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# CENTER FOR TRANSPORTATION INFRASTRUCTURE AND SAFETY


## DEVELOPMENT AND TESTING OF SYNTHETIC RIPRAP CONSTRUCTED FROM COAL COMBUSTION PRODUCTS

by

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at Missouri University of Science and Technology**

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<tr><td colspan="5">16. Abstract<br>Even with an increase in the amount of CCPs used in concrete construction, soil stabilization, and other applications, the coal power industry must dispose of a significant amount of fly ash and bottom ash. One potential avenue for the material is to develop a riprap to armor bridge abutments, bridge pilings, streambeds, and shorelines against scour and ice damage. The proposed research plan is divided into three (3) phases, which consist of the following:<br>• Phase I – Product & Criteria Development<br>• Phase II – Prototype Development & Testing<br>• Phase III – Production Plant Design<br>Phase I involves determining the most appropriate applications for the synthetic riprap. There are several ranges of potential products available depending on the specific applications, including bridge pier scour prevention, channel stabilization, lake boundary erosion control, and shoreline protection. Once the potential product areas have been determined, the next part of Phase I will be to determine the necessary design requirements and specifications for the riprap. Phase II involves prototype development and testing based on the results from Phase I. Phase III involves development of a production plan and facility layout.</td></tr>
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# DEVELOPMENT AND TESTING OF SYNTHETIC RIPRAP CONSTRUCTED FROM COAL COMBUSTION PRODUCTS

**Final Report**

**To**

**Ameren Missouri**


**Principal Investigator**

Jeffery S. Volz
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**Project Period**

August 1, 2012 – May 31, 2013

# BACKGROUND AND OBJECTIVES OF THE STUDY

Since the 1930's, fly ash – a pozzolanic material – has been used as a partial replacement of portland cement in concrete to improve the material's strength and durability, while also limiting the amount of early heat generation. From an environmental perspective, replacing cement with fly ash reduces concrete's overall carbon footprint and diverts an industrial by-product from the solid waste stream. Unfortunately, only about 40% of fly ash is reclaimed for beneficial reuse, with the remaining 60% disposed of in landfills.

In some instances, the reason for only a 40% use rate is the lack of a viable market, but in other instances, it is because the fly ash does not meet the required specification for use in concrete or as soil stabilization. For instance, current specifications limit the carbon content of fly ashes used as partial replacement of cement in concrete to less than 6%. However, Ameren Corporation's Sioux Power Plant and other plants containing cyclone-fired boilers produce ash with very high levels of unburned carbon, often in the 20 to 50% range. Furthermore, activated carbon injection for mercury control will usually increase the carbon content of fly ashes from conventional boilers, reducing potential sales of ashes from these plants as well. In general, higher carbon contents reduce the reactivity of the ash and the efficacy of air-entraining admixtures.

Bottom ash has been used in a variety of applications including aggregate in roofing shingles, road construction (subbase), asphalt paving, and concrete; as lightweight aggregate in concrete masonry units (CMUs, commonly referred to as concrete block); as an additive in clay bricks; as blasting grit; and in snow and ice control on roadways. Although relatively unreactive compared to fly ash, bottom ash does have the potential to replace either all or a portion of the natural aggregates used in concrete or other cementitious systems. In particular, the very porous nature of bottom ash lends itself to a process known as internal curing. For concrete with very low water-cement ratios, the interior of a structural element can desiccate in some instances, resulting in a significant decrease in quality of the finish material. The bottom ash prevents this problem by slowly releasing moisture over time. However, in many instances, the bottom ash does not meet the requirements for use in concrete and a substantial amount of this coal combustion product is placed in landfills.

Even with an increase in the amount of coal combustion products (CCPs) used in concrete construction, soil stabilization, and other applications, the coal power industry must dispose of a significant amount of fly ash and bottom ash. One potential avenue for the material is to develop a riprap to armor shorelines, streambeds, bridge abutments, and pilings against scour and ice damage. The ***objective*** of the proposed research was to evaluate the feasibility of constructing riprap containing 90% CCPs such as fly ash and bottom ash.

