matrix riprap will help Minnesota transportation agencies ensure bridge safety while using a greater number of rock sources in Minnesota, saving on the costs and environmental effects of transporting these materials long distances.

“Not only is matrix riprap significantly stronger than regular riprap, it helps prevent vandalism as well.”

—Nicole Bartelt,
Assistant Waterway
Engineer, MnDOT Office
of Bridges and Structures

*“Some parts of
Minnesota don’t have the
larger stone sizes needed
for regular riprap. Matrix
riprap helps open up new
sources.”*

—Jeff Marr,
Associate Director
for Engineering and
Facilities, St. Anthony Falls
Laboratory, University of
Minnesota



Grout was applied to riprap underneath a bridge in Milaca, Minnesota, creating a stronger scour countermeasure with more rounded rocks than typical riprap.

What Did We Learn?

Laboratory installation experiments showed that the porosity of the riprap decreased by approximately 10 percent with the grout added, an indicator of its degree of penetration. This penetration depends on the size of the riprap, with penetration greater for larger size stones.

Mechanical pull tests suggest that the addition of grout to traditional riprap increases the stone strength by an order of magnitude. Researchers were unable to fail matrix riprap during horizontal pulling of up to 550 pounds using a mechanical hoist. When pulling rocks vertically upward, researchers were able to fail some matrix riprap specimens at various levels of force.

For hydraulic flume tests, researchers were unable to fail matrix riprap when applying eight to 10 times the shear stress at which regular riprap failed, indicating that grout adds significant strength to riprap. They also tested matrix riprap using half the amount of grout in MnDOT specifications, leading to failures at two to four times the shear stress withstood by regular riprap, suggesting substantially reduced performance. There was no measurable difference in the performance of the matrix riprap due to the angularity of the rock, despite the fact that MnDOT specifications currently require angular rocks.

What’s Next?

MnDOT is using matrix riprap in areas of Minnesota with few sources of large angular rocks or where vandalism is a problem. It has installed matrix riprap at five sites and will install at three more in the summer of 2015. Further research is needed to establish the failure point of matrix riprap as well as its environmental effects when grouting occurs underwater.

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