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Screening Self-Cleaning Designs for Culverts Operating Free of Sediment

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Abstract

The vast majority of the U.S. Midwestern secondary roads includes culverts to enable stream crossings. Different construction types and configurations are used to accommodate the hydraulics of the culvert site and the hydrology of its drainage area for handling specific design discharges (i.e., 25, 50, or 100-year return flows). There is no substantial evidence to suggest that culvert failures are related to limited capabilities to convey the design discharges. A more prevalent cause of Mid-Continent culvert failures is the accumulation of sediment and/or debris at the multi-box culvert inlet. These sediment deposits partially block the culverts and lead to culvert over-topping and backwater formation during extreme events. Culvert sedimentation concerns are not limited to the Mid-continent area but it is widespread in the nation, from California to Pennsylvania and from Wisconsin to Florida, with direct bearing on the culvert's ability to maintain normal operation during extreme flows when the structure is essential for the communities they serve.

Despite its ubiquitous presence, the mitigation of sedimentation at culverts is a peripheral activity called upon only for extreme situations. The systematic research efforts for the mitigation of culvert sedimentation are limited, despite the availability of many technical means that can enable the comprehensive observation and understanding of the processes. This situation is not well aligned with modern design concepts that includes considerations on the long-term sustainability of the structures besides designing the structure solely based on their purpose.

Since 2004, The Iowa Department of Transportation (IDOT) has funded a series of research projects focused on searching and developing self-cleaning design concepts that once implemented in-situ drastically limit or completely eliminate the formation of sediment deposits at culverts. The key element of the self-cleaning design is the use of the stream power to convey the sediment through the culvert without additional interventions. These designs increase the flow velocities through the central area of the culvert and enhances the turbulence intensities in the side boxes. Starting with 2021, the Iowa pioneering research in this area has been joined by other states facing this operational nuisance. Specifically, DOT in Mississippi, Missouri, New Mexico, and Utah are currently proposing, evaluating, and formulating guidance on reducing the culvert sedimentation.

This paper summarizes the research on the design of self-cleaning solutions developed under the lead of the Iowa research team from its inception to date. This research has entailed a multi-prong, end-to-end

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approach whereby the field survey and measurements were modeled in laboratory experiments and simulated with numerical models. The best performing self-cleaning design candidates were subsequently implemented in situ for evaluating the reliability of the conducted research.