# RESEARCH PLAN

This report covers Phase I of the proposed project and lays the groundwork for the feasibility of synthetic riprap constructed from CCPs. This phase examined the various types of riprap in use today and determined the most appropriate applications for the proposed product. This phase also developed the design requirements and specifications for evaluating the performance of the synthetic riprap in Phase II. The five (5) tasks necessary to accomplish Phase I included the following:

1. Literature Review
2. Product Development
3. Design Requirements & Specifications
4. Phase I Report
5. Presentation to Ameren & Go/No Go Decision on Phase II

### TASK 1: LITERATURE REVIEW

The purpose of this task was to conduct a comprehensive and critical literature review related to the proposed project. Specifically, the literature review first focused on the various types of riprap currently in use, such as armoring shorelines, streambeds, bridge abutments, and pilings against scour and ice damage. Scour is particularly critical for bridge abutments and pilings, as it is the number one cause of bridge failures. This aspect of the literature review will examine actual projects as well as the design methodologies for stream-bank stabilization, scour protection, and energy dissipation. Next, the literature review will focus on the necessary chemical and physical testing regimes for CCPs and the synthetic riprap, including testing for mechanical properties, durability, and leachate.

### TASK 2: PRODUCT DEVELOPMENT

Based on the results from Task 1, the research team developed potential riprap products constructed from CCPs. These products were based on different types and shapes of erosion armor, including loose and interlocking designs, as well as products designed for placement above, at, or below the waterline. For instance, products above the normal waterline should stabilize the stream-bank but promote drainage, while applications below the waterline should focus on energy dissipation.

### TASK 3: DESIGN REQUIREMENTS AND SPECIFICATIONS

This task focused on developing the design requirements and specifications for the synthetic riprap. With regard to hydraulic design, the seminal guide is the U.S. Federal Highway Administration Publication No. FHWA-NHI-09-111 HEC-23, Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (HEC-23). This publication provides design guidance as well as successful measures implemented by various State departments of transportation and encompasses everything from preliminary design through erosion critical structures.

With regard to structural design of the various potential products, this portion of Task 3 will begin with HEC-23 but will use precast concrete erosion armor design guidelines to develop design criteria for the synthetic riprap.

In addition to design requirements, this task will address specifications for CCP erosion armor including material requirements.

### Task 4: Phase I Report

The research team summarized the results of Phase I in a final report prepared for Ameren. This task included draft submittals of the final report to allow review, comments, and suggestions from Ameren.

### Task 5: Presentation to Ameren and Go/No Go Decision on Phase II

A presentation was scheduled with Ameren to coincide with submittal of the draft report. Based on the presentation and the final report, Ameren decided whether to proceed with Phase II of the project.

## RESULTS

### Task 1: Literature Review

The research team completed a thorough literature review which served as the basis for the research work.

### Task 2: Product Development

The research team developed designs for each of the erosion control measures shown in **Fig. 1**. These designs have been transmitted to Ameren for review.

### Task 3: Design Requirements and Specifications

The research team developed the conceptual design requirements and specifications for the erosion control measures shown in **Fig. 1**. However, each specific application of armoring requires a corresponding hydrologic evaluation. Nonetheless, the research team proved that the synthetic riprap constructed from CCPs is equivalent to current precast concrete systems in terms of strength, armoring ability, and leachate resistance.

### Task 4: Phase I Report

This report summarizes the results from Phase I.

### Task 5: Presentation to Ameren and Go/No Go Decision on Phase II

Although the results from Phase I are promising, Ameren has chosen to hold on proceeding with Phase II.

(a) Shoreline Protection

(b) Channel Stabilization

(c) Lake Boundary Erosion Control

(d) Bridge Pier Scour Protection

**Figure 1**: Synthetic Riprap Applications